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REVIEW ARTICLE

The developing role of simulation within surgical training and the need for equitable access: a narrative review

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Abstract

Background: In recent years, surgical training has undergone considerable change and COVID-19 has accelerated the rate at which training methods have needed to be updated. Education of surgical trainees is now transitioning from that of a clinical setting to that of a simulated skills laboratory. This article aims to outline the importance of ensuring equitable access to high-fidelity surgical training equipment and to bring to attention the potential consequences of non-standardized surgical simulation exposure. **Methods:** Data collection was performed using the PubMed, Ovid MEDLINE and Embase bibliographical databases with a predefined search strategy between 11 February 2021 and 1 June 2021. All articles considering surgical education via simulation technologies were considered. **Results:** Twenty-eight studies were deemed eligible for inclusion in a qualitative synthesis. Despite the increasing popularity of simulation, simulation-guided learning has yet to become fully integrated within all curricula, and the use of these technologies is yet to be adequately evaluated in a post-pandemic context. Therefore, there is a need to educate and inform medical students and surgical trainees, who will all be required to learn from and be assessed on simulated clinical technologies. **Conclusions:** Surgical training methods must be consistently updated so that they reflect the transitioning cultural, social-economic, and political expectations and restraints on surgical curricula. Continual development of simulation facilities is required to ensure sustainable integration within surgical training. Equitable access for all trainees must be a future point of focus if surgical training is to continue at its current level.

Keywords: *simulation; simulated learning; surgical training; surgical education; high-fidelity*

Introduction

The traditional Halsted approach to surgical training is largely disputed, and there is a need for change within the education of future surgeons. Training is moving from that of a clinical setting to that of a simulated skills laboratory.[1–3] The requirement of trainees to be able to further their competencies outside the clinical setting has been further elucidated by the COVID-19 pandemic.

Following the European Working Time Regulations, increased patient awareness and a transition away from patient and cadaveric practice, there is now a greater need to seek alternative methods of surgical training.[2,4] When this is considered alongside the increasingly remote nature of education, a simulated learning environment initially appears to provide a suitable answer.[2,3,5,6]

Since COVID-19, trainee logbooks show a 50% reduction in primary trainee operations, and there is now a severe backlog of unmet surgical trainee requirements.[7] Many are turning to simulation technologies for an answer, but trainee exposure to simulation remains relatively low and simulation-guided learning has yet to become common-place within all standard curricula.[8–10] Despite some medical schools reporting successful use of such technologies, there is an increasing need to educate and inform all medical students and trainees to ensure equitable and fair surgical training.[11,12]

Simulation refers to a technique that replicates situations from the real-world in an interactive and immersive manner.[1,2] In the context of health care, a simulator is usually considered to be a device that represents a patient and simulated practice refers to a range of activities that emulate a clinical setting.[2,8] Simulation within surgical training can be considered as a relatively new concept compared with industries such as aviation and the military.[1,2,5,13] It may therefore appear contradictory that until recently, simulation has not occupied a large proportion of surgical training programmes. Although there are similarities between surgery and the aviation industry, we must not assume that successful pedagogical approaches in one industry are automatically successful in another.

Despite an increased uptake of simulation within surgical training, it is not yet integrated across all educational institutions and is still subject to controversy.[8] In a post-pandemic environment where simulation may provide the only opportunity to develop surgical competencies, inequitable access is resulting in increasing educational inequality. Those fortunate enough to have access to such technology can continue along their surgical training, whereas those without access are currently severely disadvantaged. This review explores the applications of simulation within surgical training and assesses the factors influencing its implementation. This review also addresses the issues regarding equal access to training facilities and postulates how access may be made ubiquitous in a post-COVID era.

Methods

For this literature review, data collection was performed using the PubMed, Ovid MEDLINE and Embase bibliographical databases with a predefined search strategy between 11 February 2021 and 1 June 2021. Key search terms included "simulation", "simulated learning", "surgical training" "surgical education" and "surgical curricula". All articles considering surgical education via simulation technologies were considered.

Citation retrieval and study inclusion was performed on Rayyan (a web and mobile app for systematic reviews, designed by Rayyan Systems Incorporated, Cambridge, MA, USA). To ensure adequate literature coverage, no date, place of publication or journal restrictions were applied. Only English language articles were considered and inclusion, and exclusion of studies was performed independently in duplicate by the two authors. Disagreement was resolved via author discussion.

Results

The bibliographical and non-bibliographical databases yielded 402 papers, of which 198 remained after removal of duplicates, 155 papers were excluded after screening the titles and abstracts and a further 18 studies were excluded after full text review. An additional three studies were identified through the references of the included studies, resulting in 28 studies being deemed eligible for inclusion in a qualitative synthesis (Fig. 1). Table 1 outlines the characteristics of each of the articles, including the type of simulation used and the results and challenges of these technologies. Despite the level of evidence being low and anecdotal at times, the included literature provides limited available insight into the current need for equitable access to simulation within surgical training.

Discussion

The role of simulation within surgical curricula and the importance of equitable access

One of the most influential factors contributing to the increasing prevalence of simulation in recent years is, perhaps unsurprisingly, COVID-19. COVID has resulted in the cancellation of elective operating lists and the complete termination of early trainee surgical placements.[14] This has meant that, for many, simulation provides the only opportunity to practice surgical skills.[15] Therefore, it can be inferred that those without access to simulation technologies may be unable to adequately practice their surgical competences.

Before COVID, reduced clinical exposure originated from the introduction of the work-hour restrictions of the European Working Time Directive (EWTD).[4] The EWTD reduced clinical exposure of surgical trainees[16] and created a disparity between the operative competences required to be learnt and the time available in which to learn them. As a result, there is an increasing need to provide more higher quality surgical training in a shorter period of time.[6]

Furthermore, patient awareness and an ever-increasing emphasis on patient safety mean that patients are now more aware than ever of the fallible nature of doctors, something that was catalysed by the 1999 report, To Err is Human.[17] This has meant that there is a greater need to ensure adequate practice is undertaken before conducting surgery.[2,8] This resulted in a change from the traditional approach, whereby a trainee would be able to practice on patients more freely, to a new cultural expectation that a trainee should have a certain degree of proficiency before operating on a patient.[2,6] With reduced training time experienced by many during the pandemic and increased patient awareness, patients may begin to question the competency levels of future surgeons, leading one to think that unless sufficient action is taken, we may be in the midst of a less skilled future surgical cohort.

Lastly, current surgical training is partially limited by the availability of a trainer, but seldom does a consultant's time

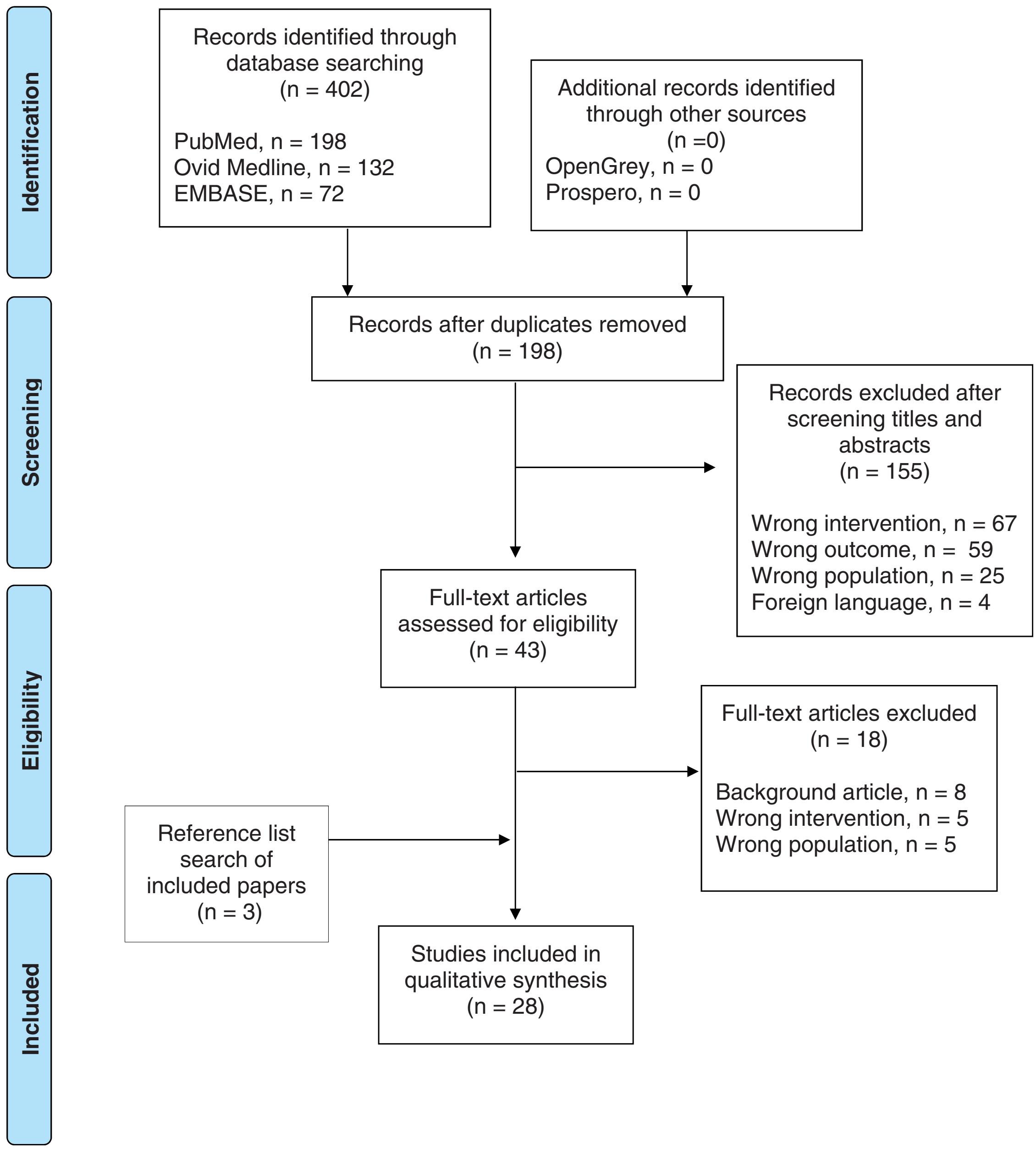

Figure 1. PRISMA flow diagram.

table warrant adequate time to devote to detailed and comprehensive training.[18] Another factor made worse by the increasing pressures of COVID. This is placing greater emphasis on self-directed and independent learning.[8] To date, simulation has largely received positive feedback since its implementation.[2,6] However, these advantages are localized only to those individuals who are fortunate enough to have access to the technology. If we want to see true global advantages for both patients and the NHS, all future surgeons must have access to simulation training. Until such time, the advantages of simulation will be restricted to only the individual level.

Applications of simulation within surgical training

Simulation has a range of diverse applications within health care. They have been categorized previously into 11 dimensions.[2] A key factor for fully understanding potential applications is realizing that simulation is not limited to training or to the surgical discipline. It has applications in training, assessing, revalidating, and appraising.[2,6,13,19]

Most notably, simulation has possibly its greatest application in the teaching of specific surgical techniques and competencies.[4] Simulated training allows the repetitive practice of skills of controllable and scalable complexity, in a low-risk,

Table 1. The study characteristics

Study	Article type	Population	Simulation used	Results	Simulation limitations
De Montbrun and MacRae (2012)[1]	Review	General surgical trainees	Laparoscopic trainers, bench top models and virtual reality trainers	A range of high and low fidelity surgical simulation technologies prove effective in developing technical and non-technical skills	Limited supporting evidence and limited access to high-fidelity technologies
Gaba (2004)[2]	Commentary	General surgical trainees	Unspecified simulation technologies	Simulation has a range of applications categorized into 11 dimensions	Limited availability of sites and simulation may distract from patient care
Brown (2013)[3]	Commentary	Surgical trainees	Various forms of simulation	It has been shown that skills can be learned and retained using various forms of simulation	Access and high quality comparative data are still very limited
Nicholas et al. (2019)[4]	Prospective, cross-sectional study	Royal College of Surgeons surgical trainees	Unspecified simulation technologies	Delivery and accessibility of simulation training varies widely	Less than half of respondents had access to simulation training at their place of work
Zerbato and Dall'Alba (2017)[5]	Review	Robot-assisted surgery trainees	Six robotic surgery training systems	It is currently very hard, to faithfully reproduce the complexity of human anatomy	There is no consensus about the tasks to include in a curriculum or the level of realism required to be useful
Isaranuwatchai et al. (2014)[28]	Randomized controlled trial	Third year nursing students	Automated virtual patient simulation	The virtual patient simulation was rated positively	The group scores did not differ significantly over time
Kurashima and Hirano (2017)[24]	Systematic review	Resident surgical trainees	Unspecified simulation technologies	Most simulators are laparoscopic focused and assessment consists mostly of speed of task completion	Few studies explore how simulation is actually implemented from a logistical perspective
Heitz et al. (2011)[10]	Survey	Surgical clerkship residents	General simulation facilities	A focused, stepwise application of simulation to student curricula can help optimize student benefit/faculty time ratio	Objective comparative data are limited
Marshall (2012)[6]	Commentary	Resident surgical trainees	Thoracic surgical simulation facilities	Incorporation of simulation allows us to increase hours of practice for a given technique and develop expertise	There are very few simulation models available for trainees
Dayal et al. (2009)[22]	Randomized controlled trial	Medical students	Simulation training for vaginal delivery manoeuvres	Students who receive simulation training participate more actively in the clinical environment	Student simulation training is primarily in a minimal risk environment
Munro et al. (2021)[7]	Commentary	Surgical trainees during COVID-19	Unspecified simulation technologies	COVID-19 elucidated the need for greater access to non-patient based surgical training	COVID-19 and a lack of simulation meant that early years trainees and those approaching the end of training were worse affected
Milburn et al. (2012)[8]	Editorial	Surgical trainees	Unspecified simulation technologies	Simulation in surgical training is well established, with proven validity and transfer of skills	Financial restraints limit the ability of many institutions to acquire simulation models
Bath and Lawrence (2011)[9]	Commentary	Vascular surgical trainees	Vascular surgical simulators	Simulation enables trainees to practice on a simulator, attain competency, then perform surgery under supervision before leading a surgery	Success will only be achieved by the widespread incorporation of open vascular simulation into current vascular training programmes
Sturm et al. (2008)[25]	Systematic review	Surgical trainees	Varied simulation technologies	Skills acquired by simulation-based training seem to be transferable to the operative setting	More studies are required to strengthen the evidence base

Table 1. Continued

Study	Article type	Population	Simulation used	Results	Simulation limitations
Issenberg et al. (1999)[13]	Special communication	Surgical trainees	Four areas of high-technology simulations	These systems help to address the problem of poor skills training and proficiency	Future objective and comparative research is required
Robertson et al. (2010)[11]	Cohort study	Medical and nursing students	TeamSTEPPS simulators	Students improved their knowledge of team and communication skills	Can be hard to study students who have limited clinical responsibilities
McGaghie et al. (2010)[12]	Review	Medical students	Simulation-based medical education facilities	Simulation-based medical education needs to be planned and practised with attention to organizational contexts	More thematic programmes of research are needed
Binstadt et al. (2007)[23]	Curricula design study	Medical students	Unspecified simulation technologies	Complete curriculum redesign to a fully integrated medical simulation model is feasible	Long-term impacts and sustainability of the programme is not yet known
White et al. (2021)[14]	Questionnaire-based study	General surgery programme directors	Simulated surgical training programmes	Dramatically reduced face-to-face learning opportunities for surgical trainees during COVID-19	Disparity between university programmes and independent programmes may be cause for action
Egle et al. (2015)[21]	Cohort study	Vascular surgeons	Web application trainer	The application was acceptable considering the low range of inter-operator variation	Such studies still only act as stand-alone studies
Parsons et al. (2011)[16]	Questionnaire-based study	General surgical trainees	Unspecified simulation technologies	Trainees are spending less time in surgery at the senior house officer level, and this is reflected in reported operative ability	Reduction in working hours must be offset by implementing measures to maximize training opportunities
Sutherland et al. (2006)[19]	Systematic review	Surgical trainees	Computer surgical simulation	Computer simulation generally showed better results than no training at all	Video simulation did not show consistently better results than groups with no training at all
Pascual et al. (2011)[20]	Cohort study	Intensive care unit advanced practitioners	Human patient simulator-based training	Improvement was seen in participants' scores combining all parameters	Studies need to identify individual populations for simulation integration
James et al. (2019)[28]	Systematic review	Surgical trainees	Cadaveric simulation	Cadaveric simulation induces short-term skill acquisition as measured by objective means	There is currently a lack of evidence of skill retention and of transfer of skills
Hamza-Lup et al. (2019)[31]	Survey	Surgical trainees	Visuo-haptic simulations	Organizations are in the process of developing cost-effective visuo-haptic simulation scenarios for laparoscopic surgery	Software components available are not sufficient to allow rapid development of robust simulation scenarios
Rebolledo et al.(2015)[30]	Comparative laboratory study	Junior orthopaedic surgery residents	Arthroscopy surgical simulator	Orthopaedic surgery residents who trained with a surgical simulator outperformed the didactic-trained residents	Future validation of surgical simulator training for orthopaedic surgery residents remains warranted
Coelho and Defino (2018)[29]	Validation study	Neurosurgical trainees	Mixed reality simulation	Simulators for spine surgery were approved by an expert surgical team and considered adequate for educational purposes	The virtual models are limited with regard to their real-time interactions with the trainee
Rehman et al. (2013)[31]	Cost-effectiveness study	Surgical trainees	Robotic surgical simulator (RoSS)	RoSS is a cost-effective surgical simulator for implementation of a simulation-based robot-assisted surgical training programme	A full comparative economic analytical study is required to validate these findings

high feedback environment. This enables novices to practice skills they otherwise would not have the opportunity to practice and to do so in a cost-effective and standardized manner.[2,13,19]

Within the UK, simulation training has improved trainee confidence in high-risk scenarios and in complex surgical procedures.[20,21] Within the hospitals and medical schools that have integrated simulation, it has also increased medical student confidence and participation during clinical placements as well as trainee operative skills.[22–25] The benefits of this curricula reform are well demonstrated and only serve to highlight the importance of ensuring all students can benefit from what appears to be an inseparable part of the future of surgical training.

Learning via simulation enables all three of the major learning domains, (cognitive, affective and psychomotor), to be addressed, therefore enabling it to act as a successful and effective means of education and training.[26,27] Surgical trainees rarely have the opportunity to practice complex or potentially harmful operations.[1,6,10] Simulation provides a solution by creating a learning environment that enables inexperienced individuals to train at no risk.[1,2,6,13] This paired with the absence of infection control or risk of contamination makes it hard to envision a COVID-related health care environment that does not include simulation.[28–30]

It seems clear that theoretically, simulation may enable wider access to surgical training through its portable nature and cost-effectiveness.[4] Recent business models have suggested that it would be financially beneficial for NHS Trusts to invest in these technologies.[2,4,27] Therefore, in theory, simulation removes geographic and financial barriers to accessing surgical training by offering the opportunity to learn in a dedicated on-site centre or from home.[2]

However, in practice, due to the costs associated with purchasing and using simulation equipment, academic institutions with greater financial flexibility are more likely to provide their students with access to this technology. This creates a bias in surgical education and may potentially result in differing surgical performance based on simulation availability.[8] If simulation training is to be an effective adjunct to the current curricula, its access must become universal and fully integrated in a parallel fashion across all institutions. Given the likely role that simulation will play in the future of surgical training, access to simulation facilities appears to present an educational inequality that is increasing insidiously within surgical training and doing so mostly undetected.

Beyond the remits of education, simulation also provides the opportunity for research and evaluation into organizational practice, human factors, and other operating and clinical aspects.[2,8] Simulation may be used within surgical training assessment and in the revalidation of professionals.[8,19,25] This is now relatively well established because to become a Member or a Fellow of the Royal College of Surgeons, simulated non-technical clinical scenarios must be completed.[8] This emphasizes the fact that those who have had access to such technology may be at an advantage over those who have not. If simulation is to form part of the assessment of all trainees, then all trainees must have equal exposure in the years preceding.

The future

So, what will this look like in the years ahead (Fig. 2)? Will simulation become a globally accredited form of training and assessment or will this simply be looked back upon as a passing fad? It is not yet possible to know and as is common with change and innovation, only time will provide the answer.

What is currently known, however, is that those involved within the simulation community must be proactive to ensure simulation is widely accessible. We are currently in a privileged position in which for many, simulation is no longer a futuristic concept. This position carries with it a responsibility to ensure that others have the means to be in the same position. If we do not take proactive measures to ensure all can benefit from this technology, then we will be contributing to the start of increasing education inequality.

Several of the points raised in this review are well documented within the literature, however this review highlights the need to focus on equitable access to simulation technology. This is yet to be sufficiently considered and is an increasing concern within surgical training. We must now look to a post-COVID world and hypothesise strategies to address what appears to be disparity in access to the future of surgical training facilities. We must also think about ways in which we can ensure that the skill levels of current trainees do not suffer as a result of COVID.

This review suggests that efforts should be taken to evaluate the extent of simulation facilities in all UK institutions to gain a comprehensive understanding of where access to these facilities is greatest and where access could be improved. This will enable all future efforts to be focused in the areas where the need is greatest. This review also suggests that additional and more rigorous surgical skill validation and appraisal should be considered for the current surgical trainee cohort. Currently, the negative implications of COVID-19 on surgical training are mostly restricted

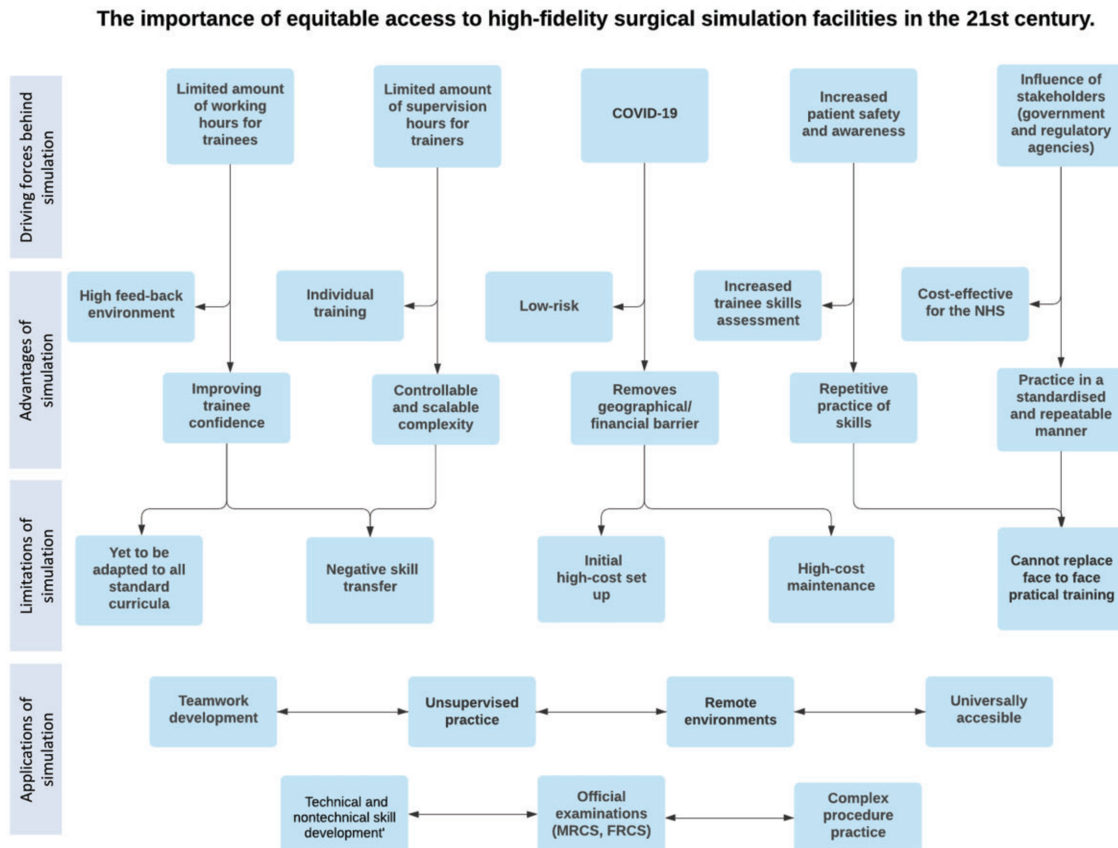

Figure 2. Schematic outlining the driving forces, advantages, limitations and applications of simulation in surgical training.

to the surgeon. However, in the years to come, these negative implications will be transferred to the patient and to clinical outcomes. To ensure that this does not happen, additional efforts must be made to ensure surgical proficiency is not affected.

Conclusion and recommendations

Surgical education is changing. The way surgeons are trained is being updated so that it reflects transitioning cultural, social-economic, and ethical expectations and restraints. However, greater emphasis should be placed on achieving nation-wide equitable access. Simulation has shown promise in several circumstances and should be supported as a supplement to current curricula and not as a replacement. Continual development of simulation facilities and proactive efforts to encourage accessibility are required to ensure sustainable integration within surgical training.

Conflict of interest

None declared.

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