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Review Article

Simulation Fidelity in the Context of Surgical Training in Orthopaedics

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Abstract

Surgical training has evolved in the last two decades from the traditional master apprentice model to a method of deliberate practice through simulation based learning. Simulation based learning is an established form of training in the aviation industry. Efficient and effective transfer of clinical skills through training is the final goal of all training methods. This article aims to critically review and analyse the relationship between simulation fidelity and surgical skills transfer in Orthopaedics to present a pragmatic perspective.

Keywords: Surgical Training; Orthopaedics; Simulation-Based Learning (SBL)

Introduction

Surgical training has evolved in the last two decades from an on-going conflict between service provision and training needs. Ethical concerns over the use of patients for learning [1] along with working hour restrictions have shifted the focus of training from opportunistic learning to a method of deliberate practice through simulation-based learning (SBL). Ericsson stated in his study that deliberate practice is a powerful predictor of superior performance compared to academic aptitude or experience [2]. Deliberate practice is the hallmark of SBL in clinical education [3]. Orthopaedics has a long history of using SBL for training. Arbeit gemeinschaft für Osteosynthesefragen (AO) foundation has been delivering training in basic and complex fracture management with synthetic bone and various other simulation techniques over the past 60 years. SBL has the potential to offer greater efficiency compared to opportunistic learning through clinical experiences while minimising risks to patient safety, operating theatre usage and expenditure [3,4]. The relationship between simulation fidelity and transfer of learning is multidimensional [5]. This article aims to critically review and analyse the relationship between simulation fidelity and surgical skills transfer in Orthopaedics to present a pragmatic perspective.

Categories of skills in orthopaedic training

Surgical competence is an eclectic combination of intellectual exercise of decision making with the ability to perform mechanical tasks [6]. The skills in Orthopaedic training can be categorised into three broad groups according to Stirling., *et al.* [4].

- Basic psychomotor skills- In Orthopaedics this would mean skills for tissue handling, handling basic tools, implants and familiarity with their usage.
- Procedural skills- this consists of preoperative planning and preparation, exposure and closure, intraoperative technique and postoperative management skills.
- Cognitive skills- this consists of decision-making, communication, teamwork, negotiating multi-tasking interference as well as personal wellbeing, motivation and stress management aspects.

Training simulators and fidelity

Training simulators in Orthopaedics comes in various forms; examples are cadavers, chicken or porcine models, synthetic bone models, virtual reality (VR) suites, arthroscopic simulators and cognitive simulators [4]. These have a wide range of fidelity and educational efficacy. In this context, it is important to critically look at the concept of fidelity.

Fidelity of simulation has been described under two major dimensions according to Allen., *et al.* [7]. The structural or Engineered fidelity describes how it looks, whereas functional or psychological fidelity describes what it does. Hamstra., *et al.* proposed a new nomenclature of physical resemblance and functional task alignment respectively, replacing the term fidelity altogether [8]. For this article, we'll use this new terminology.

It is traditional to differentiate simulators as high (HFS) or low (LFS) fidelity simulators based on physical resemblance alone. Cook in his systematic review has suggested that improving physical resemblance is one of the ways of increasing learner engagement resulting in an enhanced transfer of learning [9]. However, HFS systems are expensive in both initial set up and running costs, restricting their usability in repetitive and deliberate practice of skills. On the contrary, LFS with reliable functional task alignment is more affordable and available. LFS, in general, are low resource-intensive allowing multiple exposure and repetition of simulation practice to maximize educational effectiveness [10]. An analysis of various Orthopaedic SBL models will help us to shed more light on this argument.

Simulation models in orthopaedic training

Cadavers are considered as the gold standards in psychomotor skills training. This is an expensive HFS system. A study by Leong., *et al*. suggests that cadaveric simulation can differentiate experienced from the inexperienced surgeons in SBL encounters [11]. This is known as construct validity, held with high regard in educational effectiveness [12]. This system is capable of training basic as well as complex motor skills, catering to a wide range of surgical training needs. However, it suffers from lack of standardisation, availability and high expenses. This is the oldest simulation method used in surgical specialities and remains most relevant in motor skills training. However, there is a lack of direct evidence that cadaveric simulation training translates into surgical performance improvement.

Synthetic bone models are perhaps most widely used LFS in fracture fixation skills worldwide. They are extremely useful for junior trainees in basic psychomotor skills training and certainly most affordable. However synthetic bone behaves drastically different from human tissue, rendering them low in functional task alignment. Also, they do not present challenges of soft tissue envelope around them like the human skeleton. They are not that useful for expert surgeons to improve their existing psychomotor skills [4].

Chicken and Porcine models are considered as affordable LFS with modularity. Innovative methods render high functional task alignment, making them useful for basic and complex skills training. Uncooked chicken bones add a layer of tissue handling authenticity, making them superior to synthetic bones [13]. These models are capable of challenging the learner with soft tissue handling skills in Hand and Microsurgical training.

Arthroscopic simulators can be either benchtop or VR assisted. VR models allow improved skills assessment by counting probe collision and produce better learning curves [4]. However, there is no direct evidence of VR assisted training transferring skills to improve operative performance. Benchtop models are HFS with useful functional task alignment. Evidence exists to prove the transferability of skills to operating theatre from benchtop knee arthroscopy simulator [14].

Cognitive simulation is the most trending concept in surgical skills training. They are the only method that can recreate all the components of surgical practice together. Adding cognitive variants to a simple psychomotor exercise can enable faster and higher volumes of training [15]. Non-technical skills or human factors training is only possible through cognitive simulation. These simulators can be extremely simple as a structured mental exercise or can be a component of VR suites. They are affordable and easily available with high functional task alignment. A cognitive-task surgical simulator and rehearsal tool for carpal tunnel surgery has been successfully validated and made available as a mobile app [16].

Fit for purpose fidelity

Educational theories underpinning SBL in healthcare depends on deliberate practice, feedback, cognitive interactivity and reflective practice [3,8]. In their systematic review, Norman., *et al.* showed psychological fidelity (functional task alignment) seems to be the more important factor in both basic and complex skills training [5]. They argued that LFS allows more opportunity to practice over HFS, helping to develop more expertise. HFS in psychomotor skills training improves trainee confidence and reduces operative error as evident in cadaveric training. Advantages of cadaveric training can be replicated in chicken and porcine models (LFS) for hand surgery and microsurgical skills training.

It is observed that when trainees gradually progress to more complex models (higher fidelity) in motor skills training, their performance improves. This is known as the concept of progressive fidelity [10]. HFS thereby has potential use in complex skill acquisition and teaching of an approach to rare and difficult problems as well. Paradoxically, such training relies less on physical resemblance and more on context. Most elements of complex skill training can be reliably transferred via mental exercise, i.e., cognitive training. These arguments are in alignment with the findings of Norman., *et al.*

Technical skills are only one component in determining surgical competence. Surgical performance relies on variables grouped as non-technical skills that include situation awareness, decision-making, communication, teamwork, leadership and performance-shaping factors [17]. Cognitive simulation is perhaps the only possible SBL method of training these skills. Cognitive simulation training has brought a seismic shift in the concept of fidelity in surgical training. It has introduced fluidity in the definition of fidelity. A VR assisted cognitive-task simulator provides both context and high functional task alignment although remains affordable like an LFS. Such a system has proved useful for both junior trainees and experienced surgeons with different training needs [15]. It is proposed that proper medical skills are learnt by skilled interaction with the simulator by the participants [18]. Fidelity in this context is defined by the end-user and is only limited by their imagination. This is the main argument of this critical review. Fidelity transcends the barriers of physical resemblance or functional alignment, it becomes "fit for purpose". Shiralkar argues that when an experience is imagined in a specific manner there remains very little difference between a real and imagined experience [19]. Aviation industry and high-end athletics are the biggest proponents of cognitive training. Clinical education and more specifically Orthopaedic training will certainly benefit from the inclusion of cognitive training in the curriculum.

Conclusion

Dr Spencer in 1978 pointed out that 75% of the important events in a surgical procedure are related to decision-making and only 25% to manual skills [20]. Although it is not possible to confirm this hypothesis with objective clinical data, but recent evidence suggest that psychological aptitude in surgical trainee selection is still an undervalued process [21]. Surgical training must evolve to shift focus from motor skills only to more holistic human factors. The term fidelity is now a spectrum rather than a defined parameter. Functional task alignment providing the correct context is the key for effective skills transfer. Higher fidelity simulation remains relevant for psychomotor skills transfer for junior trainees. It is possible to replace and shift this reliance towards cognitive simulation with VR assistance. For more experienced surgeons cognitive simulation is a viable alternative and perhaps a better one. Aviation industry shows that more is not necessarily better in terms of fidelity of simulation for complex skills transfer [22]. Medicine has adopted many lessons from the aviation industry for improving patient safety and outcome. It would be prudent to follow suit in this regard.

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Volume 5 Issue 9 September 2022