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Review

The use of simulation in the acquisition of laparoscopic suturing skills

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ABSTRACT

Objective: Laparoscopic suturing is recognised as one of the most difficult laparoscopic skills to master. With the use of simulation increasing in the training of future surgeons, a comprehensive literature review was carried out to evaluate the current evidence for the role of simulators in facilitating the acquisition of this particular skill.
Method: A PubMed search was performed using terms 'laparoscopy', 'suturing', and 'simulation'. The resulting literature was then analysed for relevance and summarised.
Results: A total of 68 relevant articles were found and evaluated; despite the relatively small sample size in most studies, simulation has been proven to provide an effective method for the tuition of surgical trainees in laparoscopic suturing. Furthermore, the skills acquired through simulator training appear to be successfully transferable to the operating room environment. Simulators have also shown potential as valuable tools in the assessment of proficiency in trainees, with their evaluation of individuals correlating well with expert observer ratings in complex laparoscopic tasks such as suturing. Questions regarding the type of simulator to be used, the nature of the training curriculum, and how such a curriculum can practically be integrated into current surgical training programmes remain to be answered.
Conclusions: Simulation is an integral tool in the training of future laparoscopic surgeons, and further research is required to answer the question of how to maximise benefit from these invaluable training implements.

1. Introduction

Laparoscopic suturing is a means of tissue approximation without the use of mechanical clips or staples. It is a surgical technique required to perform many complex laparoscopic operations, being described as the rate limiting step in a laparoscopic skills training as it prevents practicing surgeons from performing more advanced procedures [1,2]. While laparoscopy offers advantages like better visualisation through magnification, it also introduces challenges for the operator, to the extent that even experienced surgeons initially struggle when facing obstacles such as: loss of depth perception, limited haptic feedback, and fulcrum effect of instruments. Laparoscopic suturing in particular is a skill with a steep learning curve, its acquisition within current surgical programmes being difficult; this is mainly due to the trainee's lack of adequate exposure to advanced laparoscopic procedures requiring intracorporeal suturing, and to the fact that training for such an advanced technique in the operating room is both time consuming and expensive [3,4].

The use of simulation in the acquisition of laparoscopic skills is fast becoming integrated into surgical training worldwide. Simulators provide an effective means of acquiring complex skills such as laparoscopic suturing through repetitive practice in a non-threatening environment before entering the operating room. Since ever more complex laparoscopic procedures are being carried out using this technique, it is therefore imperative that an efficient means of teaching laparoscopic suturing to trainee surgeons should be established.

The aim of this literature review is to evaluate the use of simulation in the acquisition of laparoscopic suturing skills by assessing the following three areas:

- Type of simulator providing the most effective means for acquiring complex laparoscopic skills;
- Role of construct validity for simulation and the transferability of simulator acquired skills to the operating room;
- How the simulator based training curriculum for laparoscopic suturing could be shaped.

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2. Search strategy

A search of the PubMed database was carried out using the following phrase: "laparoscopy" AND "suturing" AND "simulation", resulting in 91 articles.

After exclusion of 5 non-English language articles, the remaining 86 abstracts were examined. Of these, a further 38 articles were deemed irrelevant as they did not focus on the topic in question; 16 articles focused on subjects other than the acquisition or evaluation of laparoscopic suturing with simulators, 7 were concerning laparoscopic tasks other than suturing, 6 discussed robotic surgery, 2 did not feature simulators, 2 were reviews not focused on this topic, 2 were editorial comments, 1 discussed game consoles, 1 concerned veterinary medicine, and 1 was a duplication, discussing results from an already included publication.

The remaining 48 papers were read in detail, and their references lists searched for further relevant articles, leading to the addition of 20 more studies.

3. Type of simulators

A wide variety of laparoscopic simulators are available commercially, or as prototypes, and they can be broadly categorised as [5,6]:

1. *Video-scopic (VS)*: surgical box trainers allowing manipulation of real objects, often using real laparoscopic instruments. Whilst this group offer real, or physical, haptic feedback, a pure box trainer would require manual collection of performance metrics (Fig. 1).
2. *Computer-enhanced (CE)*: a video-scopic simulator with the additional ability of providing computer generated performance metrics (Fig. 2).
3. *Virtual reality (VR)*: a completely virtual environment with the capability of producing computer generated performance metrics [7].
   a) *Low fidelity*: with no computer generated haptic feedback (Fig. 3)
   b) *High fidelity*: with computer generated haptic feedback (Fig. 4);

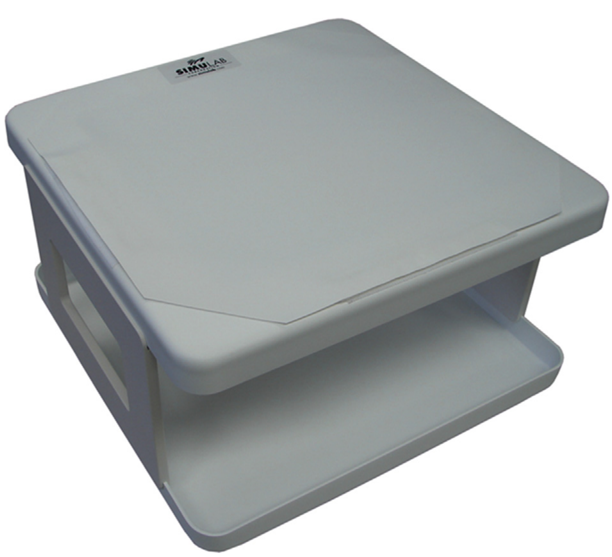

Fig. 1. The Pop-up trainer (Simulab Corporation, Seattle, Washington, USA) is an example of a video-scopic box trainer.

Fig. 2. The CAE ProMIS (CAE Healthcare, Toronto, Ontario, Canada) is an example of a computer-enhanced simulator.

A major technical discriminator between the above simulators categories is the presence of haptic feedback, and several studies tried to ascertain whether this feature has any impact on the ability of a simulator to teach laparoscopic suturing.

While subjectively surgical trainees often prefer VS simulators to low fidelity VR simulators when learning laparoscopic suturing, often citing the lack of haptic feedback as the main disadvantage of low fidelity VR equipment [5,8–10], some objective investigations showed that no significant difference can be detected in novices' performance in laparoscopic suturing tasks after training on simulators with and without haptic feedback. This lack of difference in performance was demonstrated when comparing CE and low fidelity VR simulators [11], and when comparing VS with low fidelity VR simulators [12–14].

A recent review of the range of simulators available for laparoscopic training [15] concluded that CE simulators are better suited for teaching complex tasks such as laparoscopic suturing due to the combination of realistic physical haptic feedback, use of real instruments, and the provision of performance metrics. However, the authors did not incorporate more recent high fidelity VR simulators which have subsequently been proven to be as effective as VS box trainers in teaching laparoscopic suturing to novices with no significant differences in performance [16].

One interesting study compared the performance of two randomised groups on learning a complex laparoscopic task not strictly related to suturing. Surprisingly, it was found that the group which started training with haptic feedback, and then moved on to a non-haptic feedback training session, performed significantly better than the group which carried out the training in the reverse fashion; despite both groups received equal tuition time in both training conditions, the authors concluded that haptic feedback could accelerate the performance curve in surgical simulator training [17]. A more recent investigation looking at laparoscopic suturing, reinforced that haptic feedback improved training efficacy, but only significantly in the first 5 h of training [18].