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Development and implementation of a virtual reality laparoscopic colorectal training curriculum

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ABSTRACT

Background: Contemporary surgical training can be compromised by fewer practical opportunities. Simulation can fill this gap to optimize skills' development and progress monitoring. A structured virtual reality (VR) laparoscopic sigmoid colectomy curriculum is constructed and its validity and outcomes assessed.

Methods: Parameters and thresholds were defined by analysing the performance of six expert surgeons completing the relevant module on the LAP Mentor simulator. Fourteen surgical trainees followed the curriculum, performance being recorded and analysed. Evidence of validity was assessed.

Results: Time to complete procedure, number of movements of right and left instrument, and total path length of right and left instrument movements demonstrated evidence of validity and clear learning curves, with a median of 14 attempts needed to complete the curriculum.

Conclusions: A structured curriculum is proposed for training in laparoscopic sigmoid colectomy in a VR environment based on objective metrics in addition to expert consensus. Validity has been demonstrated for some key metrics.

1. Introduction

Medical simulation has been shown to be beneficial in a variety of settings and has become an essential part of medical training.[1] There has been an established political and professional pressure to drive simulation to the forefront of training strategy.[2] This is as a result of shortened training times and fewer practical patient-derived training opportunities for junior doctors than in the past, rising patient expectations and service delivery pressures.[3,4] The high priority of the patient safety agenda dictates that health professionals are able to demonstrate an appropriate level of competence prior to direct patient contact.[5] All doctors need training in both the theory and practice of their clinical duties, but technical skills simulation is a particularly important aspect of preparing surgeons for the operating theatre. Skills learned in the simulated environment can be successfully transferred into the operating theatre in order to improve outcomes.[6–8] Availability of simulators for surgical trainees is highly variable in the UK.[9] Even where there is access, trainees may not utilise these resources effectively unless motivated by relevant and specific goals.[10]

Simulation curricula have emerged as a viable way of providing surgical trainees with appropriate and relevant skills for their career. The Fundamentals of Laparoscopic Surgery programme has been running in the USA for many years and certification is now considered mandatory for trainee progression.[11,12] Alongside current methods of testing theoretical knowledge, objective assessment of technical skills is now increasingly desirable for surgical trainers. Thanks to the recent advances in computer graphic and haptic feedback technology, virtual reality (VR) high-fidelity simulators have become increasingly appealing to both educators and trainees. The degree of realism is enhanced by the high fidelity representation of the anatomy and related pathology which maximises the learning experience. In addition, the software programme captures the trainee's performance with computer generated metrics enabling them to visualise their learning curve. This process can improve motivation in achieving target metrics within a curriculum. Although high fidelity VR and augmented reality simulators now provide validated, objective measures of

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psychomotor skills and specialty-specific procedures,[13,14] new infrastructure and methodology are needed to deliver this type of training.

The laparoscopic approach is now considered to be the gold standard for colorectal surgery,[15] its advantages have been thoroughly evaluated with respect to shortened hospital stay, reduced postoperative pain and early mobilization of bowel function.[16] Laparoscopic colectomy poses significant challenges to trainees because of its high level of technical complexity[17,18] and variability of cases,[19] requiring an extended learning curve which is estimated to be over 90 cases according to its various definitions.[20,21] As a result, trainees are expected to achieve competence in advanced laparoscopic techniques at an earlier stage of their training than before. This study describes the development and implementation of a VR training curriculum and explores whether this a useful tool for trainees wishing to improve their laparoscopic skills.

2. Material and methods

The study consisted of two parts. Firstly to select computer generated metrics from the VR simulator thought to be most relevant to a real life sigmoid colectomy and subsequently to define the value of these metrics in expert hands during a complete VR colectomy. The second part aimed to apply these data to formulate a VR training curriculum for junior surgeons with little or no experience of colorectal surgery. Pre-assessment and performance data were collected from trainees to calculate their learning curves. All technical skills assessment was carried out using the LAP Mentor (Simbionix Corporation, Cleveland, Ohio, USA) a VR simulator that included haptic feedback. Data were collected and analysed using SPSS v20 software (IBM Corporation, USA). Bivariate correlations were assessed with Chi square, Fischer's exact, Mann-Whitney U, Independent Samples Median test and Spearman's correlation as appropriate. A p value of <0.05 was considered statistically significant and a p value between 0.1 and 0.05 was considered suggestive.

2.1. Expert metrics

The study enrolled six surgeons who had each performed more than 100 laparoscopic colorectal resections. A modified Delphi method allowed this group to select a range of computer generated metrics that were thought to represent the important aspects of a real life colectomy. This selection considered the skills required to use the simulator in comparison to the skills required to perform a live laparoscopic colorectal resection, focusing primarily on safety and economy of movements' parameters. Specific operative steps were defined, standardised and agreed by this group to ensure that the colectomy module was performed in a consistent manner by all participants. After familiarisation and warm up with the simulator and the colectomy module, the expert surgeons completed two simulation sessions on the same day. Benchmark metrics were defined based on the performance of the expert group, using median and range values.

2.2. Trainees enrolment

Fourteen surgical trainees (6 Core Surgical Trainees, 7 Specialist Registrars and 1 Consultant) who had completed less than 10 laparoscopic colorectal resections were enrolled in the curriculum. Pre-assessment data were collected using a pro-forma. The curriculum was structured using theoretical classroom teaching, simulator induction and familiarisation and finally a 60-day period of self-directed learning with expert support both within the simulation centre and remotely via telephone and email. Trainees were taught about the evidence base for laparoscopic colorectal surgery, the relevant anatomy and physiology, in addition to the technical aspects of both live surgery and virtual reality simulation. Trainees were allowed to perform only one colectomy per day according to the principles of distributed learning[22] and had access to a web-based VR colectomy that had been performed by an expert surgeon (https://youtube.com/watch?v=9rjJCNGwrK0); (Fig. 1).

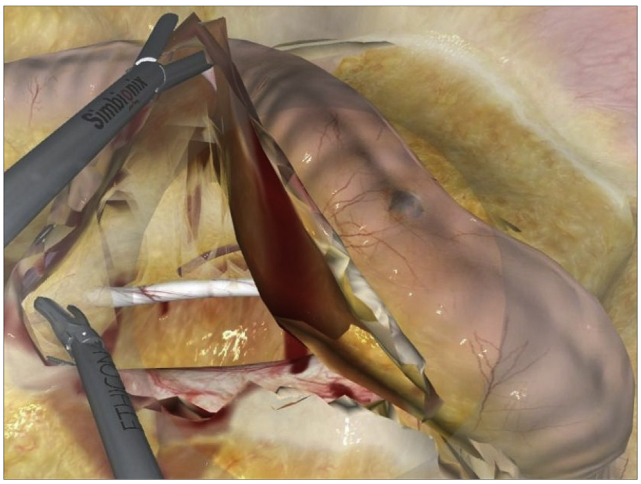

Fig. 1. Virtual reality view of medial to lateral mobilization of left hemicolon with ureter and gonadal vessels exposed.

Procedure-related data were collected through the simulator's software. Data analysis for the right and left instrument was corrected for handedness of the operator if necessary i.e. right sided data correlated with the dissecting instrument and left sided data with the retracting instrument. A formative assessment of posture, instrument handling and laparoscopic technique was made by an expert surgeon at the start of the curriculum and a similar summative assessment made after pre-set metrics had been achieved. This assessment also provided an opportunity to ensure that the correct steps of the colectomy were performed in sequence so that all trainees approach was similar. Completion of the curriculum was achieved only after attaining benchmark computer-generated metrics and a final satisfactory expert sign-off.

2.3. Post-completion analysis

Trainees' pre-assessment and performance data were anonymised by one of the investigators and statistically processed blindly by another investigator. The statistical significance of improvement in each parameter was tested, learning curves on scale parameters were extrapolated, and performance was examined for association with pre-assessment parameters. The latter included age, gender and a standardised scoring system of assessing experience and skills in simulation and laparoscopic surgery (Table 1).

3. Results

3.1. Parameters and threshold values

Expert group consensus concluded that the inclusion of the following eleven parameters gave a realistic representation of a live colectomy: total time to completion, distance of inferior mesenteric artery (IMA) division from its origin, injury to a blood vessel, risk of injury to colon, safety of electro-cautery, accuracy of dissection, time to division of IMA, number of movements of right and left instruments and total path length of right and left instrument. The

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