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Effect of Continuous Motion Parameter Feedback on Laparoscopic Simulation Training: A Prospective Randomized Controlled Trial on Skill Acquisition and Retention

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OBJECTIVE: To investigate the effect of motion parameter feedback on laparoscopic basic skill acquisition and retention during a standardized box training curriculum.

DESIGN: A Lap-X Hybrid laparoscopic simulator was designed to provide individual and continuous motion parameter feedback in a dry box trainer setting. In a prospective controlled trial, surgical novices were randomized into 2 groups (regular box group, $n = 18$, and Hybrid group, $n = 18$) to undergo an identical 5-day training program. In each group, 7 standardized tasks on laparoscopic basic skills were completed twice a day on 4 consecutive days in fixed pairs. Additionally, each participant performed a simulated standard laparoscopic cholecystectomy before (day 1) and after training (day 5) on a LAP Mentor II virtual reality (VR) trainer, allowing an independent control of skill progress in both groups. A follow-up assessment of skill retention was performed after 6 weeks with repetition of both the box tasks and VR cholecystectomy.

SETTING: Muenster University Hospital Training Center, Muenster, Germany.

PARTICIPANTS: Medical students without previous surgical experience.

RESULTS: Laparoscopic skills in both groups improved significantly during the training period, measured by the overall task performance time. The 6 week follow-up showed comparable skill retention in both groups. Evaluation of the VR cholecystectomies demonstrated significant decrease of operation time ($p < 0.01$), path length of the left and right instrument, and the number of movements of the left and right instruments for the Hybrid group (all $p < 0.001$), compared to the box group. Similar results were found at the assessment of skill retention.

CONCLUSION: Simulation training on both trainers enables reliable acquisition of laparoscopic basic skills. Furthermore, individual and continuous motion feedback improves laparoscopic skill enhancement significantly in several aspects. Thus, training systems with feedback of motion parameters should be considered to achieve long-term improvement of motion economy among surgical trainees. (J Surg Ed ■:■■■-■■■. © 2017 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: motion parameters, motion feedback, simulation training, laparoscopy, skill acquisition, surgical skills

COMPETENCIES: Systems-Based Practice, Practice-Based Learning and Improvement

INTRODUCTION

It is now generally accepted that various abdominal operations can be performed using laparoscopic techniques with at least equivalent or even better outcomes to conventional

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open procedures.[1] However, minimally invasive procedures require different skills from the surgeon such as dealing with a 2-dimensional (2D) view while working in a 3D space, handling tissues with decreased haptic sensation, working in changing angles, and coping with the so called fulcrum effect.[2] This results in longer learning curves compared to open operations.[3] As a result of long working hours, time for training is vastly limited for most surgical trainees,[4] thus the necessity for fast, effective, standardized, and affordable[5,6] training methods to obtain and improve laparoscopic skills are needed more than ever.

Various studies have shown that laparoscopic simulation training leads to skill improvement, regardless whether a simple box trainer[7,8] or a virtual reality (VR) trainer[8,9] is used. Further methods such as using cadaveric animal or human tissues in box trainers exist, but are associated with ethical concerns and demand thorough preparation.[10] It remains controversial which type of simulator enables best preparation for laparoscopic surgery on patients. Some studies favor box trainers,[11,12] while others consider VR trainers to be equivalent[13] or even better[14] for skill acquisition and preparing surgical beginners for the operation room (OR).[15]

So far, performance time has been the reference value of choice to determine skill improvement.[16] Besides procedural time, correctness (often considered by adding penalty time in case of deviations) and scores like the global operative assessment of laparoscopic skills score,[11] VR simulators for laparoscopic surgery routinely offer motion parameters (or metrics) as an additional tool to assess overall task performance. Motion parameters are items such as path length, number of movements, instrument velocity, and time in which an instrument is not used (idle time), captured separately for both hands. They are often listed to give a final feedback on the task performance in form of a digitalization of the entire procedure. Trainers that register motion parameters are known to indicate enhancement of motion efficiency by means of decreased operation time, path length, and numbers of movements after training.[17] Hence, motion analysis can serve as a method to measure dexterity.[18] However, it remains unclear whether these parameters truly contribute to learning improvement.

Recently, the medical teaching and training company *Medical-X* (The Netherlands) has developed a novel box trainer system: the Lap-X Hybrid system. In cooperation with our department, adjustments to the commercially available Hybrid trainer were conducted, enabling the Hybrid to provide a digital feedback of motion parameters in a regular dry box setting. Using special trocars for registration of metrics in a box environment and by continuously giving feedback to the trainee while working with authentic instruments, the Hybrid simulator combines the advantages of more complex and expensive VR Trainers with those of rather basic low-cost box trainers with complete preservation of real haptics. In this new approach, motion parameters are supplied with a supplemental function by displaying personal metrics as feedback reference.

The aim of this prospective randomized trial was to investigate the effect of continuous motion parameter feedback on skill improvement and skill retention by including the Hybrid trainer into our standardized and validated[7] curricular basic 5-day laparoscopic training program. We hypothesized that an additional motion parameter feedback might help to increase skill progress, motion economy, and the effectiveness of laparoscopic training.

METHODS

Participants

In 2016 and 2017, 36 ($n = 36$) surgical novices (medical students from Muenster Medical School) were chosen randomly from voluntary applicants to complete a 5-day basic laparoscopic training program. Written informed consent of each student for analysis of registered data was obtained. Each participant completed a questionnaire concerning demographics (sex, age, dominant hand, and semester) and previous surgical and video gaming experience.

Study Design

Students were randomized into 2 groups: Hybrid group ($n = 18$) and box group ($n = 18$), named after the respective training device. The participants completed a structured laparoscopic curriculum (Fig. 1). In brief, training began with a general introduction to laparoscopic surgery and a tutorial video of a human laparoscopic cholecystectomy (CE) commented by a senior surgeon. A laparoscopically experienced surgeon demonstrated all 7 curricular tasks (described later) to the participants. On day 1, after randomization into either box or Hybrid group, each participant performed a standard CE on a Simbionix LAP Mentor II VR Trainer. Baseline values (CE-BL) were registered (operation time, instrument path lengths, numbers of movements, and velocities). All subsequent tasks were performed in fixed pairs. One partner was scored, while the other one operated the camera and vice versa. Change of training partner or simulator was not permitted. On day 2, BL evaluation of the curricular exercises was measured. Without coaching or further explanation each partner performed every task twice, allowing the calculation of means. A swap of the beginning partner followed after each task. During days 3 and 4, 2×2 repetitions of the curricular tasks were executed, supervised by qualified surgeons. During the repetition cycles, the surgeons supported the trainees with intensive individual coaching, motion sequence feedback, and demonstration. The same 4 surgeons rotated within the groups, thus ensuring equal coaching in both groups. Day 5 consisted of posttraining