

Chapter 7

Learning curve on the TrEndo laparoscopic simulator compared to an expert level

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Abstract

Background

The aim of this study was to determine growth in trainee laparoscopic skill as recorded by the TrEndo laparoscopic simulator during a laparoscopic training course, compared to an expert level.

Methods

A prospective observational cohort study was conducted between February 1 and November 31 in 2010. Trainees in laparoscopic surgery completed a basic laparoscopic suturing task on a laparoscopic box trainer at 3 successive assessment points during a laparoscopic training course. Experts were assessed only once to define an expert level. The TrEndo recorded four motion analysis parameters individually for each hand and the amount of time taken to complete the suturing task.

Results

72 residents and 56 experts were included in this study. Overall, the amount of time taken on the suturing task and 7 out of 8 MAPs significantly increased toward an expert level during the course, representing an improvement in task efficiency. During the first training day, the amount of time spent on the suturing task and 5 out of 8 motion analysis parameters improved significantly. After the retention period, 5 out of 8 MAPS demonstrated a significant improvement compared to the end of the first training day.

Conclusion

In this study we demonstrate that laparoscopic skill of trainees as recorded by the TrEndo laparoscopic simulator grows toward an expert level during a laparoscopic training course in a large and heterogeneous study group. As in our previous study, construct validity of the TrEndo is established.

Introduction

Simulation based practice in minimally invasive surgery (MIS, or laparoscopic surgery) is gaining interest to enhance patient safety and to comply to legal and ethical concerns¹. Several studies demonstrated that simulator based practice improves laparoscopic psychomotor skills, translatable to fewer errors and improved performance in the operating room (OR)²⁻⁴. Simulation based practice is also cost-effective and easily implementable in a surgical training curriculum^{5,6}. Simulator based practice in MIS is based on various simulators: computerized virtual reality trainers (VR), traditional box trainers (BT) or a combination of the two; augmented reality trainers (AR)^{1,7}. Previous research demonstrated that residents with no laparoscopic experience were able to perform a task after a simulator based laparoscopic training course⁸⁻¹⁰.

Unfortunately, basic laparoscopic skill training remains unrealistic as VR simulators are entirely computer based and most do not provide realistic haptic (tactile) feedback. Laparoscopic box trainers on the other hand preserve natural instrument-tissue interaction, depth perception and feasibility in the use of actual laparoscopic instruments. Low fidelity simulators have proven equally effective in laparoscopic skill acquisition compared to high-fidelity VR simulators¹¹.

Inclusion of a motion-tracking device on a laparoscopic box trainer is a relatively new training option, incorporating the advantages of a computer-based simulator to (the advantages of) a traditional box trainer¹². An example of such a device is the TrEndo (Delft University of Technology, Delft, the Netherlands), which allows free manipulation of standard MIS instruments while tracking instrument motions.

Construct validity (i.e., the ability to distinguish between different levels of skill) of the

TrEndo was recently established by our research group and by Chmarra et al.^{13;14}.

The relevance of movement-economy in an in vivo situation was first demonstrated during a laparoscopic cholecystectomy on a porcine model by the ability to discriminate between surgeons with different levels of experience¹⁵.

An objective assessment tool is vital in the assessment of laparoscopic skill.

Furthermore, residents display better performance when training goals are set^{8;16;17}.

Previous studies employed time as a single parameter to establish learning curves^{18;19}. However, it has been demonstrated that a learning curve based on time alone is not accurate and that basic MIS skills have to be assessed using at least two different outcome measures²⁰⁻²².

This study investigates the learning curve of resident laparoscopic performance as recorded by the TrEndo at 3 successive assessment points during a laparoscopic training course, compared to an expert level. Expert level was defined by performance of the identical task. We determined if a trainee's motion analysis parameters (MAPs) as recorded by the TrEndo altered during the training course, and whether there was a difference in the number of trainees attaining expert level during the course.

Materials & Methods

A prospective observational cohort study was conducted in The Netherlands and Belgium between February 1st and November 31st 2010.

Participants

Trainees in urology, gynecology and surgery attending a laparoscopic suturing course organized by the VU University Medical Center at hospitals in The Netherlands and Belgium voluntarily enrolled in this study^{23;24}. Course participation was allowed as early as the final 6 months of the second postgraduate year when open and laparoscopic basic skill training programs of previous years have been completed. Experts were defined as having performed over 200 laparoscopic procedures and were recruited at two Dutch surgical conferences.

Systems and hardware

Laparoscopic box trainers measuring 45x30x25 cm (Camtronics Nederland B.V., Son, The Netherlands) simulate an abdominal cavity by an aluminium frame and allow regular insertion of traditional laparoscopic trocars and conventional laparoscopic instruments (B. Braun Medical B.V., Melsungen, Germany), plus a 0° scope connected to a video monitor on which the simulated laparoscopic environment is viewed²⁵.

The TrEndo is constructed as a trocar on a box trainer through which laparoscopic instruments may be regularly inserted. Instrument movement is measured in four degrees of freedom: X-, Y-, Z- axis and axis-rotation¹². Motion analysis parameters (MAPs) are recorded with a sample frequency of 100 Hertz individually for the right

and left hand, including: path length (mm , length of curve described by tip of the instrument), motion in depth (mm , total distance traveled by the instrument along its axis), angular area (deg^2 , related to the distances between the farthest positions of the instrument during a task), volume (mm^3 , three-dimensional space used), and time (sec)²⁶. A MAP-decrease represents an improvement of task-efficiency.

Tasks

Participants were asked to correctly position a curved tapered needle into a laparoscopic needle holder (task 1) and complete a standard laparoscopic square knot (task 2) on an artificial skin patch using a 15 *cm* single 3-0 suture (Vicryl, Ethicon). Each task was recorded independently and a 5-minute time limit was set for task 2. Equipment and instruments used were kept identical.

Evaluation of technical skills

The Advanced Suturing Course (ASC) consists of two training days with a 6-week in-between period allowing for voluntary autonomous training at home on the box trainer. Trainees were evaluated at the start (baseline) and end (post) of the first training day and subsequently after a 6-week training period (follow-up). Only residents completing all 3 assessment points were evaluated. Experts were assessed only once to define an expert level.

Expert comparison

The MAP results of the participants during the course were compared to the benchmark for proficiency as the mean of the experts' performance, plus/minus one standard deviation.

Statistical analysis

Data were analyzed using SPSS version 16.0; SPSS, Inc., Chicago, IL, USA. A nominal significance level of 0.05 was used and all test were performed two sided. Values for continuous variables are given as mean (SD). With regard to multiple TrEndo parameters, learning curve analyses were performed using repeated measures ANOVA's, while comparison of the number of trainees performing at expert level over time was assessed using Chi-square tests. Values for categorical data are specified as frequency (%).

Results

A total of 56 experts (71,1% active in general surgery, 13,2% in gynecology and 15,8% in urology) and 72 residents participated in this study. Most residents were active in general surgery (n=47; 65.3%), 15 (20,8%) in gynecology and 10 (13,8%) in urology. All residents had completed their first two years of residency. The resident-supervisor ratio during the course was 4:1.

59 (81,9%) residents completed the baseline assessment, 71(98,6%) residents the second assessment, and 71(98,6%) follow-up assessment. 50 (69,4%) residents attended all 3 assessment points. 12(16,7%) residents were unable to attend all 3

assessment points due to logistic reasons, however average scores were similar compared to residents attending each assessment point.

Figure 1 displays mean parameter scores (SD) at all three assessment points for residents, and the expert scores. All parameters except left depth ($p=0,36$) demonstrated a significant decrease over the entire course ($p<0,05$).

Between assessment point 1 and 2 the amount of time taken, and the MAPs left path, left area, right path, right area and right volume demonstrated a significant decrease ($p<0,01$). There was no significant decrease for left depth ($p=0,10$), left volume ($p=0,15$) and right depth ($p=0,26$). Between assessments point 2 and 3, there was a significant decrease for MAPs right volume ($p=0.02$), left area, right path, right depth and right area ($p<0,01$). Parameters time, left path ($p=0,07$), left depth ($p=0,48$) and left volume ($p=0,17$) demonstrated no significant decrease.

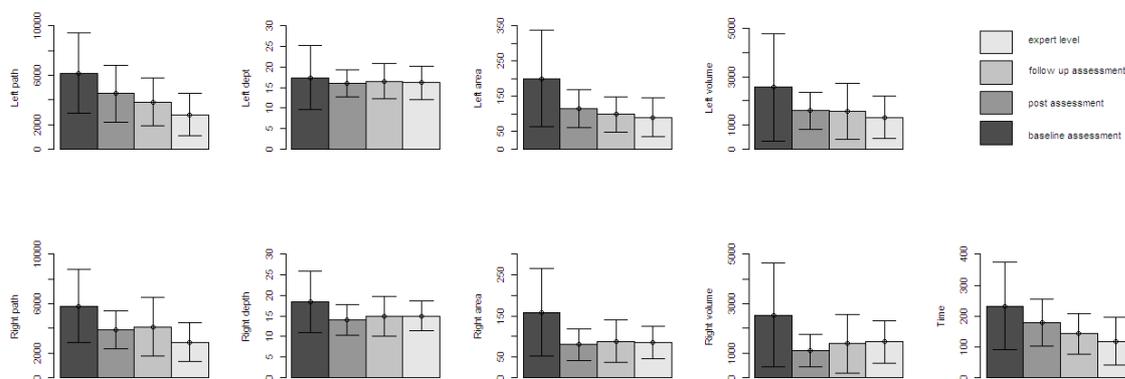


Figure 1. Mean resident and expert scores. Resident scores are shown for each assessment point. Baseline (first) assessment at the start and post (second) assessment at the end of the first training day. Follow-up (third) assessment point at the second training day. MAP: motion analysis parameter. N=50 residents. N=56 experts.

Figure 2 displays the percentage of trainees that achieved an expert level for each parameter at each assessment point. All parameters except left depth displayed a significant increase in the number of residents achieving expert level over the three assessment points ($p < 0,05$).

Between assessment points 1 and 2, the number of residents achieving expert level increased significantly for the MAPs left path, left area, left volume, right path, right depth, right area and right volume ($p < 0,01$). There was no significant increase in the number of residents reaching expert level for time taken ($p = 0,07$) and MAP left depth ($p = 0,48$). Between assessments point 2 and 3, the number of residents achieving an expert level only increased significantly in the amount of time taken for the task ($p < 0,01$). The number of residents achieving an expert level did not change significantly for the remaining parameters.

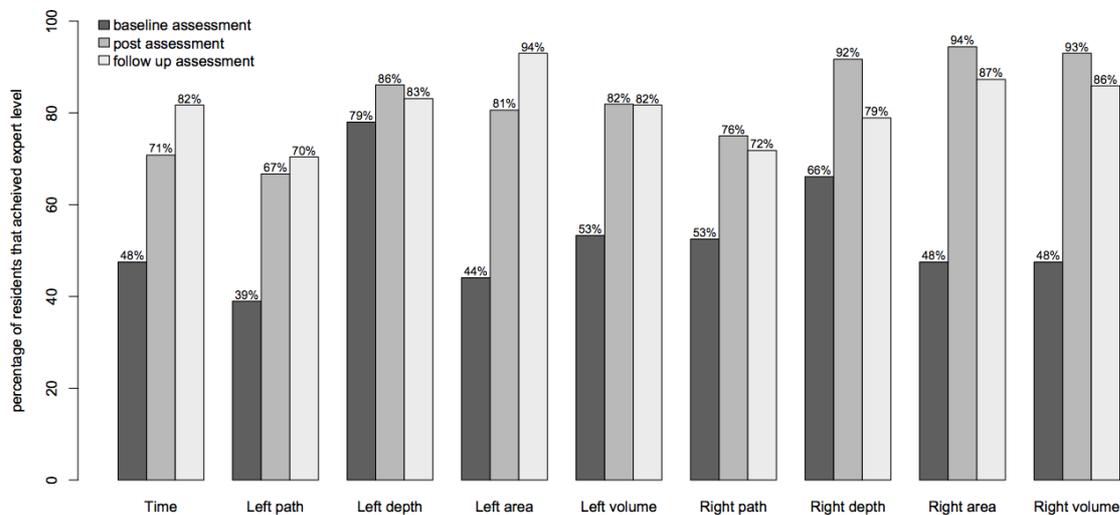


Figure 2. Percentage of trainees achieving an expert level at each assessment point per parameter. N=50 residents. N=56 experts

Discussion

In this study we set an expert competency level for a laparoscopic suturing task on a laparoscopic box trainer and demonstrate that MIS skill of laparoscopic trainees as recorded by the TrEndo laparoscopic simulator grows towards an expert level during a laparoscopic training course in a large and heterogeneous study group. As in our previous study, construct validity of the TrEndo is established¹⁴.

A laparoscopic suturing task incorporates all basic laparoscopic skills including ambidexterity, depth perception and instrument manipulation²⁷ and is therefore a suitable simulator-based task and indication of laparoscopic skill^{8;28}. Improving TrEndo parameters translate into improved task-efficiency and possibly, as was discussed in our previous study, improved laparoscopic skill which is transferable to OR-performance.

In total, all MAPs except left depth improved significantly over 3-assessment points; at the start of the suturing course, after one day of training, and after a six-week autonomous training period. After one day of training, the number of trainees attaining expert level significantly increased for all MAPs except left depth and the amount of time taken on the suturing task. After the six-week autonomous training period, only the amount of time spent on the suturing task improved significantly. We feel that a lack of time spent on training during the autonomous training period may be crucial in the absence of further skill improvement after this time²⁵. As is demonstrated in previous research, frequent training and rehearsal on simulators is essential for durable skill retention²⁹⁻³¹.

As noted, the only MAP not significantly improving during the study course was left depth. However, at baseline level (assessment point 1), 79% of residents already

attained an expert level for this parameter. The discriminating ability of this parameter may be limited. When assuming the symmetry of the device measurement system - and the right depth demonstrated variance - the difference in improvement could also be associated with a performance variable that is common to both groups and does not vary between the groups, such as handedness. However, it can not be excluded that trainees use their less dominant (mostly left) hand less frequently compared to experts and that a lower value of this MAP does not represent more efficient movements but rather an insufficient use of the less dominant (left) hand.

Our study is limited for several reasons. First, we did not track the number and types of laparoscopic cases the participants performed during the retention interval. We are currently investigating the implementation of a time-log to record the amount of time spent on practice. On the first training day, we advised participants to spend time training on the box trainer only on the laparoscopic procedures as demonstrated during the ASC. Second, our expert group displayed a large spread in performance. Therefore, the approximation of a resident toward expert level may have been influenced by a large SD. A large spread in simulator performance by experts may be due to variance amongst experts in terms of their performance abilities. In future research we should perform a subgroup analysis. Third, we did not divide residents by specialism. Residents of different specialism may not have equal laparoscopic experience. However, all residents had completed basic laparoscopic surgical skill training during their first year of residency prior to participation in the ASC. Fourth, we did not record handedness. As 90% of the world population is right hand dominated³², we can assume that most participants in this study were right handed. However, in future, we should record handedness and perform subgroup-analyses. Fifth, we demonstrate in this study that a significant number of trainee attain an

expert level during a laparoscopic training course. In the absence of a control group however, we cannot assign this to the influence of training or mere familiarity with the TrEndo.

The surgical landscape is calling for objective means to train, record and maintain laparoscopic skill^{33;34}. Some empirical studies suggest that an improved performance on the laparoscopic training box correlates with improved clinical performance³⁵. Our study finding might comply with these needs in providing a (objective) tool to train laparoscopic skill.

We individually compared MAPs to an expert level. Future research should integrate MAPs into an overall rating score on the TrEndo for an easier-to-read indication of laparoscopic skill. Cotin et al. introduced an integrated score based on 5 MAPs on the Virtual Laparoscopic Interface (VLI) (Immersion Corp., San Jose, CA)³⁶, however unfortunately they did not report on the weight of each MAP.

Adequate performance in MIS demands a broad range of skills beside procedural performance such as technical- and psychomotor-competency³⁷. In our opinion, a comprehensive training program of MIS skills ideally combines all MIS competencies¹.

Conclusion

In this study we demonstrate that laparoscopic skill of trainees as recorded by the TrEndo laparoscopic simulator grows significantly toward an expert level during a laparoscopic training course in a large and heterogeneous study group. As in our previous study, construct validity of the TrEndo is established.

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