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Original Article

Intracorporeal Knot Tying in a Box Trainer: How Proficient Is in Vitro Evaluation in Laparoscopic Experts?

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ABSTRACT **Objective:** To determine the applicability of motion analysis parameters of intracorporeal knot tying in box trainers in experts as predictors of surgical outcome.

Design: Consecutive series of 1534 advanced laparoscopic hysterectomies (Canadian Task Force classification II-2).

Intervention: Time, path length, and motion in depth of a standardized intracorporeal knot-tying task were compared with mean risk-adjusted primary clinical outcomes for each participant.

Results: Although a large variety in proficient knot tying and surgical skills factors was observed; after correction for patient mix in 50 expert surgeons, motion analysis of intracorporeal knot tying could not significantly determine surgical outcome skills in advanced laparoscopic surgery.

Conclusion: Levels of proficiency in advanced laparoscopic surgery cannot be appropriately determined using motion analysis in box trainers. Therefore, box trainer assessments do not adequately differentiate proficient from suboptimal clinical performance. Journal of Minimally Invasive Gynecology (2014) 21, 291–295 © 2014 AAGL. All rights reserved.

Keywords: Advanced laparoscopy; Knot tying; Quality measures; Skills training

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Laparoscopy is characterized by unique operative skills [1]. In particular, lack of a directly visible 3-dimensional operating field, limited tactile feedback, and the fulcrum effect due to the long-shafted instruments used challenge the surgeon's skills. As a result, it has become clear that obtaining laparoscopic skills needs attention [2]. Initial laparoscopic training should be practiced outside of the operating room, and therefore basic skills must be acquired using laparoscopic box trainers and/or virtual reality simulators [3].

Currently, in several countries, sufficient basic skills training in laparoscopy is mandatory before residents are allowed to enter the minimally invasive operating room [4]. Numerous laparoscopic tasks in box trainers and virtual reality trainers are validated for residents [5,6].

Within these tasks, intracorporeal knot tying is considered one of the most difficult basic maneuvers and comprises all skills characteristic of laparoscopy [7]. Moreover, all basic laparoscopic skills are incorporated in this task, i.e., ambidexterity, depth judging, handling of materials, manipulating of instruments, and the need to apply fluent movements [8]. In addition, proficiency in suturing, including intracorporeal knot tying, is prerequisite to performance of advanced laparoscopic surgical procedures [1]. Suturing skills are needed if a complication occurs (e.g., bleeding or a lesion in the urinary tract or intestine) or in case of dysfunction of conventional suturing devices.

In previous research we validated this task using TrEndo box trainer, with addition of economy of movement to time, consequently adding the potential to refine acquisition of skills of residents [9]. All residents showed rapid

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improvement in proficiency until achieving expert level performance.

Nevertheless, should the "experts" meet certain preconditions at regular time intervals? Unlike residents, laparoscopic surgeons who already perform advanced laparoscopic procedures lack validated box trainer tasks to measure their skills [10]. In addition, until now, no criterion standard of surgical competency against which the validity of a skills task can be judged has been available [11]. With recent calls for continuous quality assessments in minimally invasive health care, a validated task for testing experienced surgeon skills outside of the operating room is needed [12]. Because residents must prove their psychomotor skills in a skills laboratory before commencement of performing endoscopic surgery in the operating room, both governments and insurance companies, and patients now demand a reliable quality and proficiency control for experts.

From previous research we learned that with time, path length, and motion in-depth analysis we are able to differentiate between groups with different levels of experience during an intracorporeal knot tying task in a physical box trainer [13]. This indicates the construct validity of these objective assessment parameters for psychomotor skills for intracorporeal knot tying. With respect to the group of experts, no substantial improvement over 3 attempts was measured, confirming the expert status of this group.

The objective of the present study was to quantify and qualify correlations between intracorporeal knot-tying skills in the box trainer and proficiency in advanced laparoscopic surgery. Does swift and efficient intracorporeal knot tying predict surgical skills of an expert in advanced laparoscopic surgery?

Material and Methods

To define good surgical outcomes, a 1-year consecutive series of performed advanced laparoscopic procedures (in this case, laparoscopic hysterectomies) was registered. Risk adjustment for several patient and procedure characteristics was performed.

Every gynecologist who participated in this 1-year prospective observational study of laparoscopic hysterectomy outcomes was requested to perform an intracorporeal knot-tying task in the TrEndo box trainer. The Department of Biomechanical Engineering at the Technical University of Delft developed this tracking system to provide reliable motion analysis in laparoscopic box trainers [9].

Historically, gynecologists who perform laparoscopic hysterectomies (i.e., advanced level laparoscopic procedures) are considered experts in this field. Before the intracorporeal knot-tying task, a videotaped example of the procedure was shown and an animated instruction was provided. Thus, each participant was informed about the intracorporeal knot-tying technique to be used. This technique, also known as the C method, consists of a series of knots, starting with a double loop around the needle holder of the dominant hand, followed by a single loop around the contralateral needle holder, followed by a final single loop around the needle holder of the dominant hand. Every knot was judged for firmness and stability. Starting position of the needle was at the tip of the needle holder of the dominant hand. Both needle holders were set up on standardized marked starting points. The knotting area was indicated by a vertical line on the artificial soft tissue pad, exactly in the middle front of both needle holders. The suture material used was 7.5 cm of 3-0 polyglactin thread, with a taper point 3/4 circle needle [13].

The movements of the laparoscopic instruments were recorded using the TrEndo tracking device in 4 degrees of freedom (df): an up-down translation (first df), a forward-backward translation (second df), and a left-right (third df) ration around the incision point, and the rotation of the instruments around its longitudinal axis (fourth df) [9] The 3 recorded motion analysis parameters were time (defined as the total time taken to perform the task), path length (defined as the average path length of the right and left instrument tips during the task), and motion in depth, in millimeters (defined as the average of the distance travelled by right and left instruments along their axes).

Each participant was told that swiftness and efficiency of intracorporeal knot tying would be studied and that the better of 2 attempts would be included for analysis.

From previous prospective clinical research, we learned that patient factors (i.e., uterus weight, body mass index, American Society of Anesthesiologists classification, and number of previous abdominal procedures) and type of laparoscopic hysterectomy predicted surgical outcome insofar as blood loss, operative time, and adverse events [14]. After correction for these multiple covariates in a mixed-effects logistic regression model, this model showed an independent surgical skills factor, which varied between individuals.

On the basis of provided surgical outcomes during the study period, for each participant an operative time index and a blood loss index were constructed. An index of 0 indicated moderate skills, a surgical skills factor of +4 indicated superb skills, and a surgical skills factor of –4 indicated (relatively) poor skills.

The operative time index and blood loss index for each participant were plotted with the 3 intracorporeal knot-tying motion analysis results of the best attempt. Data were analyzed using statistical software (SPSS 17.0; SPSS, Inc., Chicago, IL).

Results

Fifty gynecologists volunteered to tie an intracorporeal knot using the TrEndo box trainer. In addition, for each participant we had already obtained an 0perative time index and a blood loss index (see Material and Methods). Surgeon characteristics are given in Table 1. Fewer than half of the participants (38.5%) used intracorporeal knot tying in daily