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Chapter nine

Intracorporeal knot
tying in a box trainer:
how proficient is in vitro
evaluation in laparoscopic
experts?

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Abstract

Background

Motion analysis of intracorporeal knot tying in laparoscopic box trainers can differentiate between novices, intermediates and experts. In search of predictive models for quality of care we researched the applicability of motion-analysis parameters of intracorporeal knot tying in box trainers in experts as predictors for surgical outcome.

Methods

Time, path length and motion in depth of a standardized intracorporeal knot tying task were compared to average risk-adjusted primary clinical outcomes for each participant; the Operative Time Index and Blood Loss Index as obtained from 1,534 laparoscopic hysterectomies.

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 discriminate surgical outcome skills in advanced laparoscopic surgery.

Conclusion

Levels of proficiency in advanced laparoscopic surgery cannot be appropriately discriminated by motion analysis in box trainers. Therefore, box trainer assessments do not adequately distinguish proficient from suboptimal clinical performance.

Introduction

Laparoscopy is characterized by unique operative skills.¹ Especially, lack of a directly visible three dimensional operating field, limited tactile feedback and the ‘fulcrum’ effect due to the long shafted instruments used, are challenging surgeon’s skills. As a result, it became clear that obtaining laparoscopic skills needed attention.² Initial laparoscopic training should be practiced outside the operating theatre and therefore basic skills needed to be acquired in laparoscopic box trainers and/or Virtual Reality (VR) simulators.³

Nowadays, in several countries sufficient basic skills training in laparoscopy is mandatory before residents are allowed to enter the minimally invasive OR.⁵ Numerous laparoscopic tasks in box trainers and VR trainers are validated for residents.^{6,7}

Within these tasks the Intracorporeal Knot Tying (IKT) task is considered one of the most difficult basic maneuvers and comprises all skills characteristic for laparoscopy.⁸ Moreover, all basic laparoscopic skills are incorporated in this task, i.e. ambidexterity, judging depths, handling materials, manipulating instruments, and the need to apply fluent movements.⁹ Additionally, being proficient in suturing, including IKT, is a prerequisite to perform advanced laparoscopic surgical procedures.¹ Suturing skills are needed if a complication occurs (e.g. a bleeding, a lesion in the urinary tract or the intestine), or in case of a dysfunction of conventional suturing devices.

In former research we validated this task in the TrEndo, with addition of economy of movement to time, consequently adding the potential to refine acquisition of skills of residents.⁴ All residents showed a rapid improvement of 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 in order to measure their skills.¹⁰ Additionally, until now, no ‘gold standard’ of surgical competency against which the validity of a skills task can be judged, is available.¹¹ With recent calls for continuous quality assessments in (minimally invasive) healthcare, a validated task for testing experienced surgeons’ skills outside the operating theatre is wanted.¹² Since residents have to proof their psychomotor skills in a skills lab prior to commencement of endoscopic surgery on the OR, both government/insurance companies and patients now demand a reliable quality and proficiency control for experts. [IGZ rapport 2007]

From former research we learned that with time, path length and motion in depth analysis we are able to discriminate between groups with different levels of experience during an IKT task in a physical box trainer.¹³ This indicates the construct validity of these objective assessment parameters for psychomotor skills for IKT. With respect to the group of experts, no significant improvement over three attempts was measured; confirming the expert status of this group.

The aim of this study is to quantify and qualify correlations between IKT-skills in the box trainer and proficiency in advanced laparoscopic surgery. Does swift and efficient IKT predict surgical skills of an expert in advanced laparoscopic surgery?

Materials and methods

In order to define good surgical outcomes, a one-year consecutive series of performed advanced laparoscopic procedures (in this case laparoscopic hysterectomies; LHs) was registered. Risk adjustment for several patient and procedure characteristics was executed.

Every gynecologist participating in this one-year prospective observational study on laparoscopic hysterectomy (LH) outcomes was requested to perform an IKT task in the TrEndo box trainer. The department of Biomechanical Engineering from the Technical University of Delft developed this tracking system, in order to provide reliable motion analysis in laparoscopic box trainers.⁴

Historically, gynecologists performing laparoscopic hysterectomies (i.e. advanced level laparoscopies) are considered to be experts in this field. Prior to the IKT task, a videotaped example of the procedure was displayed and an animated instruction was provided. In this way, every participant was informed about the IKT technique to be applied. This technique, also known as the 'C-method', consisted 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 contra lateral 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. Applied suture material was a 3-0 polyglactine thread of 7.5 cm, with a taper point $\frac{3}{4}$ needle.¹³

The movements of the laparoscopic instruments were recorded with the TrEndo tracking device in four degrees of freedom (DOF): an up-down translation (1st DOF), a forward-backward translation (2nd DOF), and a left-right (3rd DOF) rotation around the incision point, and the rotation of the instruments around its longitudinal axis (4th DOF).⁴ The three recorded motion-analysis parameters were time (s), defined as the total time taken to perform the task, and the following three motion analysis parameters; path length (mm), defined as the average path length of the right and the left instrument tip during the task; motion in depth (mm) defined as the average of the distance travelled by right and left instrument along its axis.

Each participant was explained that swiftness and efficiency of IKT would be studied and the best attempt out of two was included for analysis.

From previous prospective clinical research, we learned that patient factors (i.e. uterus weight, body mass index, ASA status, numbers of previous abdominal procedures) as well as type of laparoscopic hysterectomy predicted surgical outcome with respect to 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. This factor largely varied between individuals.

Based on the provided surgical outcomes over the study period, for each participant an Operative Time Index and Blood Loss Index were constructed. An Index of 0 indicated moderate skills, an SSF of + 4 indicated superb skills, and an SSF of -4 indicated (relatively) very poor skills.

The Operative Time Index and Blood Loss Index of each participant were plotted with the three IKT motion-analysis results of the best attempt. Data were analyzed using SPSS 17.0 statistical software (Chicago, IL, USA).

Results

Fifty gynecologists volunteered for tying an intracorporeal knot in the TrEndo box trainer. Additionally, of each participant we already obtained an Operative Time Index and Blood Loss Index, as described in the Materials and Methods section. Surgeon's characteristics are shown in Table 1. Less than half of participants applied IKT in daily practice (38.5%). The remaining group applied extracorporeal knot tying, barbed wire suturing and/or used a knot pusher.

Experience (expressed in numbers of laparoscopic hysterectomies performed) could not be predicted with knotting time, path length and motion in depth in the box trainer (Figure 1).

Participants in the left upper quadrant (A) of Figure 1 showed both suboptimal performance on the box trainer as well as less than average experience, while participants in the upper right quadrant (B) also showed suboptimal performance on the box trainer, however with more than average experience. Participants in the lower left quadrant (C) showed proficient performance on the box trainer with less than average experience and participants in the lower right quadrant were both beyond average proficient on the box trainer as well as more than average experienced with LH.

Figure 2 shows the distribution of performance in the box trainer, compared to risk adjusted clinical performance, by means of the Operative Time Index and Blood Loss Index. A wide dispersion of outcomes over the previously described four quadrants is seen. A filled circle depicts extreme outliers in performance on the box trainer. Also without taking these outliers into account, an almost even distribution between the four quadrants can be observed.

Table 1 Surgeon's characteristics (n = 50)

	Median	Interquartile range
Baseline characteristics		
Experience with LH (years)	6.0	3 – 10
Total numbers of performed LHs	37.5	16 – 75
Volume during study period (LHs/year)	14	10 – 24
Unadjusted operative characteristics		
Blood loss (mL)	181	122 – 235
Operative time (min)	118	100 – 135
Motion analysis characteristics		
Knotting time (s)	133	104 – 177
Path length (mm)	3060	2410 – 4420
Motion in depth (mm)	1380	1060 – 2080

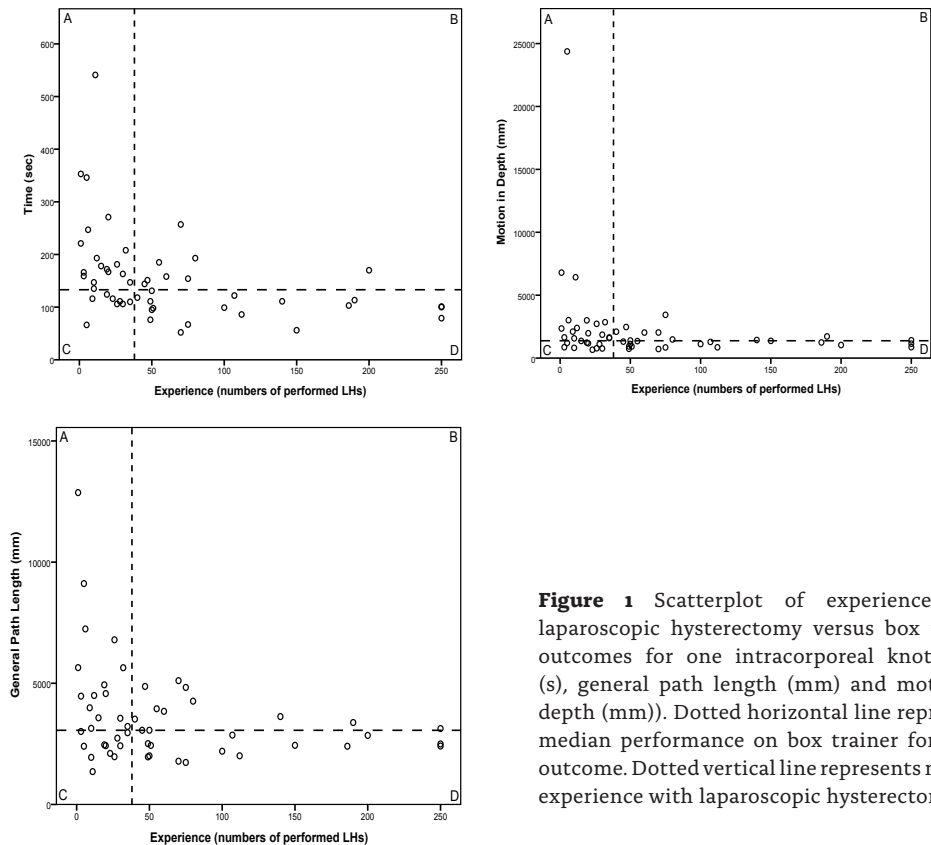


Figure 1 Scatterplot of experience with laparoscopic hysterectomy versus box trainer outcomes for one intracorporeal knot (time (s), general path length (mm) and motion in depth (mm)). Dotted horizontal line represents median performance on box trainer for given outcome. Dotted vertical line represents median experience with laparoscopic hysterectomy.

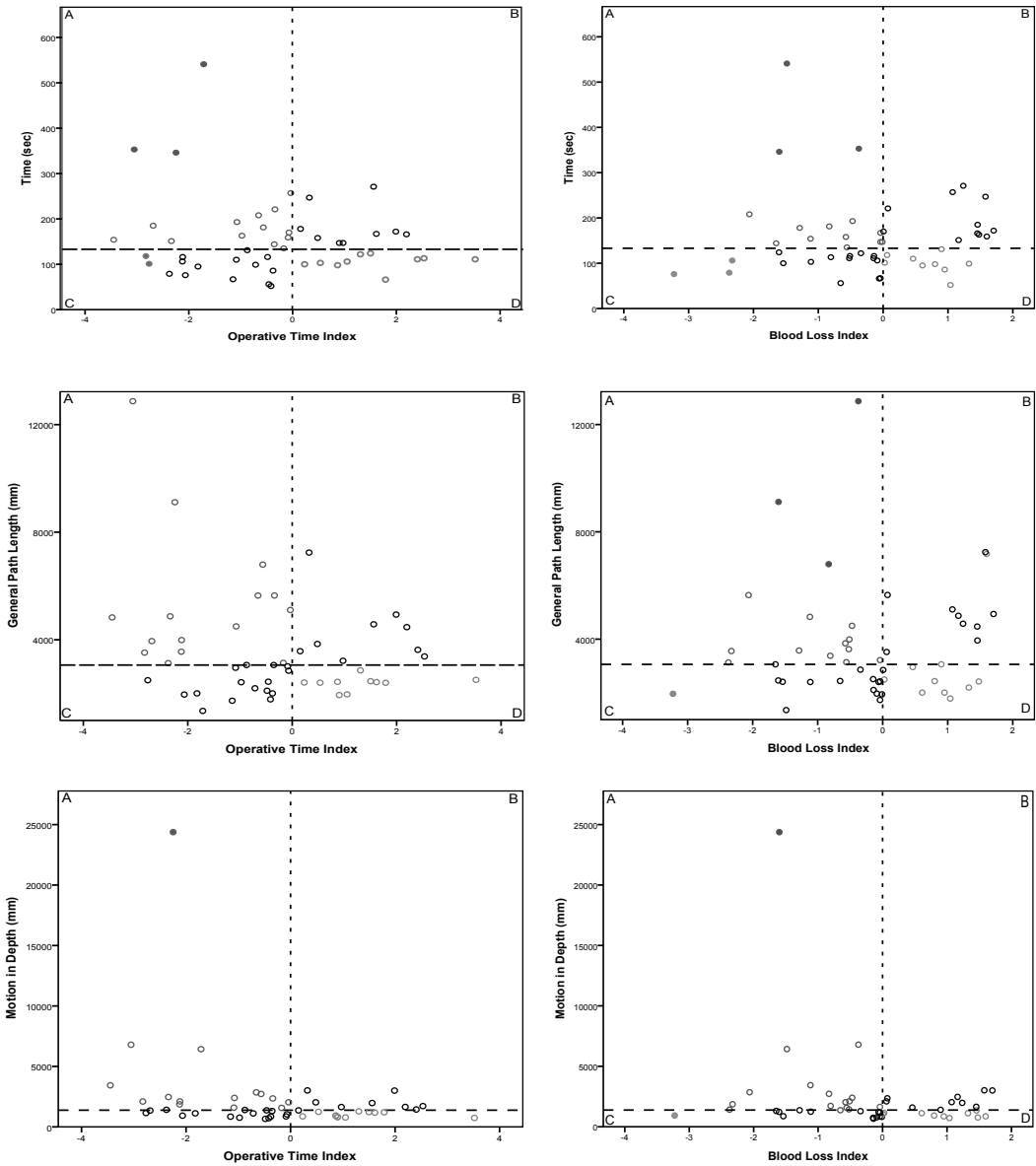


Figure 2 Left column: Operative Time Index versus box trainer outcomes (time (s), general path length (mm) and motion in depth (mm), respectively). Right column: Blood Loss Index versus box trainer outcomes (time (s), general path length (mm) and motion in depth (mm), respectively). Dotted horizontal line represents median performance on box trainer for given outcome. Dotted vertical line represents average clinical performance index. Positive indices represent superior clinical performance; negative indices represent inferior clinical performance. Outcomes of extreme outliers are depicted by filled dots. Quadrant A represents both suboptimal clinical as well as box trainer performance.

Discussion

Surgical outcome in the operating room does not sufficiently correlate with motion-analysis of intracorporeal knot tying in a box trainer. Surgical experience and surgical volume positively influences IKT skills in the box trainer in some subjects, however no predictive value can be derived from these outcomes. Furthermore, with respect to proficiency in the operating room (by means of Operative Time Index and Blood Loss Index) of laparoscopic experts, no predictive value with respect to the studied surgical outcomes can be derived from performance on the box trainer. Only a minority of participants showed relatively poor results in the box trainer with respect to time, path length and motion in depth, combined with suboptimal Operative Time Index and Blood Loss Index.

Based on our results we would like to state a number of possible explanations. Firstly, during acquiring the first competencies in (laparoscopic) surgical skills, monitoring of VR or box trainer results provides useful information regarding the proficiency-gaining curve and discriminates skillful novices from less competent residents. However, after reaching the nebulous-termed and ill-defined 'expert level', surgeons tend not to show significant improvement over multiple attempts on a box trainer.¹³ Secondly, we imply that in experts, single task observations in box trainers lack the complexity of 'real' advanced laparoscopic surgery and therefore fail to mimic results from these complex procedures. Perhaps, with the evolution of VR trainers, comprising of realistic full procedure tasks including augmented and force feedback, a more predictive outcome measurement tool will become available. Until then, a more pragmatic approach should be applied.

Unfortunately, proficiency in advanced laparoscopy cannot be predicted with an in vitro evaluation tool such as the box trainer, because the same proportion of 'clumsy' knot tiers happen to operate as swift and bloodless as their handy counterparts. Furthermore, a good score on the box trainer will not guarantee swift and bloodless surgery. Therefore, the proposed task is not reliable and therefore not applicable by means of evaluation of clinical proficiency. Also in this light, perhaps a more 'real-time' monitoring tool should be considered.

It is conceivable that the outliers we depicted in Figure 2 (filled red dots) should reconsider their initial (knot tying) skills, however, the same number of participants with swift and efficient knot tying performance did show comparable suboptimal clinical performance (filled orange dots) by means of a negative Operative Time Index and Blood Loss Index.

This study reflects performance of an unique large group of gynecologists with a wide diversity on the OR as well as in the box trainer. As a result, we consider the outcomes representative for an even larger cohort of surgeons that perform advanced level laparoscopic surgery. In this light, we should reconsider the limited additive value of testing basic laparoscopic skills in experts, and search for alternative monitoring tools.

At this point we suggest that a continuous risk adjusted and comparative monitoring of advanced laparoscopic tasks can assist in signal derailing surgical competence. Examples with

cumulative summation analysis can be found in the field of minimally invasive obstetrics and laparoscopic colorectal surgery.^{15,16} In conclusion, the novice and intermediate are well served in using box trainers with motion analysis. This provides them with usable tools in order to optimize their proficiency gaining curve prior to performing minimally invasive surgery on patients. Once surgeons have achieved this level of competence, they face advanced level 'tasks' in real patients, of which each requires a multidimensional approach. Exclusively dexterity with basic box trainer tasks will not guarantee good surgical outcome. Definition of the 'real' expert requires a yet to be revealed palette of skills, indication strategies and patient outcome measures.

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