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Maintenance training for laparoscopic suturing: the quest for the perfect timing and training model: a randomized trial

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Abstract
Background Although excellent training programs exist for acquiring the challenging skill required in laparoscopic suturing, without subsequent reinforcement, performance is prone to decay. Therefore, maintenance training is proposed to ensure better skill retention. This study aimed to elucidate the ideal timing and frequency of maintenance training as well as the best model to be used for this training.
Methods After completing a proficiency-based laparoscopic suturing training, 39 medical students attended different maintenance programs represented by four groups: a control group without additional training (group 1), a massed training group with one supervised training session (150 min) after 2.5 months (group 2), and two distributed training groups with five monthly unsupervised training sessions of 30 min on a box trainer (group 3) or the LapMentor® (group 4). Retention testing, after 5 months, included suturing on a box trainer and on a cadaver porcine Nissen model. Performance scores (time and errors) were expressed in seconds. Afterward, time needed to regain proficiency was measured.
Results On the box trainer, the median performance scores were 233 s (interquartile range [IQR] 27 s) for group 1, 180 s (IQR 55 s) for group 2, 169 s (IQR 26 s) for group 3, and 226 s (IQR 66 s) for group 4 ($p = 0.03$). No difference was seen between groups 2 and 3, both of which significantly outperformed groups 1 and 4. On the porcine Nissen model, no differences were detected between the groups ($p = 0.53$). Group 3 reached proficiency more quickly than the other groups.
Conclusions Maintenance training is a valuable and necessary addendum to proficiency-based training programs for laparoscopic suturing. A maintenance-training interval of 1 month with unsupervised training sessions on simple box trainers seems ideal. The LapMentor® did not show any benefit. Performance differences between groups did not translate to a clinically relevant model, indicating that transfer of training is not perfect.

Keywords Laparoscopy · LapMentor® · Maintenance · Suturing · Training · Virtual simulation

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Currently, skill laboratories and structured training programs are an essential part of the training curriculum for surgical residents. Technically challenging skills such as laparoscopic suturing and knot tying can be taught and practiced in a patient-free and thus a stress-free environment [1, 2]. One problem with these laboratory-based training programs is that the acquired skills are not subsequently reinforced in a clinical setting [3]. Of course, this makes the skills prone to decay.

Several studies concerning laparoscopic suturing and knot-tying skills have reported a deterioration of performance with time [3–7]. Stefanidis et al. [4] stated that short maintenance practice sessions on a regular basis provided better skill retention. Likewise, Castellvi et al. [3] and Mashaud et al. [5] suggested that ongoing training in laparoscopic suturing is beneficial. Therefore, an effort should be made to associate such maintenance training with the existing curricula.

Currently, surgical residents in the University Hospital of Leuven (KUL network, Belgium) have two main options for maintaining their laparoscopic suturing skills. Once or twice yearly, they have the opportunity to attend intensive 1-day training courses in which five or six trainees practice their laparoscopic skills under expert supervision [8].

On the other hand, in many hospitals, simple training facilities such as box trainers are provided to allow motivated residents to perform unsupervised deliberate practice. Previous research has shown that massed practice is inferior to distributed practice [9]. This study investigated whether this also applies to maintenance training and aimed to elucidate further the ideal timing and frequency of the training sessions.

Sophisticated virtual trainers with suturing programs have been proved capable of good skill acquisition and transfer of skill [10–12]. The advantages of these facilities are ease of use, push of only one button needed to start training, no additional costs for suturing thread, good feedback provided by the system, a variety of exercises available, and differing difficulty levels, planes, and types of suture. This study also investigated whether this training model has advantages over simple box trainers in an unsupervised practice maintenance schedule.

Materials and methods

Study setup

The study recruited 40 medical students for a randomized controlled trial at the Center of Surgical Technologies, KU Leuven, Belgium. Informed consent was obtained from all the participants. Before study entry, all the subjects completed a proficiency-based training program in laparoscopic suturing and knot tying. The subjects then were stratified according to their suturing performance and randomized into four groups. They all trained according to the maintenance program assigned and performed a retention test 5 months after study entry.

Participants

The study population consisted of preclinical medical students with no laparoscopic experience. A questionnaire concerning demographic information (age, gender, and dexterity), motivation for surgery, and prior laparoscopic, video game, or billiard experience (using a 10-point Likert scale) was administered.

Psychomotor innate ability was measured as the average time score (in seconds) for three trials of the bean drop and running string exercises on the box trainer [13]. Afterward, the students all completed our suturing and knot-tying program [6] and daily practice on a Penrose drain model until predetermined proficiency criteria were reached. The criteria required two consecutive expert performances, defined as the mean performance score (outliers excluded) of 10 trials by 2 expert laparoscopist (= 145 s [2, 6]).

Subsequently, 1 week after training, all the study subjects performed a skills test involving three trials of the suturing and knot-tying exercise (sliding knot) on the Penrose drain model. Performance scores were based on time and errors, with higher scores indicating worse performance, using a previously described formula with a maximum score of 600 [6]. The mean performance on these three trials was used for stratified randomization. This way, four balanced groups were created.

Maintenance training programs

The control group did not receive any further training during the 5 months (group 1). The first experimental group received one intensive training session 2.5 months after completion of training (group 2). This training session was organized with five students simultaneously and one supervisor attending the training session.

The training session lasted 150 min. An instructional stepwise video demonstration was used [6], and multiple suturing and knot-tying exercises were provided. First, the Penrose drain training model was used, but afterward, suturing was performed on a porcine stomach and chicken wings. These exercises were added to prevent boredom and maintain motivation of the students. This group represented the massed training facility or how training is organized currently for residents at the University Hospital of Leuven, KUL network, Belgium [8].

The second and third experimental groups trained in a distributed manner. The trainees attended five practice sessions of 30 min once monthly without supervision. Before each training session, the same instructional stepwise video demonstration was shown [6]. For the second experimental group, only the Penrose drain model was used during these training sessions (group 3).

The third experimental group trained on the LapMentor® (Simbionix, Cleveland, USA) virtual trainer (group 4). On this virtual trainer, 12 suturing exercises are available. Students were free in their choice of the exercises, but finally, all 12 exercises should have been performed at least two times [10].

Retention testing

The retention test was not preceded by an instructional video. This allowed retention of the cognitive and skills aspects of suturing to be measured simultaneously. All testing was performed by one research fellow not blinded to training status.

First, suturing skills were tested on a previously described in vitro porcine Nissen fundoplication model [2]. Students received an illustrated text on the clinical indication and proceedings of the actual operation as well as the specific features and error scores of the simulated operation. The fundus was draped around the esophagus and attached to prevent dislodgement. Markers were placed in the fundus on either side of the esophagus at 1-cm intervals to serve as targets.

The students placed three sliding knots, and the mean performance score on these three trials was used. The performance score was calculated using the time used to perform the suture corrected for errors. These errors were based on the same system as described for the Penrose drain model [6] but adapted to the cadaver porcine model.

Accuracy of suture placement and tissue gap distance was objectively measured with a ruler. Security error was determined by inserting a pair of laparoscopic scissors within the loop and spreading it. Again, the maximum score was set at 600. Afterward, the students' suturing and knot-tying skills were tested on the Penrose drain model using the conventional scoring. The students performed three trials of the suturing and knot-tying exercise, and the mean performance score was calculated. Finally, they were allowed to watch the instructional stepwise video demonstration, and for 2 h they had the possibility of training until the proficiency criterion was reached again (two consecutive expert performances).

Statistical analysis

The choice of 10 subjects per group was based on previous trials [2, 4, 11, 12]. All data are shown as medians and interquartile ranges (IQRs) unless stated otherwise. The groups were compared using the Kruskal–Wallis and Mann–Whitney *U* tests. Because three different outcome variables were evaluated (Nissen, Penrose drain, learning curve), the *p* values of those Kruskal–Wallis tests were multiplied by three (Bonferroni correction). A *p* value lower than 0.05 was considered statistically significant.

Results

During the initial training, one participant dropped out, so three experimental groups of 10 students and one control group of 9 students were created. All these students were able to complete the proficiency-based suturing training and to attend baseline and retention testing. The four groups were comparable in terms of demographic data, motivation, prior experience, innate psychomotor ability, and baseline suturing performance (Table 1).

The final performance results for the cadaver porcine Nissen model are shown in Fig. 1. The performance scores were 428 s (IQR 77 s) for group 1, 369 s (IQR 75 s) for group 2, 357 s (IQR 165 s) for group 3, and 364 s (IQR 130 s) for group 4 ($p = 3 \times 0.18 = 0.53$).

The final performance results for the Penrose drain model, as shown in Fig. 2, were 233 s (IQR 27 s) for group 1, 180 s (IQR 55 s) for group 2, 169 s (IQR 26 s) for group 3, and 226 s (IQR 66 s) for group 4 ($p = 3 \times 0.009 = 0.03$). Compared with the proficiency level (expert performance = 145 s), this means a performance deterioration of 61 % for group 1, 24 % for group 2, 17 % for group

Table 1 Baseline characteristics

	Group 1 (control)	Group 2 (massed practice)	Group 3 (distributed practice on box trainer)	Group 4 (distributed practice on VR trainer)	*p* value
Age (years)	22 (2)	21 (3)	21 (2)	21 (2)	0.61
Gender (% women)	44	40	40	40	1
Dexterity (% right handed)	100	90	80	80	1
Motivation for surgery[a]	10 (1)	8 (1)	8 (1.5)	8 (1.6)	0.09
Prior experience					
Laparoscopic[a]	1 (0)	1 (0)	1 (0)	1 (0)	1
Computer games[a]	5 (2)	3.5 (5.5)	3 (2.5)	3 (5.5)	0.54
Billiards[a]	3 (3)	2.5 (1.8)	2.5 (1)	3 (1.8)	0.39
Innate psychomotor ability (s)	115 (6)	121 (17)	109 (23)	120 (27)	0.75
Baseline suturing performance (s)	194 (31)	203 (47)	205 (47)	196 (60)	0.98

Interquartile range (IQR) values are in parentheses

VR virtual reality

[a] Scored on a 10-point Likert scale

3, and 56 % for group 4. Groups 2 and 3 performed significantly better than groups 1 and 4 (Table 2).

After retention testing, only one student (in group 3) was not able to reach proficiency after the 2 h of training. For that student, the maximum of 120 training minutes was assigned. That student also needed the most trials to reach proficiency in the initial suturing training. She scored average on innate psychomotor ability (117 s).

Proficiency was reached after a median of 60 min (IQR 25 min) in group 1, 43 min (IQR 16 min) in group 2, 20 min (IQR 21 min) in group 3, and 63 min (IQR 39 min) in group 4 (Fig. 3, $p = 3 \times 0.004 = 0.01$). Group 3 performed significantly better than all the other groups, and group 2 performed significantly better than the control group (Table 2).

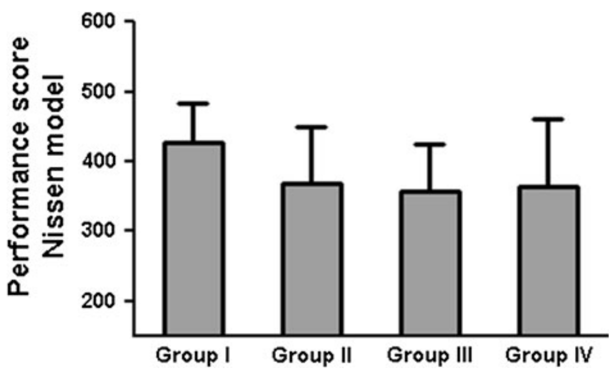

Fig. 1 Performance scores on the porcine Nissen model for all the groups. Data are shown as medians and interquartile ranges

Discussion

Technically challenging skills such as laparoscopic suturing and knot tying currently are taught in skill laboratories during structured training programs [1, 2]. Because the acquired skills are not reinforced in a clinical setting, performance is prone to decay [3–7]. Therefore, maintenance training is proposed to ensure better skill retention [3–5]. This study aimed to elucidate the ideal timing and frequency of maintenance training as well as the best model to be used for this training.

The final aim of laboratory-based training is the transfer of skill to the operating room. Therefore, the most important evaluation in this study was the performance on the porcine Nissen model.

First, all the groups performed the suturing exercises on this clinical model much slower than on the conventional Penrose drain model. Second, no differences in performance between the groups were detectable. Most likely, the transfer of training to the porcine model was far from complete, and the subtle differences in performance captured on the Penrose drain model did not translate to this clinically more relevant model [14]. This might have been due to the type of subjects that participated because the students were completely naïve concerning laparoscopic procedures. Therefore, the adaptation to the differences in tissue handling might have influenced their performance and concealed existing differences in performance.

Fig. 2 Performance scores on the Penrose drain model for all the groups at baseline (1 week after training) and at retention (5 months after training). Expert performance was a proficiency level of 145 s. Data are shown as medians and interquartile ranges

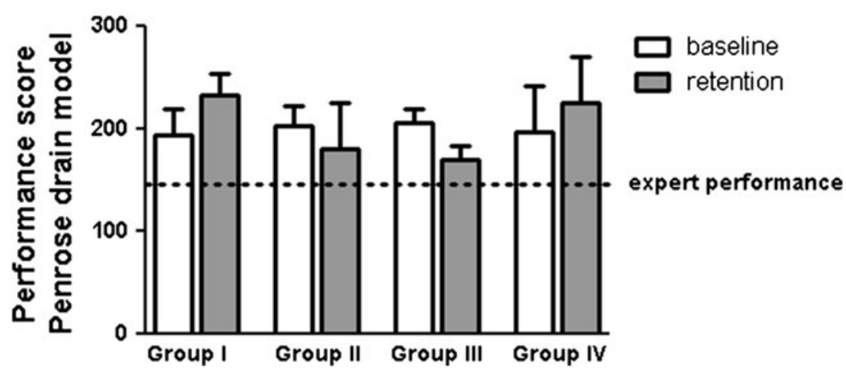

Table 2 The results of the Kruskal–Wallis test (multiplied by 3 for Bonferroni correction) and the Mann–Whitney *U* test (MWU) for the three outcome parameters

	Nissen model	Penrose drain model	Time to re-achieve proficiency
Kruskal–Wallis	3 × 0.18 = 0.53	**3 × 0.009 = 0.03**	**3 × 0.004 = 0.01**
MWU 1 vs 2	–	**0.02**	**0.03**
MWU 1 vs 3	–	**0.01**	**0.001**
MWU 1 vs 4	–	0.9	0.9
MWU 2 vs 3	–	0.5	**0.02**
MWU 2 vs 4	–	**0.03**	0.1
MWU 3 vs 4	–	**0.01**	**0.007**

p values lower than 0.05 were deemed significant and are shown in bold

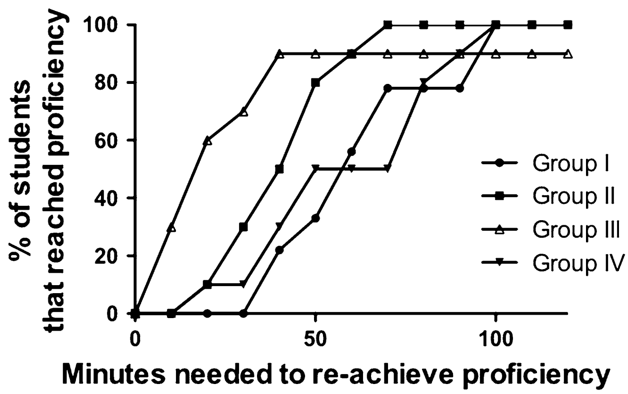

Fig. 3 Time needed to re-achieve proficiency after retention testing

Indeed, Van Sickle et al. [15] showed significantly slower performance on an animal Nissen model by students compared with surgical residents who attended the same proficiency-based suturing training (285 vs 559 s). Furthermore Korndorffer et al. [2] showed that even for residents, transfer of suturing skill to a Nissen model is not 100 %. Although proficient in laparoscopic suturing on a Penrose drain model, residents in that study achieved an overall score of only 389 s compared with expert performance of 504 s [2].

Korndorffer et al. [2] suggested additional modifications to increase the efficiency of training such as including more difficult suturing tasks and implementing virtual simulation. In our study, several models such as chicken wings, porcine stomach, and the LapMentor® virtual trainer system were included. But none of these models resulted in a better performance of the laparoscopic Nissen procedure. After all, it is not illogical that laboratory-based training cannot fully replace real-life training in the operating room. The final touch will have to be taught the good old Halstedian way, or preferably, a more structured version of it [8].

To answer our research questions further, we used the results of the Penrose drain model. We believe this gives a good idea concerning the pure technical aspect of a trainee's suturing skills, not influenced by other factors such as tissue handling.

Training frequency

Stefanidis et al. [4] claimed that a 3-month training interval was ideal for maintaining suturing skill. Therefore, we chose to reevaluate this type of training interval (2.5 months, massed practice, group 2) compared with a control group (5 months, group 1), and especially to investigate the impact of shorter training intervals (1 month, distributed box trainer, group 3). This 1-month interval was chosen because participants in the study of Stefanidis et al. [4] showed very stable performance between immediate post-testing and testing at 1 month.

Performance on the Penrose drain model was significantly better for both groups 2 and 3 than for the control group. No difference was seen between these two maintenance groups. The purpose of training difficult skills in a laboratory setting is to achieve proficiency in that skill so that it is available at any given moment, suddenly and unexpectedly, when it is needed in the operating room. Based on this criterion and assuming that the performance on the Penrose drain reflects operating room performance, the results of our study promote a maximum training interval of 2.5–5 months because shorter intervals (monthly) did not result in better performance, and longer training intervals (5 months) resulted in significant skill loss. This is very similar to the results of Stefanidis et al. [4], who proposed a maintenance training interval of 3 months.

We believe, however, that monthly training sessions are preferable for two main reasons.

First, the maintenance training schedule of group 3 provided significant logistic advantages. In a previous study, we showed that structured training with video demonstrations and peer feedback can replace expert supervision for teaching laparoscopic suturing skills to novices [6]. Recently, Korndorffer et al. [16] showed that home training results in excellent laparoscopic skill acquisition and retention. In this study, the students who were offered 150 min of training with feedback from an expert, including several models with animal tissue, did not show any advantages over an unsupervised training group that used only the Penrose drain model. This again confirms the validity of independent deliberate practice.

Second, as can be seen from our results, it takes students a median of 20 min after 1 month (group 3) to re-achieve proficiency, whereas it lasts significantly longer (43 min) after 2.5 months (group 2; $p = 0.02$). This probably indirectly indicates a superior skill level. It corresponds with the results of Bonrath et al. [17], who found deterioration of intracorporeal suturing skill already after 11 weeks.

On the other hand, one student in group 3 was not able to re-achieve proficiency during the 2-h training period. This indicates that, in the end, maintenance training, like conventional training, needs to be tailored to the individual needs and innate abilities of the trainee [13] and that frequency and duration of training periods are personal and most likely better determined by re-achievement of proficiency, as suggested in other maintenance programs [4, 5].

In a previous study, we found a correlation ($\rho = 0.53$; $p = 0.02$) between psychomotor innate ability and the number of trials needed to reach proficiency in suturing [6]. We suggested that this might be useful for detecting students that need supplementary training.

In the current study, with the same concept, measurement of innate psychomotor ability could not identify the need of these students for extra training during both the initial and maintenance learning curves. Therefore, although predictive value has been ascribed to innate psychomotor ability [6, 13], further research is needed to identify other players such as motivation.

Training model

The virtual trainer group (group 4) showed performance results equal to those of the control group and was significantly outperformed by the box trainer group (group 3) on the Penrose drain model. The time needed for re-achieving proficiency was 63 min, equal to that of the control group (60 min), indicating that the virtual simulator had no learning effect whatsoever.

Previously, no studies had investigated the role of virtual simulation in suturing maintenance training, but promising results have been obtained concerning the initial suturing training possibilities using virtual simulation. Munz et al. [11] showed a transfer of suturing training from a LapSim (Surgical Science, Gothenburg, Sweden) and Tanoue et al. [18] for the Procedius MIST (Mentice AB, Gothenburg, Sweden) suturing simulator to a conventional box trainer, and Verdaasdonck et al. [12] showed a transfer of suturing training from the Simendo (Dellta Tech, Delft, The Netherlands) virtual trainer to an anesthetized pig model. On the other hand, Halvorsen et al. [19] did not show any training benefit for suturing on a virtual simulator compared with a control group that had no training.

In a comparison of virtual and box training models for suturing, no differences could be detected during performance assessment in several live animal models [10, 20, 21]. Moreover, research investigating an additive role of the virtual trainer to the conventional box trainer in suturing programs failed to show any benefit of adding the virtual simulator to the suturing program [22, 23]. Furthermore, participants in comparative suturing studies systematically favor the box trainers due to their realism and haptic features [20, 22, 24].

The role of virtual simulation in maintenance training has not been investigated to date. Probably the virtual reality systems still are lacking the necessary haptic sensations that are of crucial importance for advanced laparoscopic (suturing) training [22]. In the initial stages of training, it might be useful to teach the main steps and cognitive parts of suturing, but in considering a maintenance training, which aims at refinement of a known technique, the system fails.

Some limitations of the study included the small number of participants and thus a power problem, especially for the Nissen model, in which small differences between groups might have been concealed. The number of participants in this study was based on a previous maintenance study [4] and transfer studies to animal models [2, 12]. Because, to our knowledge, this is the first study to use an animal model for comparing different maintenance schedules, our results might be useful for power calculations of future studies with a similar setup.

The study subjects were students who did not have ongoing clinical training opportunities in the operating room, so the ideal training interval might be longer for residents with current on-the-job training. On the other hand, training opportunities for a skill such as laparoscopic suturing do not need to be overrated because most residents are afforded very few opportunities to practice them in the operating room.

Finally, we did not include overtraining in our initial proficiency-based training schedule (the criterion for proficiency is two consecutive expert performances without reinforcement); nor did we include proficiency criteria in the maintenance training. Indeed, in a recent study, Stefanidis et al. [25] proposed training until automaticity instead of proficiency. In our study, the median baseline suturing performance, measured 1 week after completion of the proficiency-based training, varied from 194 to 205 s, which means a performance deterioration of 34–40 % compared with the proficiency level reached at the end of the initial training (145 s).

In a previous study we found an equal degree of skill loss [6], and Mashaud et al. [5] similarly found that only 58 % of residents were able to reach the proficiency level on an immediate post-test. This indicates that proficiency-based training was most likely insufficient. During maintenance testing, however, students performed better than on the immediate post-test, with the distributed box trainer group exhibiting only 17 % skill deterioration compared with the proficiency level.

This same phenomenon is suggested in the study of Mashaud et al. [5], which means maintenance training not only minimizes skill loss but also even enhances performance. This might be a more attractive and intuitively more relevant way of reaching real proficiency than including excessive overtraining until automaticity in the initial training course.

Conclusions

Maintenance training is a valuable and necessary addendum to proficiency-based training programs for laparoscopic suturing. A maintenance training interval of 1 month with unsupervised training sessions using simple box trainers seems ideal. The LapMentor® virtual simulator did not show any benefit. Performance differences between groups did not translate to a clinically relevant model, indicating that transfer of training is not perfect.

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