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Prospective comparison of single encounter versus distributed laparoscopic training in novice learners: A controlled trial

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Abstract:

BACKGROUND: The traditional model of teaching surgical skills on "real" patients using graded responsibility is being seriously questioned, and there is a paradigm shift toward exploiting simulators. There is a lack of clarity on the impact of using simulation as a teaching strategy in novice learners. The purpose of our study was to determine if the number and duration of training sessions influence the acquisition and retention of laparoscopic skills in naïve learners. There are some data to suggest that distributed training programs might have better outcomes, but the results are inconclusive. We designed a controlled trial at Aga Khan University, Karachi, with the hypothesis that students trained using the distributed method may have enhanced learning outcomes.

MATERIALS AND METHODS: 100 medical students were assigned in a 1:1 ratio to one of two groups. Group A underwent a single orientation and supervised practice session of 3 h duration. Group B underwent distributed teaching with three learning sessions of 1 h each spread over 3 consecutive weeks. Participant scores were analyzed before and after the intervention and at 3- and 6-month intervals using repeat measures of ANOVA.

RESULTS: Pretest and immediate posttest scores were comparable between the two groups. The 3-month interval test showed significantly higher scores in Group B (difference = −2.90, $P < 0.001$). The 6-month interval test showed no differences in scores between the two groups ($P = 0.178$).

CONCLUSIONS: Distributed teaching resulted in significantly enhanced scores at 3-month assessment. However, similar scores at 6 months suggest the need for repeated intervention.

Keywords:

Distributed learning, laparoscopy, massed learning, psychomotor skills

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Introduction

Teaching and learning of psychomotor skills is the cornerstone for surgical training programs. The "traditional" model of teaching surgical skills on "real" patients using graded responsibility is being seriously questioned.[1,2] Moreover, the development and rapid introduction of new technology in surgical procedures, including laparoscopic surgery, has presented new challenges for trainees, teachers, and institutions.[3,4] Acquisition of such complex skills requires many hours of hands-on training, which becomes even more challenging in the face of reduced trainee working hours.[5] Work hour restrictions, pressure to increase theater throughput, and the ethical debate regarding inexperienced surgeons operating on patients meant that the traditional model of surgical training needed to be revised.[6] As a result, focus has shifted to the use of models and simulators, with the objective

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of better preparation of trainees for real-life operating room experience.[1]

Recent studies on naïve medical students suggest that even long-term retention of skills is possible after short courses of simulation-based laparoscopic training.[7-9] The role of simulators and simulation-based training is well established in surgical curricula. Despite wide acceptance of the principles of simulation training, it is not clear how actual learning occurs during simulation and what facilitates the learning process in the naïve medical students. One important factor influencing learning in simulated workshops is the number of training encounters and the duration over which they occur. Single encounter training courses have the advantage of convenience and superior test scores but may have associated disadvantages such as fatigue and stress for the trainees, lack of time to prepare and study, and inability of continued reflection on self-improvement. There are some data to suggest that distributed training programs, with the curriculum being distributed over a longer period of time, might have better outcomes.[10]

We proposed a study to understand the factors influencing the acquisition of laparoscopic skills in naïve medical students with a special focus on the number and duration of training encounters. The objectives of the study were to determine if acquisition and retention of laparoscopic skills were superior with multiple training encounters as compared to a single training session of similar duration and to identify the factors influencing learning laparoscopic skills in naïve medical students.

Materials and Methods

Study design and setting

This was a parallel nonrandomized controlled study design with a 1:1 ratio in each arm conducted at the Centre for Innovation in Medical Education at our University Hospital.

Study participants and sampling

Medical students of 2nd, 3rd, and 4th year volunteered to participate in the study and were given the option of choosing their own group on a first-come first-serve basis. The sample size of fifty participants in each arm was calculated using the statistical formula based on the data from previous studies.

Group A (Single Encounter) was offered a single teaching session of 3 h and Group B (Distributive Training) had three teaching sessions of 1 h each, divided over a period of 3 weeks.

The total duration of training was the same for both groups, but the number of encounters and duration of each encounter were different. All participants were offered a 15-min tutorial on the basic principles of instrument handling, depth perception, and hand eye coordination followed by a demonstration of specific tasks. This was followed by hands-on practice of the following tasks:

Task 1: Transfer of pegs across the field by the nondominant hand.

Task 2: Precision cutting-cutting a circle on gauze paper with endoscissors.

Task 3: Passing a thread through hooks using the dominant hand.

Data collection tool and technique

A pretest questionnaire was administered regarding demographics, dominant hand, and hobbies requiring hand dexterity like playing console-based video games and musical instruments. At the beginning of the study, an assessment of baseline psychomotor skills of the participants on laparoscopic skills simulator for all three tasks (pretest assessment) was done.

The pretest was followed by the supervised training session, followed by the posttest assessment. No further training was offered to participants during the interim period and re-assessment of skills on the three tasks was undertaken at 3-month and 6-month intervals. The assessment of skills was conducted by experienced faculty members, and participants were scored using the previously validated GOALS (Global assessment of laparoscopic skills) scale, as shown in Table 1.[11] Each student was given 180 s to complete each task with their performance scored according to the predefined rubric.

SPSS version 20 software (SPSS Inc., Chicago, Ill., USA) was used for statistical analysis.[12] Demographic data and distribution of hobbies were described as frequencies and percentage. The scores at various readings were described as mean, median, minimum, and maximum values with standard deviations. The preintervention, postintervention, and interval assessment mean scores were compared using repeat measures of ANOVA. The effect of gender and hobbies on scores was analyzed using one-way ANOVA. The level of significance was 0.05.

Ethical consideration

The study was funded by the University Research Council. An ethical approval for the conduct of the study was obtained from the institutional ethics committee. Informed consent was obtained from the participants for inclusion in the study.

Table 1: Global assessment of laparoscopic skills scale

Task assessment as per GOALS scale	Task 1 Placing the pegs with both hands	Task 2 Cutting a circle in a gauze	Task 3 Passing a thread across the hooks
Depth perception	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Bimanual dexterity	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Efficiency of movement	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Tissue handling	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Quantitative data	No of pegs placed across: 1 2 3 4 5 6	Section of Circle Cut: Less than a quarter Less than half Three quarter Complete circle	No of hooks crossed: 1 2 3 4 5 6 7 8
Task completed in 3 min	No Yes	No Yes	No Yes

GOALS=Global assessment of laparoscopic skills

Results

One hundred students were enrolled in the study, with fifty participants in each group. There were 21 students in year 4, 41 students in year 3, and 38 students in year 2 of the medical school. Mean age of the students was 20.7 ± 1.3 years and 61 were males. Most of the students were right-handed (90%) and 39% students reported an interest in playing video games, as shown in Table 2.

Table 3 depicts the total scores for each tasks and the comparison of scores between the two groups. The difference in mean total scores at pretest assessment between Group A and B was 0.2 for Task 1, 1.52 for Task 2, and 1.06 for Task 3. The difference in scores was only found to be significant for Task 2, where Group A scored significantly better than Group B (P = 0.010). The cumulative difference for all three tasks between the groups was 2.8 and was not found to be significant (P = 0.060).

At immediate posttest assessment, the difference in mean total scores was 1.28 for Task 1, 0.12 for Task 2, and 1.14 for Task 3. Group B scored significantly better than Group A in Task 1 (P = 0.010) and Task 3 (P = 0.040); however, the difference in Task 2 scores was negligible. The cumulative difference for all three tasks between the groups was 2.3 which was not found to be significant (P = 0.060).

At 3-month posttest, the difference in mean total scores was 1.04 for Task 1, 0.6 for Task 2, and 1.26 for Task 3. Group B still scored better than Group A in all three tasks with the difference being significant for Task 1 (P = 0.020) and Task 3 (P < 0.001). The cumulative difference for all three tasks between the groups was 2.90 and showed a significantly better performance by Group B (P < 0.001).

A 6-month posttest, the difference in mean total scores was 0.49 for Task 1, 0.96 for Task 2, and 0.14 for Task 3. Group A had better scores than Group B in all three tasks, with a significantly better score in Task 2. However, the cumulative difference for all scores between the groups was 1.59 which was not significant (P = 0.178).

Details of student performance over time are shown in Table 4 and Figure 1. There was a significant improvement in immediate posttest scores when compared to pretest scores for both groups. The mean difference in scores for Group A was 16.5 (P < 0.001), and the difference in scores for Group B was 21.6 (P < 0.001). There was a significant decline in scores at 3-month assessment as compared to the immediate posttest scores for both groups (P < 0.001), but the scores were superior to pretest scores in both groups, the difference being significant in Group B (P < 0.001). When 6-month assessment scores were compared with the 3-month assessment scores, the performance of Group A remained consistent (P = 0.124), while performance of Group B declined significantly (P < 0.001). When 6-month assessment scores were compared with the pretest scores, performance of both groups at 6-months was significantly better from baseline (P < 0.001), but performance significantly declined when compared with immediate posttest performance (P = 0.002 and P < 0.001 for Group A and B, respectively).

In a subgroup analysis, gender, dominant hand, and playing video games had no significant impact on the scores of students in both groups. However, playing music significantly improved the performance of all students at immediate posttest assessment (P < 0.05) as compared to pretest scores as shown in Table 2.

Discussion

Learning is a complex process and influenced by a number of factors including the innate ability of the trainee, previous experiences, learning style, and the overall learning environment.[13-15] Similar to the conclusions of our study, previous studies also suggested that distributed practice in learning laparoscopic skills

Table 2: Demographics of study participants

Variable	Total numbers	Single encounter	Distributive training
Gender			
Male	61	31	30
Female	39	19	20
Year of medical school			
Second year	38	30	8
Third year	41	17	24
Fourth year	21	3	18
Handedness			
Ambidextrous	3	2	1
Left handed	7	4	3
Right handed	90	44	46
Video games			
Yes	39	20	19
No	61	30	31
Musical Instruments	14		
Guitar	12	7	5
Violin	2	1	1
Impact of demographics on performance of students		***P***	
Gender			
Pretest		0.475	
Immediate posttest		0.249	
3 months posttest		0.248	
6 months posttest		0.978	
Year of medical school			
Pretest		0.717	
Immediate posttest		0.131	
3 months posttest		0.051	
6 months posttest		0.959	
Handedness			
Pretest		0.965	
Immediate posttest		0.131	
3 months posttest		0.247	
6 months posttest		0.021	
Video games			
Pretest		0.742	
Immediate posttest		0.053	
3 months posttest		0.891	
6 months posttest		0.255	
Musical instruments			
Pretest		0.056	
Immediate posttest		0.003	
3 months posttest		0.685	
6 months posttest		0.690	

enables memory consolidation that is more significant in between practices rather than during training and improves long-term retention of motor skills.[8] A large body of literature supports using the concept of distributive practice for developing laparoscopic skills. Spruit *et al*.[16] investigated the effects of single versus distributed training on laparoscopic skills acquisition and retention in medical students and found that distributed training was more efficient in both short-term (two weeks) and long-term retention (one year). Similar results have been reported by Stefanidis and Heniford[17] in their studies, where development and retention of skill were superior in distributed teaching groups. Understanding the learning process and factors influencing the learning can direct the development and planning of an effective curriculum for trainees. For acquisition and retention of laparoscopic skills, training can be offered to naïve learners as short-duration workshops (single encounter) or ongoing long-term courses (distributive training). Short-term approach encompasses several hours of intense practice, while distributed approach consists of multiple sessions of practice at different intervals. Although single encounter practice is cheap and a more convenient way to train learners, it has proven to be less efficient than the distributed practice.[16]

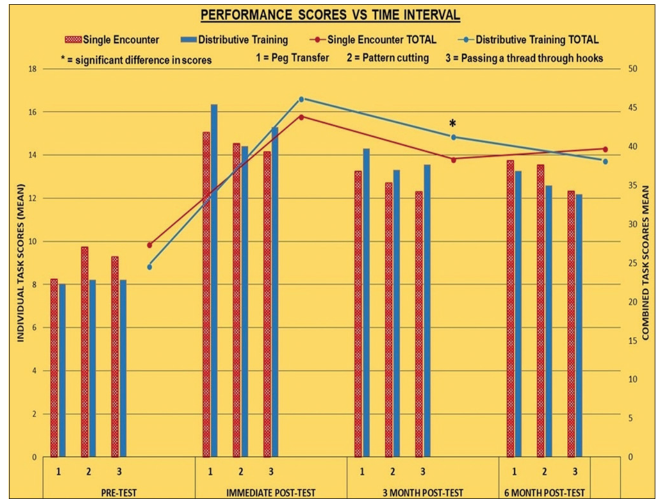

Figure 1: Performance of students over time

The results of our study indicate that the distributed training sessions have a significant impact on short-term skill retention at 3 months, but the scores declined at 6 months post intervention. Our finding supports the idea of distributed teaching for short-term retention of skills at 3 months, but also point toward the phenomenon of skill decay with time without reinforcement. A prospective randomized study conducted by Gallagher *et al*.[4] demonstrated that laparoscopic skills are optimally acquired on an interval training schedule and they significantly decline with 2 weeks of nonuse. Learning curve in laparoscopy is recognized as a process of skill enhancement, but the process of skill degradation called forgetting curve is not frequently discussed in relation to retention of skills.[18] A study by Bonrath *et al*.[19] comprising 36 medical students novice to surgery concluded that basic laparoscopic skills learned by students are retained for at least 6 weeks, but skills deterioration is likely after 11 weeks and therefore practice and repetition are desirable. Our study highlights the issue of forgetting curve and the need for reinforcement to retain the acquired skills at the same level.

We enrolled medical students for our study, as they have little or no prior knowledge or experience of laparoscopic skills. Similarly, designed studies in the past have also recruited medical students without prior exposure to laparoscopic education.[8] Using medical students with no prior exposure to laparoscopic surgery and therefore no baseline muscle memory, we were more confident about being able to appreciate the true learning curve of acquiring motor skills. Years 3 and 4 at our medical school are clinical years. Year 4 students had been through at least one general surgery rotation. However, our results showed no significant difference in the performance of laparoscopic tasks between these groups at baseline, most likely since the students get minimal hands-on exposure to laparoscopic instruments during these clinical rotations. This leads us to conclude that having knowledge about instruments and procedures had no impact on the development and retention of motor skills to use those instruments, which is also true about other areas of education and training that require motor and physical skill development.[8] To appreciate any actual difference, it was important that possible baseline differences were identified, which could potentially be considered confounders. For this purpose, a pretest of baseline skills was conducted which showed no difference in the performance between the two groups. Regardless of the type of training, whether single or distributed, one of the most interesting findings of this study was significant improvement in scores of both groups at posttest assessment as compared to baseline, suggesting acquisition and retention of laparoscopic skills in novice learners.[8]

Dexterity directly influences surgeons' performance in the operating room. However, the impact of handedness on the surgeon's performance in not well understood and remains controversial. A study by Alnassar *et al*.[20] reported no difference in the performance of right and left-handed 1st year medical students in performing different psychomotor skills

Table 3: Comparison of actual scores of students

	Total scores					
	Single encounter		Distributive training		Difference	*P*
	Mean	SD	Mean	SD		
Pretest						
Task 1	8.24	3.46	8.04	3.1	0.2	0.760
Task 2	9.74	2.87	8.22	2.51	1.52	0.010
Task 3	9.28	3.22	8.22	2.33	1.06	0.060
Total	27.26	7.65	24.48	6.92	2.78	0.060
Immediate posttest						
Task 1	15.06	2.52	16.34	2.28	−1.28	0.010
Task 2	14.54	2.38	14.42	1.96	0.12	0.780
Task 3	14.16	2.98	15.3	2.31	−1.14	0.040
Total	43.76	6.59	46.06	5.43	−2.3	0.060
3 months posttest						
Task 1	13.26	1.89	14.3	2.49	−1.04	0.020
Task 2	12.7	1.54	13.3	1.58	−0.6	0.060
Task 3	12.3	1.75	13.56	2.25	−1.26	<0.001
Total	38.26	4.35	41.16	5.02	−2.9	<0.001
6 months posttest						
Task 1	13.76	2.91	13.27	2.23	0.49	0.353
Task 2	13.55	2.10	12.59	2.03	0.96	0.024
Task 3	12.33	2.44	12.18	2.67	0.14	0.782
Total	39.69	5.83	38.04	5.79	1.59	0.178

SD=Standard deviation

Table 4: Comparison of performance of students over time

	Interval difference in scores			
	Pretest	Immediate posttest	Difference	*P*
Single encounter	27.3	43.8	−16.5	<0.001
Distributive training	24.5	46.1	−21.6	<0.001
	Immediate posttest	**3 months posttest**	**Difference**	***P***
Single encounter	43.8	38.3	5.5	<0.001
Distributive training	46.1	41.2	4.9	<0.001
	Pretest	**3 months posttest**	**Difference**	***P***
Single encounter	27.3	38.3	−11.0	0.064
Distributive training	24.5	41.2	−16.7	<0.001
	3 months posttest	**6 months posttest**	**Difference**	***P***
Single encounter	38.3	39.6	−1.4	0.124
Distributive training	41.2	38.0	3.3	<0.001
	Pretest	**6 months posttest**	**Difference**	***P***
Single encounter	27.3	39.6	−12.3	<0.001
Distributive training	24.5	38.0	−13.6	<0.001
	Immediate posttest	**6 months posttest**	**Difference**	***P***
Single encounter	43.8	39.6	4.2	0.002
Distributive training	46.1	38.0	8.1	<0.001

including basic laparoscopy and suturing. In our study, there was no significance difference when compared the performance of right and left-handed students in performing peg transfer task with nondominant hand and passing thread across the hooks with dominant hand. On the other hand, Nieboer *et al*.[21] suggested that additional training of the nondominant hand may result in the improvement of the performance of the dominant hand, and this was referred as intramanual transfer.

Literature suggests that playing console-based video games significantly influence laparoscopic skills acquisition.[13] However, we did not identify a positive correlation of video games and laparoscopic skill acquisition in our study subjects, results being similar to a systematic review published by Glassman *et al*.[22] The only significant correlation observed in our study was playing musical instruments. Students who played musical instruments showed better immediate post scores compared to those who did not play musical instruments in both groups; however, this is still a controversial topic in literature, and further studies are required to identify a true correlation between playing musical instruments and acquisition of laparoscopic skills.

There are conflicting data about the association of gender and acquisition of surgical skills and most existing literature suggests women generally perform worse than men.[23] We did not identify an impact of gender on laparoscopic skill acquisition and retention in both groups. Similar findings were observed by a study by White *et al*.[24] with medical students and 1st-year residents novice to laparoscopy undergoing fundamentals of laparoscopic surgery training. Another study by Kolozsvari *et al*.[25] concluded that gender did not affect the learning curve for a fundamental laparoscopic task in medical students novice to laparoscopy.

Limitation and recommendation

A limitation of our study is the small number of participants in each group. However, we wanted to include only those students who accepted a voluntary participation and were truly novice and had no prior experience in surgical rotation. We recommend a future study with larger numbers to exclude any bias or possibility of chance finding in the study.

The sample size in our study was not designed to analyze the true association of secondary objectives including effect of gender, dominant hand, and playing video games on acquiring the psychomotor skills and hence further studies may be conducted on each of these confounders.

Conclusions

Based on our study, we conclude that distributed teaching produced significantly better acquisition of psychomotor skills at 3 months posttest in learners naïve to laparoscopy. However, both teaching strategies yielded similar retention of skills at 6-month assessment. These findings suggest that skills acquired decline over time and may need repeated exposure and practice to maintain dexterity.

Ethical approval

An ethical approval for the conduct of the study was obtained from the institutional ethics committee. ERC Approval # 2019-1150-2970.

Informed consent

Informed consent was obtained from the participants for inclusion in the study.

Financial support and sponsorship

The study was funded by the University Research Council, Aga Khan University (Project ID–172008SUR). The study protocol was reviewed approved by the University Ethics Committee, and the data were collected anonymously without any identifiers.

Conflicts of interest

There are no conflicts of interest.

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