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Preoperative Warm-Up Using a Virtual Reality Simulator

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ABSTRACT

Background and Objectives: All modern surgical procedures require a high level of cognitive and psychomotor skills achieved using different training methods, but could be influenced by fatigue and other psychological factors. We evaluated the effect of warm-up exercises on operative laparoscopic performances.

Methods: The surgical team operated on a consecutive series of 20 patients with gallstones. Patients were randomly allocated in 2 groups: group A to be operated on without warm-up exercises and group B to be operated on after a short-term warm-up. All the patients were operated on by the same surgical team. The full-time records of the operation were analyzed by 2 independent reviewers. A modified simplified Global Rating Score (GRS) was used to assess the surgical procedures. A training module using the Lap Mentor simulator was designed for the warm-up.

Results: Better performances were noted by both observers in group B only regarding "Respect for tissue" scores (3.75 ± 0.16 vs 4.43 ± 0.20, $P = .021$ and 3.87 ± 0.22 vs 4.57 ± 0.20, $P = .041$) achieving significant or marginally significant differences for all categories; GRS scores for "time and motion" and "overall impression" tend to be better after warm-up, but differences failed to reach statistical significance in our series.

Conclusion: Surgeons, even the most experienced in laparoscopic surgery, can increase specific psychomotor skills associated with a laparoscopic environment by doing simple exercises on a virtual reality simulator, just before an operation. These improvements are reflected in more accurate handling of tissue during laparoscopic cholecystectomy.

Key Words: Laparoscopic education, Warm-up, Computer simulation, Cholecystectomy.

INTRODUCTION

Surgery is a skill-based profession. Many modern surgical procedures and especially minimally invasive techniques require a high level of cognitive and psychomotor skills, and could be influenced by fatigue as well as other psychological factors.[1] All other professions with comparable cognitive and psychomotor skill requirements (eg, dancers, musicians) use some warm-up exercises to enhance their abilities.[2] It was demonstrated that a 15-minute to 20-minute warm-up led to a 33% overall reduction in errors in a series of exercises that simulated surgical skills.[2] However, it is not clear "whether improved task performance will transfer to improvement in the operation room."[2]

MATERIALS AND METHODS

Surgical Team and Procedures

One experienced surgical team (1 senior surgeon and 1 cameraman) was selected for the experiment, lead by a senior surgeon with substantial experience in laparoscopic cholecystectomy (over 1000 procedures performed). All procedures were performed by the senior surgeon as the main operator, and the study aimed at evaluating this operator's psychomotor skills with or without a warm-up. The team agreed to follow the protocol

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regarding random assignment of cases to each study arm, without prior information. Patients involved in the study protocol were chosen consecutively from the elective list regardless of clinical form or ultrasonic characteristics. All procedures were performed using a standardized approach, with the patient in the "American" position and both operators situated on the left side of the patient. A standard laparoscopic set of instruments was used with a high-definition laparoscopic camera that allowed for digital recordings. The surgical team had all the freedom to choose the operative approach as well as to choose to convert to an open approach.

Exclusion criteria were history of open surgery in the upper abdomen and acute cholecystitis diagnosed before randomization, major changes in technique due to associated diseases diagnosed during exploratory laparoscopy and difficult cholecystectomy (difficulty level 3 or 4, using Cuschieri classification[3]). We decided to exclude such cases to separate errors generated by nonoptimal coordination and improper surgical skills, from those that could be associated with difficult anatomical situations, inflamed tissue, and severe adhesions. Pooling these cases in the series might confound evaluators in their analysis and increase the variability in the sample cohort.

Warm-up Tasks

We used a Lap Mentor simulator (Simbionix, Cleveland, OH), which combines a PC running Windows XP, a console that simulates the patient's abdomen with 3 trocars already inserted, and complex software with different modules and tasks. We used a console that allows for force feedback that adds a tactile sense to the artificial 3D environment. Lap Mentor has good construct validity providing the possibility to distinguish between subjects with varying laparoscopic experience.[4,5] According to our previous experience in laparoscopic training,[6] we designed a training module consisting of 7 measurable tasks considered important in laparoscopic cholecystectomy module **(Figure 1)**: 1) camera navigation; 2) instruments coordination; 3) clip applying; 4) clipping and grasping; 5) electrocautery; 6) cystic pedicle dissection (critical view); 7) cystic pedicle clipping and cutting. The subject had to fulfill a training module at his own pace (~15 to 20 minutes), just before the surgical procedure. Time interval between the preoperative warm-up and the start of the surgical procedure could not exceed 15 minutes.

Skills Assessment

Patients involved in the study protocol were chosen consecutively from the elective list of the operating surgeon,

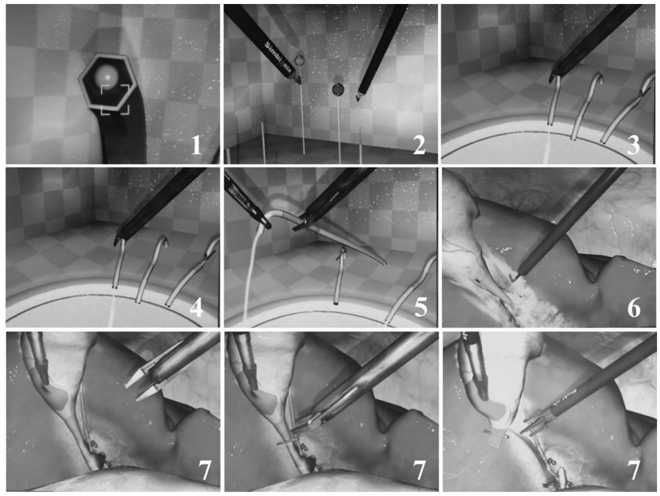

Figure 1. Virtual reality simulator warm-up tasks: (1) Camera navigation; (2) Instrument coordination; (3) Clip applying; (4) Clipping and grasping; (5) Electrocautery; (6) Cystic pedicle dissection; (7) Cystic pedicle clipping and cutting.

regardless of clinical form or ultrasonic characteristics that could predict a difficult cholecystectomy. The series of 20 patients were randomly assigned to 2 groups using online randomizer software (www.randomizer.org): group A – patients to be operated on without warm-up exercises and group B – patients to be operated on after a short-term warm-up task. All procedures were recorded in DVD format and analyzed by 2 independent reviewers to assess the surgeons' skills. The evaluators were blinded for patient randomization status and postoperative follow-up. A simplified Global Rating Scale/Score (GRS)[7,8] was used to assess the surgical procedures **(Figure 2)**. The modified scale consisted of 6 categories: 1) respect for tissue (aiming for errors in tissue handling, unwanted movements that produce disruption of tissue, gallbladder wall breaks, cystic duct or cystic artery lesions, or errors generating avoidable lesions in the liver or surrounding tissues); 2) time and motion progress (aiming for unwanted movements or badly predicted amplitude of movements of the operator, as well as a bad coordination between laparoscope and operating field); 3) instrument handling and safety (aiming mostly at errors in handling of instruments – eg, cross-over, unnecessary touching, abnormal movements, errors in safety regarding coagulation and manipulation of adjacent organs); 4) depth perception (aiming at errors generated by the adjustment process to bidimensional representation of the space, eg, malposition of the instrument in front or behind structures); 5) bimanual dexterity (aiming at errors generated by misuse of the nondominant hand, which results in difficulties in exposure) and 6)

WARM-UP STUDY - Global Rating Score

DVD No ………… REVIEWER No ① ②

	SCORE 1	SCORE 2	SCORE 3	SCORE 4	SCORE 5	Exposure of biliary region and adhesiolysis	Dissection of the cystic pedicle and critical view	Dissection of the gallbladder	Overall
RESPECT for „tissue"	Frequent unnecessary force on tissue or caused damage by inappropriate use of instruments	→	Careful handling of tissue but occasionally caused inadvertent damage	→	Consistently handled tissue appropriately with minimal damage to tissue				
TIME & Motion	Many unncessary moves	→	Efficient time / motion but some unnecessary moves	→	Clear economy of movement . Maximum efficiency				
Instrument **HANDLING**	Tentative moves / inappropriate use	→	Competent use of instruments / occasionaly inappropriate	→	Fluid moves with instruments				
Depth **PERCEPTION**	Constantly overshoots, swings wide, slow correction	→	Some overshooting but quick to correct	→	Accurately directs instruments in correct plane				
BIMANUAL dexterity	Uses only one hand, poor coordination between hands	→	Uses both hands but does not optimize their interaction	→	Expertly uses both hands to provide optimal exposure				
OVERALL impression	Novice	→	Experienced	→	Expert				

CHOLECYSTECTOMY DIFFICULTY ① ② ③ ④

Figure 2. Global Rating Scale/Score (GRS) used to assess the surgical procedures.

overall impression (which intends to offer a general impression regarding the whole procedure, rather than a sum of all previous scores). Each category was scored from 1 to 5 on a Likert-type scale. Additional data were also required: operating time (recorded from the insertion of the laparoscope until removal of the gallbladder from the liver bed) and cholecystectomy difficulty. The difficult cholecystectomies graded as "3" or "4" (conversion) were excluded from the final analysis.

Reviewers were asked to evaluate only psychomotor skills in this experiment. Scales are subjective, but reviewers were instructed to identify errors and pitfalls in laparoscopic manipulation, navigation, and safe handling of tissue during the whole procedure. Special care was directed towards adjusting to depth perception and good control of the instruments, as these could be relevant to the preoperative warm-up.

To increase the sensitivity of evaluation, each GRS category was separately noted **(Figure 2)**: 1) exposure of the biliary region, including adhesiolysis; 2) dissection of the cystic pedicle (including the quality of "critical view")[9]; 3) the final dissection of the gallbladder; and 4) global category score. Due to marked subjectivity in evaluation, we preferred to present results from each evaluator, rather than pool the data. This allowed for more objectivity regarding the whole experiment, while data were considered significant when both evaluators' data were concordant.

Statistical Analysis

Collected data were coded as categorical or numerical variables included in an MS Access Office XP database and statistically analyzed using SPSS version 15.0 for Windows (Statistical Package for the Social Sciences, Chicago, IL, USA). The univariate analysis was conducted with the Student t test for numerical variables and Pearson χ^2 test for categorical variables; $P<.05$ was considered statistically significant. Average values for continuous variables were reported as mean ± SEM (Standard Error of Mean). Spearman's rho test was used to test interobserver variability; the strength of the relationship was interpreted as little or no relationship ($R=0$ to 0.25), weak to fair ($R=0.25$ to 0.5), moderate to good ($R=0.5$ to 0.75), and excellent ($R>0.75$).[10]

RESULTS

Of the 20 study procedures, 5 were excluded due to the difficulty of the procedures: 3 cases noted as difficulty level "3" and 2 conversions to open surgery (difficulty level "4"). Fifteen procedures were further analyzed. There were no complications in either group, and all patients were discharged 48 hours to 72 hours after surgery, according to hospital protocol. The man to woman ratio was 7 to 8, and the mean age was 45.73±3.49 years (range, 27 to 68). Eight patients (53.3%) were in Group A (without warm-up) and 7 (46.7%) were in Group B (with warm-up). The mean age and BMI were similar in the 2 groups. Difficulty levels were similar in the 2 groups as evaluated by the independent evaluators (no significant differences between groups, P=.338): difficulty level "1", 73.3% (n=11) and difficulty level "2", 26.7% (n=4). Operative time was not an endpoint measurement in this study. Even so, the mean operative time of 27±2.44 minutes is consistent with the degree of difficulty. Also lack of significant differences between groups (P=.717) advocates for the homogeneity of procedures in both arms of the study.

Surgeon's Skills Assessment Data

Data confirmed that evaluation of each GRS score is highly subjective as can be easily demonstrated by low interobserver variability scores **(Tables 1 through 3)**. That is mostly due to lack of numerical analysis of task performance in the operative environment, as opposed to simulation. Based on this, our option was to separately compute the results of each reviewer and consider results significant in the situation when both evaluations suggest a statistically significant (or marginally significant) difference in favor of preoperative warm-up.

The only obvious improvement in psychomotor skills after warm-up was demonstrated with statistical significance in GRS scores for "Respect for tissue." Group B did better as evaluated by each reviewer, and scores improved to significant or marginally significant better results. It is notable that differences are evident in every category analyzed **(Table 1)**.

For all other GRS issues, "time and motion," "instrument handling and safety," "depth perception," "bimanual dexterity," and "overall impression" the scores were better in group B, but differences fail to achieve statistical significance. Differences are consistent in almost every category for issues regarding "time and motion" and overall impression" **(Tables 2 and 3)**, but we cannot say that warm-up significantly optimizes the psychomotor skills mentioned here.

DISCUSSION

It is well known that minimally invasive surgical procedures (MIS) require specific psychomotor and cognitive capabilities that are different from those used in conventional open surgery (eg, accurate instrument targeting in a 3-dimensional environment using a bidimensional video interface, bimanual dexterity, laparoscopic anatomic particularities).[11–14] These capabilities can be gained and improved through extensive training.[15] It was demonstrated that the specialized training for MIS is absolutely necessary to avoid or to minimize intraoperative errors.[16–18]

The beneficial role of virtual reality training for MIS has been demonstrated, especially for beginners; a recent metaanalysis revealed shorter time taken to complete a laparoscopic task, increased accuracy, decreased number of errors, and better "composite operative performance score" for the trainees who used virtual reality as a training method.[19] Moreover, virtual reality simulators record different parameters (eg, time, misses, drift, trajectory, and angular path of the instruments, tissue damage) that allow for an objective evaluation of the trainees' psychomotor performances.[6,13] It was recently demonstrated that psychomotor performances measured by virtual reality simulators correlates with intraoperative performances.[20]

We used a virtual reality simulator to perform the warm-up exercises. Based on our previous experience in MIS training,[6] we chose a combination of tasks capable of optimizing psychomotor skills that could be fulfilled in 15 minutes to 20 minutes. It was our intention to look for data that may suggest an improvement in psychomotor skills

Table 1.
Respect for Tissue's Scores

	Evaluator 1			Evaluator 2			IOV[a]
	Group A	Group B	P	Group A	Group B	P	R
Exposure of biliary region and adhesiolysis	3.88±0.35	4.71±0.18	**.059**	3.88±0.29	4.71±0.18	**.037**	0.842[b]
Dissection of the cystic pedicle and critical view	3.38±0.18	4.43±0.29	**.008**	3.88±0.29	4.71±0.18	**.037**	0,623
Dissection of the gallbladder	3±0.18	4±0.31	**.014**	3.63±0.32	4.43±0.20	**.058**	0.583
Overall issue score	3.75±0.16	4.43±0.20	**.021**	3.87±0.22	4.57±0.20	**.041**	0.350

[a]Interobserver variability.
[b]P<.05.

Table 2. Time and Motion Scores							
	Evaluator 1			Evaluator 2			IOV*
	Group A	Group B	P	Group A	Group B	P	R
Exposure of biliary region and adhesiolysis	4.50±0.32	4.29±0.18	.593	4.13±0.35	4.57±0.20	.308	0.397
Dissection of the cystic pedicle and critical view	4±0.26	4.57±0.29	.175	3.88±0.12	4.71±0.18	.002	0.507
Dissection of the gallbladder	4.38±0.26	4.57±0.20	.573	4±0.19	4.57±0.20	.059	0.560
Overall issue score	4.25±0.16	4.71±0.18	.081	4±0.19	4.86±0.14	.004	0.577

[a]Interobserver variability.

Table 3. Overall Impression Scores							
	Evaluator 1			Evaluator 2			IOV*
	Group A	Group B	P	Group A	Group B	P	R
Exposure of biliary region and adhesiolysis	4.50±0.27	4.86±0.14	.279	4.25±0.25	4.43±0.20	.595	0.361
Dissection of the cystic pedicle and critical view	4.13±0.22	4.71±0.18	.069	4.25±0.25	4.71±0.18	.169	0.617
Dissection of the gallbladder	4.25±0.16	4.71±0.18	.081	4.13±0.22	4.71±0.18	.069	0.364
Overall issue score	4.37±0.18	4.86±0.14	**.059**	4±0.19	**4.86±0.14**	**.004**	0.516

[a]Interobserver variability.

for this specific operation if the surgeon proceeds with laparoscopic cholecystectomy within 15 minutes after completion of warm-up.

Evaluation of surgical performance is difficult, and no method is universally accepted. Different possibilities have been described in the literature: VR simulator recorded data, checklists, and global scores, assessment using electromagnetic tracking devices or video tracking devices.[7,8,12,13,15,21,22] We used GRS and 2 independent observers to evaluate the operative performances, similar to other studies in the literature.[7,8,23] The low interobserver variability is proof of the subjective evaluation using GRS scores, and we consequently looked for a similar pattern of changes in each category and for each observer. Our hypothesis is that there might be an optimization if both observer scores are better in group B, even if absolute values are not concordant between the 2 of them.

Our results revealed significant better performances after a short warm-up only in the GRS category "respect for tissue" while other GRS categories ("time and motion," "instrument handling and safety," "depth of perception," "bimanual dexterity," and "overall impression") were not significantly influenced by the warm-up exercises. Better scores in "respect for tissue" may reflect a more precise handling of anatomical structures, with less damage to structures during manipulation or dissection.

Data should be interpreted regarding the potential benefit of warm-up for a very experienced surgeon, performing a highly standardized procedure. The present study has some limitations: a relatively small number of cases, a single and very experienced surgeon, and the use of a "global score" for measurement of results. Further studies should include more surgeons with different MIS experience. One hypothesis is that inexperienced surgeons might benefit more from this warm-up procedure in optimizing psychomotor skills, and the impact may decline as experience accumulates. We should also optimize evaluation methodology with a more accurate and directly measurable scoring system, but also adaptation of the warm-up procedure for more complex procedures may reveal a beneficial increase in psychomotor skills in a less familiar environment.

CONCLUSION

Using a virtual reality simulator and doing simple exercises before the operation, the surgeons, even the most experienced in laparoscopic surgery, become better prepared to perform a surgical procedure, from the point of view of psychomotor skills. However, further studies are necessary to establish the transfer of the preoperative warm-up concept to everyday surgical practice.

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