Applied Research on Laparoscopic Simulator in the Resident Surgical Laparoscopic Operation Technical Training

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Abstract The purpose of this study was to estimate the effects of surgical laparoscopic operation course on laparoscopic operation skills after the simulated training for medical students with relatively objective results via data gained before and after the practice course of laparoscopic simulator of the resident standardized trainees. Experiment 1: 20 resident standardized trainees with no experience in laparoscopic surgery were included in the inexperienced group and finished simulated cholecystectomy according to simulator videos. Simulator data was collected (total operation time, path length, average speed of instrument movement, movement efficiency, number of perforations, the time cautery is applied without appropriate contact with adhesions, number of serious complications). Ten attending doctors were included in the experienced group and conducted the operation of simulated cholecystectomy directly. Data was collected with simulator. Data of two groups was compared. Experiment 2: Participants in inexperienced group were assigned to basic group (receiving 8 items of basic operation training) and special group (receiving 8 items of basic operation training and 4 items of specialized training), and 10 persons for each group. They received training course designed by us respectively. After training level had reached the expected target, simulated cholecystectomy was performed, and data was

collected. Experimental data between basic group and special group was compared and then data between special group and experienced group was compared. Results of experiment 1 showed that there is significant difference between data in inexperienced group in which participants operated simulated cholecystectomy only according to instructors' teaching and operation video and data in experienced group. Result of experiment 2 suggested that, total operation time, number of perforations, number of serious complications, number of non-cauterized bleeding and the time cautery is applied without appropriate contact with adhesions in special group were all superior to those in basic group. There was no statistical difference on other data between special group and basic group. Comparing special group with experienced group, data of total operation time and the time cautery is applied without appropriate contact with adhesions in experienced group was superior to that in special group. There was no statistical difference on other data between special group and experienced group. Laparoscopic simulators are effective for surgical skills training. Basic courses could mainly improve operator's hand-eye coordination and perception of sense of the insertion depth for instruments. Specialized training courses could not only improve operator's familiarity with surgeries, but also reduce operation time and risk, and improve safety.

Shangxi Fu and Xiao Liu contributed equally to this work.

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Introduction

Among surgical procedures, laparoscopic surgeries are very technical demanding for surgeons. The difficulties of laparoscopic surgeries include the lack of tactile feedback for surgical instruments and the lack of sense of depth, which are

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difficult to pass on to students through the traditional surgical teaching sessions [1–4]. To meet the needs of modern medical care, in recent years, educators are trying to develop more secure and reproducible clinical skills teaching approaches. As an important clinical training tool, simulators have been used for many years in clinical teaching. Human body models and some task trainers have been widely used [5–9]. Laparoscopic simulators have also been adopted by the clinical skills training center in hospitals as the main teaching tools for laparoscopic operation for medical students [10–12]. In order to further observe the effects of laparoscopic simulator on the ability improvement in surgical laparoscopic operation, in the present study, data for the implementation of simulated cholecystectomy of standardized trainee before and after training were recorded and also the data for the operation of attending doctors. By comparing the results, we studied the effects of laparoscopic simulator training course on laparoscopic operation skills for medical students to gain experiences for future teaching sessions.

Methods

Laparoscopic simulator used in the study was Symbionix LAP Mentor™III, and the study was performed in skill operating room, Shanghai Changzheng Hospital. All participants gave informed consent. Before the experiment, all participants had filled in questionnaires about whether they previously participated in laparoscopic surgery or not.

Thirty surgeons were recruited totally. In experiment 1, 30 participants were assigned to 2 groups according to laparoscopic surgery experience. The group in which participants did not have surgery experience included 20 (age 28 ± 3.3) clinical medical graduates, who were receiving resident standardized training, and had never operated laparoscopic instruments personally, called inexperienced group. The group in which participants had surgery experience included 10 participants (age 36 ± 5.8), who were attending doctors with experience of performing cholecystectomy with laparoscopic instruments personally, called experienced group. In experiment 2, participants in inexperienced group were randomly assigned to 2 groups, which were called basic group and special group. Each group included 10 participants, and they received different training courses, respectively.

Experiment 1 was to observe the difference of operative procedure between inexperienced group in which participants operated simulated cholecystectomy only according to instructors' teaching and simulator operation video and experienced group. Specific courses were as follows: Participants in inexperienced group learned how to operate simulators for 3 class hours under the guidance of instructors (including video learning, instrument holding skills learning, instrument common error) and according to the laparoscopic simulators video

to operate cholecystectomy (separating gallbladder from the liver and then cutting the gallbladder). Participants in experienced group operated simulated cholecystectomy directly. Data of two groups was compared and analyzed.

Steps of experiment 2 were as follows: 10 participants in inexperienced group received basic training about laparoscopic simulators (lens operation, eye-hand coordination, clip applying, clipping and grasping, two-handed maneuvers, cutting, electrocautery, translocation of objects), and they formed basic group. Class hour of basic module training was 8 h, and the training was finished within 1 month. After reaching the set criteria, they were required to operate simulated cholecystectomy directly. The remaining 10 participants received cholecystectomy specialized training (clipping and cutting-retracted gallbladder, clipping and cutting-two hands, separation-clear view gaining, gallbladder separation) after their basic training reached the standard, and they formed special group. Class hour of specialized training was 16 h, and the training was finished within 1 month. After reaching the set criteria, they were required to operate simulated cholecystectomy. The set criteria by us were established by referring to articles published by Strandbygaard J research group and combining instructors' personal operation [13].

We tested and verified whether laparoscopic simulator was effective for training medical students by comparing experimental data between special group and experienced group. And then we compared experimental data between basic group and special group to analyze emphasis points of training courses for basic group and special group on training operating skills of laparoscopic surgery.

Specific Courses (class hours)

To practice and master basic laparoscopic skill training: 0-degree lens operation, 30-degree lens operation, eye-hand coordination, clip applying, clipping and grasping, two-handed maneuvers, cutting, electrocautery, translocation of objects. Eight class hours.

To practice the task of laparoscopic cholecystectomy operation: clipping and cutting-retracted gallbladder, clipping and cutting-two hands, Calot's triangle dissection, gallbladder separation. Sixteen class hours.

To master skills required in the whole process of cholecystectomy via practice in virtual cases.

Statistical Analysis

Sample size calculation was based on a two-tailed test, with $\alpha = 0.05$ and power = 0.80, and an intended reduction of 30 to 35% in time taken to complete tasks for experienced versus inexperienced operators, based on data from previous studies of VR simulation [13–15]. A minimum of 8 subjects were required in each group. Sample size was increased to 10

Table 1 Parameters of experience group and non empirical group on the full procedure Laparoscopic Cholecystectomy on the LAP Mentor

<i>T</i> test	Experience group			Non-empirical group			<i>P</i>
	<i>(n</i> = 10)			<i>(n</i> = 20)			
Total time (s)	513.8 ± 143.092			1472.5 ± 324.408			<0.01
Total path length of left instrument (cm)	184.8 ± 61.235			547.1 ± 118.295			<0.01
Average speed of right instrument movement (cm/s)	2.28 ± 0.494			4.72 ± 0.7302			<0.01
Average speed of left instrument movement (cm/s)	3.04 ± 0.631			3.795 ± 0.5799			<0.01
The time cautery is applied without appropriate contact with adhesions(s)	19.8 ± 6.713			63.25 ± 12.548			<0.01
Number of serious complications: possible Damage to vital structures	4.1 ± 1.37			11.05 ± 2.417			<0.01
Mann–Whitney <i>U</i> test	Median	Range	IQR	Median	Range	IQR	<i>P</i>
Total path length of both instrument (cm)	934	1779	656	3753.5	3494	575	<0.01
Total path length of right instrument (cm)	717	1593	576	3211.5	3137	443	<0.01
Number of movements of right instrument	370.5	556	223	1419	1025	178	<0.01
Number of movements of left instrument	129	206	74	450.5	322	67	<0.01
Number of perforations	1	1	1	3	3	2	<0.01
Number of non-cauterized bleeding	1	2	1	4	5	3	<0.01

participants per group to allow for failure of completion or missing data.

Statistical analysis was performed using the Statistical Package for the Social Science version 22.0 (IBM Corp., Armonk, NY). Distribution of continuous data was evaluated in accordance with the Shapiro–Wilk test, and parametric and nonparametric tests were applied when appropriate. In experiment 1, continuous variables were compared using the *t* test or the nonparametric Mann–Whitney *U* test, as appropriate. In experiment 2, differences in performance among the three groups were analyzed by either the multiple comparison with Bonferroni correction or the respective Kruskal–Wallis test for those consisted of independent groups. Results reported as mean values ± SD or median values and significance level predefined at *P* value less than 0.05.

Results

After listening and watching interpretation and demonstration about instrument operation by instructors and watching videos

of cholecystectomy, participants in inexperienced group were required to operate cholecystectomy according to the videos while attending doctor group operated cholecystectomy directly. Data of two groups were compared. In inexperienced group, instrument holding time and instrument move distance were significantly higher than those in experienced group (total instrument holding time *P* = 0.0072, movement distance *P* = 0.0068), the time cautery is applied without appropriate contact with adhesions, number of perforations, number of serious complications were more than those in experienced group *P* < 0.05 (Table 1).

And then participants in basic group received 8 basic modules training and reached standard of basic operation for instrument holding about laparoscopic surgeries simulator within set time. Preset standard of basic operation sees (Table 2). After reaching the preset standard, participants in basic group performed simulated cholecystectomy, and operation data was recorded.

Basic module training was conducted firstly in special group. Cholecystectomy specialized training was conducted after the preset standard was reached. And then simulated

Table 2 Preset standard of basic operation

Task	Total time (s)	Accuracy rate %	Total number of movements	Total path length of both instruments (cm)
Eye-hand coordination	<50	100	<60	<280
Clip applying	<70	>70	<100	<300
Clipping and grasping	<100	>70	<140	<500
Two-handed maneuvers	<90		<100	<440
Cutting	<100	100	<100	<260
Electrocautery	<300	100	<240	<500
Translocation of objects	<300		<700	<2000

Table 3 Preset standard of the special group

Task	Total time (s)	Accuracy rate %	Total number of movements	Total path length of both instruments (cm)
Clipping and cutting-retracted gallbladder	<90	100	<40 (right)	<100 (right)
Clipping and cutting-two hands	<80		<60	<125
Calot's triangle dissection	<280		<240	<450
Gallbladder separation	<300		<275	<500

cholecystectomy was performed after preset standard of the special group was reached (Table 3).

Later on, we compared simulated experiment data between special group and experienced group and found that there was difference only on total time ($P < 0.01$) and the time cautery is applied without appropriate contact with adhesions ($P < 0.01$) between special group and experienced group. There was no statistical significance in terms of other parameters (Table 4).

We then compared data between basic group and special group and found that total time of special group was superior to that of basic group ($P < 0.05$). Besides, safety parameters including number of perforations ($P < 0.05$), number of non-cauterized bleeding ($P < 0.05$), the time cautery is applied without appropriate contact with adhesions ($P < 0.05$), number of serious complications ($P < 0.05$) were all superior to those of basic group. There was no significant difference in terms of other parameters Table 5.

Discussion and Conclusion

In comparison with traditional simulation teaching techniques, simulation-based training was a promising way to improve laparoscopic skills for trainee operation hospital

physicians because of more efficient learning, objective and reproducible feedback, unlimited training hours, and enhanced cost-effectiveness for teaching establishments [6, 11, 16, 17]. Previous study suggested that laparoscopic learning effect was not significant via videos viewing and emulation, but previous methods are still adopted in current surgery training courses [18–21]. In our experiments, data for the implementation of simulated cholecystectomy of resident standardized trainees before and after our practice course instruction on laparoscopic simulator were recorded and also the data for the operation of surgical attending doctors in the experienced group. By comparing the results, we studied the effects of laparoscopic simulator training course on laparoscopic operation skills for medical students where many training programs apply research only on basic skills and isolated task training [22–24].

Experimental result showed that, in standardized trainees who had never received any simulator practice training course and directly operated simulated cholecystectomy only according to instructors' teaching and operation video, there was significant difference on parameters compared with attending doctors. After receiving laparoscopic simulator training course and reached the preset standard, and then operating cholecystectomy, their basic operation skills including

Table 4 Parameters of experience group and special group on the full procedure laparoscopic cholecystectomy on the LAP mentor

Multiple comparison with Bonferroni correction	Experience group ($n = 10$)			Special group ($n = 10$)			P
Total time (s)	513.8 ± 143.092			732.9 ± 129.262			<0.01
Number of movements of right instrument	414.5 ± 164.94			446.9 ± 93.082			1.000
Total path length of left instrument (cm)	184.8 ± 61.235			238 ± 56.708			0.287
Average speed of right instrument movement (cm/s)	2.28 ± 0.494			2.62 ± 0.5473			0.735
Average speed of left instrument movement (cm/s)	3.04 ± 0.631			3.04 ± 0.4526			1.000
The time cautery is applied without appropriate contact with adhesions(s)	19.8 ± 6.713			31.2 ± 6.746			<0.01
Number of serious complications: possible damage to vital structures	4.1 ± 1.37			6.1 ± 1.663			0.09
Respective Kruskal–Wallis test	Median	Range	IQR	Median	Range	IQR	P
Total path length(cm)	934	1779	656	1033.5	895	322	0.229
Total path length of right instrument (cm)	717	1593	576	828.5	723	250	0.292
Total number of movements	499.5	762	297	596	422	181	0.350
Number of movements of left instrument	129	206	74	145	88	45	0.206
Number of perforations	1	1	1	1	2	2	0.964
Number of non-cauterized bleeding	1	2	1	1	2	1	1.000

Table 5 Parameters of basic group and special group on the full procedure laparoscopic cholecystectomy on the LAP mentor

Multiple comparison with Bonferroni correction	Basic group			Special group			P
Total time (s)	885 ± 125.222			732.9 ± 129.262			<0.05
Number of movements of right instrument	506 ± 191.697			446.9 ± 93.082			1.000
Total path length of left instrument (cm)	251.8 ± 85.299			238 ± 56.708			1.000
Average speed of right movement (cm/s)	3.22 ± 0.827			2.62 ± 0.5473			0.136
Average speed of left instrument (cm/s)	3.24 ± 0.6603			3.04 ± 0.4526			1.000
The time cautery is applied without appropriate contact with adhesions(s)	45.6 ± 8.934			31.2 ± 6.746			<0.05
Number of serious complications: possible damage to vital structures	8.9 ± 2.601			6.1 ± 1.663			<0.05
Respective Kruskal–Wallis test	Median	Range	IQR	Median	Range	IQR	P
Total path length(cm)	1110	1516	590	1033.5	895	322	0.229
Total path length of right instrument(cm)	841	1306	442	828.5	723	250	0.229
Total number of movements	644	874	291	596	422	181	0.350
number of movements of left instrument	161	240	66	145	88	45	0.206
Number of perforations	2.5	2	2	1	2	2	<0.05
Number of non-cauterized bleeding	2.5	2	1	1	2	1	<0.05

number of movements of instrument, path length of instrument, average speed of instrument movement in the simulated surgery, and safety parameters including number of perforations, number of serious complications, and so on had obvious improvement. According to result analysis, we thought laparoscopic simulator training course could improve operation ability of medical students and significantly narrow the gap between medical students and attending doctors. However, there is still gap on total time, movement rate, and the time cautery is applied without appropriate contact with adhesions between medical students and attending doctors, which indicates that although laparoscopic simulators can simulate surgery process, actual operation experience in clinic still plays an extremely important role in laparoscopic surgeries and cannot be replaced by simulators.

By comparing data between basic group and special group, we found that basic courses could mainly improve operator's hand-eye coordination and perception of sense of the insertion depth for the laparoscopic simulator. Specialized training courses were about simulated operation in more actual conditions, which could reduce operation time, number of perforations, and the time cautery is applied without appropriate contact with adhesions, and improve safety of surgery. Basic courses are indispensable for laparoscopic simulator teaching. We thought if corresponding specified module training for each surgery is available after reaching the preset standard, then it will significantly improve safety of operative procedure, reduce operation time and make the surgery more smooth.

In the present study, we estimated medical students' skills learned from surgical laparoscopic simulator operation courses with relatively objective results and found that using laparoscopic simulators for surgical teaching was effective. It could help inexperienced medical students master basic

laparoscopic skills quickly. However, further study was required to ascertain whether those skills could be used in actual operation or not in the future.

The study has reflected the effect of laparoscopic simulator training courses in surgical laparoscopic teaching and set standard of skill assessment. Increasing more clinical operation modules, adding training courses of simulated operation and testing modules which are not tested before to set more parameters to evaluate teaching results are our work in the future.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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