Surg Endosc (2003) 17: 1978–1984
DOI: 10.1007/s00464-003-9000-5

SURGICAL ENDOSCOPY
and Other Interventional Techniques

The Intercollegiate Basic Surgical Skills Course

Laparoscopic skill assessment using the Xitact LS500 laparoscopy simulator

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Received: 6 January 2003/Accepted: 16 April 2003/Online publication: 23 October 2003

Abstract
Objective: This study was undertaken to establish residents' progress in minimal access surgery (MAS) after attending the Intercollegiate Basic Surgical Skills Course (BSSC) by means of the Xitact LS500 laparoscopy simulator assessment program.
Methods: Twenty-five surgical residents attended the BSSC in Leiden and Eindhoven, The Netherlands. Before and after the course, participants performed three "runs" on the Xitact LS500, featuring a standardized laparoscopic cholecystectomy clip-and-cut task. A control group of 25 interns not attending the course also performed two sessions of three runs. Parameters of interest were "score" and "time for completion of task".
Results: No significant differences were found within the resident group for the parameters "time" and "score" when comparing outcomes pre- and post-BSSC. No significant differences were found comparing time and score between residents and interns on each of the six runs, except for time in run 2. Over six runs, both residents and interns became significantly faster.
Conclusions: The Xitact LS500 cholecystectomy simulator did not detect significant improvement in MAS performance among a group of surgical residents attending the BSSC.

Key words: Surgical skills — Skills training — Basic Surgical Skills Course — Surgical simulation — Virtual reality — Laparoscopy — Assessment

Laparoscopic cholecystectomy has largely replaced open cholecystectomy as the technique of choice for uncomplicated symptomatic cholelithiasis [30]. Since the general introduction of the laparoscopic cholecystectomy in the early 1990s, a variety of laparoscopic surgical techniques for various surgical procedures have been developed [11, 14]. Today, laparoscopic surgery is an integral part of general surgery [17]. The term minimal access surgery (MAS) refers to this field of surgery [24]. Surgical skills, particularly complex psychomotor skills needed to perform MAS, are in part innate and can be learned in part from extensive, repetitive practice [27]. Although many skills and traits are needed to be a competent surgeon, the element of technical competence is eminent. However, the teaching and testing of technical skill are known to be one of the least systematic or standardized components in the classical surgical curriculum [22]. Skills needed to perform MAS correctly cannot be directly extrapolated from skills acquired from performing open surgery. MAS requires distinct psychomotor abilities and different skills [25]. It has been recognized that psychomotor skill acquisition is distinct from other types of learning [13]. The incorporation of MAS in the modern surgical curriculum has created a need for specific training and education [23, 28]. Training courses, adopted by surgical colleges and implemented by professional organizations, have addressed this need. Currently, some surgical skills courses focus on knowledge and skills needed for performing MAS safely. The Intercollegiate Basic Surgical Skills Course (BSSC) is one of them.

Since August 1996, all four surgical Royal Colleges in the United Kingdom have demanded that senior house officers entering basic surgical training successfully complete the IBSSC. It is a mandatory requirement for the membership examination of the colleges. Since its introduction in 1996, the BSSC has trained more than 2,000 surgical trainees at 42 centers in the United Kingdom. The success of the course led to its adoption and implementation in other centers in Europe, including two surgical centers in The Netherlands. The main

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Fig. 1. Xitact LS500 simulator.

areas covered by the course are basic surgical techniques for open surgery, trauma and orthopedics, and minimal access surgery [31]. The effectiveness of hands-on training courses, and the BSSC in particular, is rarely documented [19].

It has been shown that clinical laparoscopy experience is related to outcome on training tasks in a simulated environment [5]. Studies have shown that there is a link between performance and outcome parameters such as rating, score, or time [5, 23]. For the virtual reality laparoscopy simulator used to objectively assess participants in this study, the Xitact LS500, a recent construct-validity study showed that experts indeed performed better than novices on the laparoscopic basic clip-and-cut task [26]. This suggests that the reverse might be true as well—that is, that clinical performance might improve with practice resulting from training tasks. The score as generated by the virtual reality laparoscopy simulator may be an estimate of clinical improvement. Such a score may satisfy the need for accurate and objective assessment of technical process and skill acquisition since in fact, there currently is none [21]. Previous studies have shown potential and interest for virtual reality simulators in the field of laparoscopic surgery in terms of tutoring, training, and assessment of skill and performance [2, 4, 7–10, 12, 16, 33, 35]. In this study, the Xitact LS500 virtual reality laparoscopy simulator was used for objective assessment of the impact of the laparoscopic module of the IBSSC on performance.

Materials and methods

Subjects

Twenty-five residents (the intervention group) and 25 interns (the control group) were selected for the study. Eleven residents and 11 interns were tested at the BSSC in Leiden, The Netherlands, and 14 residents and 14 interns were tested at the BSSC in Eindhoven, The Netherlands.

The Intercollegiate Basic Surgical Skills Course

The BSSC is 3-day course, with 1 day for each module (open surgery, trauma and orthopedics, and minimal access surgery). In advance of the course, an instruction book and video were sent to each participating resident. The MAS module, given on day 3 of the course, starts with an introduction to MAS, Participants are introduced to the laparoscopic stack (rapid flow insufflator, light source, video camera, laparoscope, and monitor). Video and hands-on instruction are provided. Next, trainees perform the exercise of safe introduction and maintenance of the pneumoperitoneum. There is an introduction to laparoscopic instruments, and simple grasping, cutting, and manipulations skills are practiced for approximately 2½ h. Then, advanced dexterity skills, such as clipping and loop ligation, are practiced for approximately 1 h, and the use of diathermia in MAS is discussed and practiced.

Introduction to the Xitact LS500 laparoscopy simulator

All subjects were given an instructed one-on-one ''tour'' to familiarize them with the Xitact LS500, its features, and the virtual reality interface of the laparoscopic cholecystectomy clip-and-cut scene.

The tour featured a voiced-over instruction video of the clip-and-cut task showing the correct way to place clips and perform a transection of the cystic artery and cystic duct. Trained instructors gave a detailed explanation of possible errors of the procedure as well as a hands-on instruction on the apparatus. All subjects underwent baseline testing (run 1). On the first day of the course, three runs were performed by each subject because earlier studies with high-interface laparoscopic surgical virtual reality trainers have shown that familiarization occurs within three runs [2]. Next, the group of residents attended the BSSC. After completion of the course, following the laparoscopic training module, the second series of three runs was performed by the residents. As a control group, interns also performed a baseline test, three runs on day 1 and three runs on day 3, without attending the BSSC.

Apparatus

The Xitact LS500 laparoscopy simulator (Fig. 1) is a modular virtual reality training program developed for training and objective assessment of a variety of laparoscopic skills. It is a hybrid simulator, combining a physical object (the OpTable or ''virtual abdomen'') with a computer program providing the visual image and haptic feedback. The program featured and under study is the clip-and-cut task of the laparoscopic cholecystectomy simulation. Face-referent and expert validity, as well as construct validity on this module, has recently been established [25, 26]. This module not only represents the exercise of the clipping and cutting of the cystic artery and duct but also records subject's performance and computes a trainee's performance in terms of time and errors made. A specific performance outcome sheet for each resident is linked to each performance run and thus provides interesting properties for subjects' assessment. The Xitact LS500 is developed and registered by Xitact SA (Morges, Switzerland).

Questionnaire

A questionnaire consisting of a 2-page survey was given to the participant. In addition to participant demographics and previous surgical

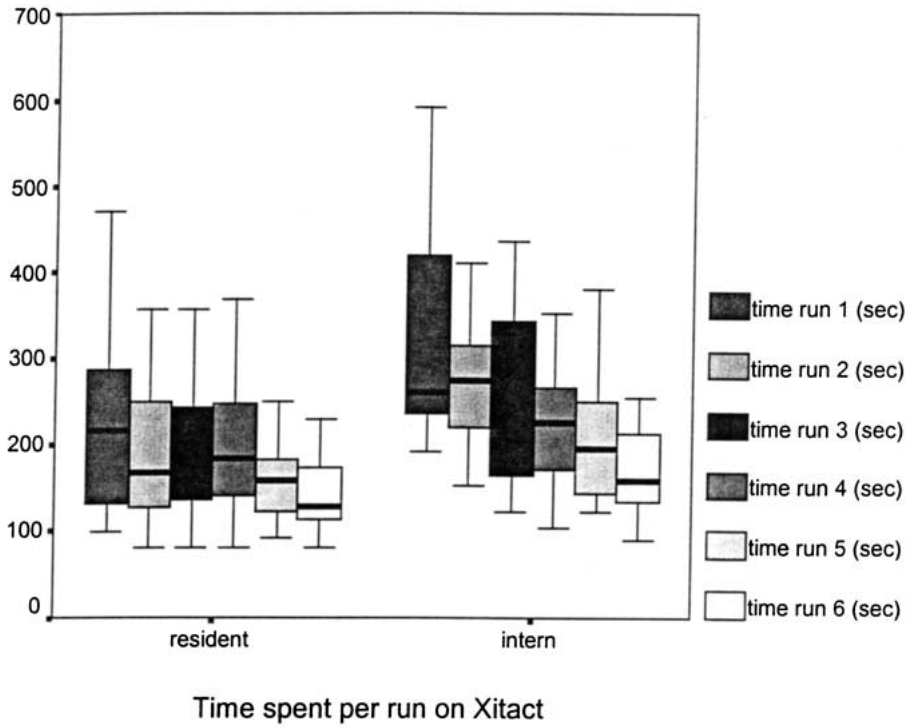

Fig. 2. Boxplot time.

Table 1. Comparison of interns and residents over runs *within* groups

	Intern		Resident	
Run	Sum (mean rank)	Time (mean rank)	Sum (mean rank)	Time (mean rank)
1	3.02	4.83	3.36	4.57
2	3.38	4.15	3.20	3.39
3	3.48	3.79	3.04	3.57
4	3.58	3.33	3.54	3.70
5	3.50	2.65	3.72	2.91
6	4.04	2.25	4.14	2.87
Friedman test				
Time	0.000*		0.026*	
Sum score	0.332		0.175	
Wilcoxon signed-ranks				
Sum6–Sum3	0.563		0.064	
Sum6–Sum1	0.025*		0.128	

* $p \leq 0.05$

laparoscopic experience, questions concerning the experience with the BSSC and the experience with the Xitact simulator were asked. Subjects' opinion on the usefulness of the simulator in terms of training/teaching capacities and error reduction was also questioned.

Data were analyzed using the Statistical Package for the Social Sciences version 9.0. A p value ≤ 0.05 was considered statistically significance.

Results

Demographics

Mean age of the residents was 30.7 years (SD = 3.5), and the mean age of the interns was 24.3 years (SD = 1.5). Groups differed in age distribution (p-value 0.000, Mann–Whitney U-test). There were 22 women and 28 men in the total population: there were 9 women (36%) residents and 13 women (52%) interns. Groups had an equal sex distribution ($p = 0.259$; Mann–Whitney U-test). Regarding dexterity, 4% of the residents and 16% of the interns were left-handed, 92% of the residents and 72% of the interns were right-handed. Four percent of the residents and 12% of the interns considered themselves to be ambidextrous. Chi-square testing could not be performed because conditions for the test could not be met. Of the residents, 36% were specializing in general surgery, 4% in gynecology, 16% in urology, 4% in thoracic surgery, 16% in orthopedics, and 24% in emergency medicine. Seventy-two percent were in their first year of training, 8% in their second, 4% in their

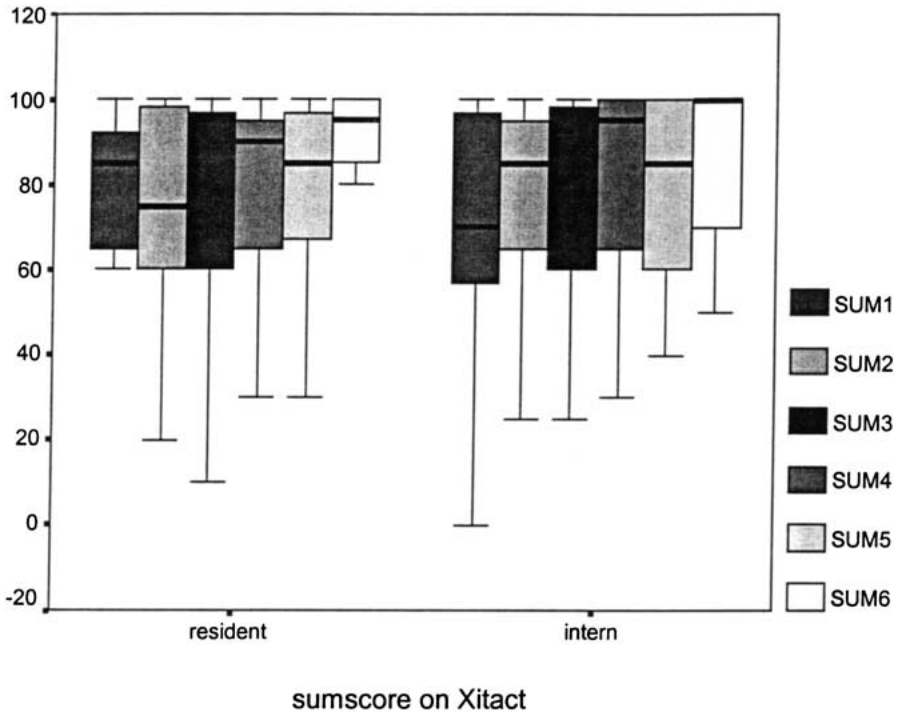

Fig. 3. Boxplot sum score.

Table 2. Comparison of interns and residents over runs *between* groups: significance tests

Variable	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6
Time[a]	0.059	0.003*	0.052	0.227	0.056	0.068
Sum score[b]	0.430	0.631	0.677	0.862	0.396	0.385

[a] Mann–Whitney *U*-test
[b] Kruskall–Wallis test
* $p \leq 0.05$

third, 4% in their fourth, and 12% had not yet started their formal specialist training. Six residents had previous experience with the clinical laparoscopic cholecystectomy. Of these residents, 4 were in their first year of training, 1 was in his third year, and 1 was in his fourth year. None of them had performed more than 25 laparoscopic cholecystectomies. In the intern group, no one had any laparoscopic experience. By definition, interns were not yet in training for a specialty.

Assessment of performance

Time

Figure 2 shows the amount of time in seconds needed for completion of the clip-and-cut task per run on Xitact for both residents and interns. There was a trend over the six runs for completion times to become shorter for both the residents and the interns. Also, standard deviations of both groups tended to become narrower over runs. Although individuals in both groups became significantly faster over the six runs (Table 1: Friedman test for time, interns, $p = 0.000$; residents, $p = 0.026$), between groups there was no difference except for run 2 (Table 2).

Score

A sum score was computed according to previously established and validated parameters [26]. Table 3 shows the distribution of this score into performance categories. There was progress over runs in both groups: 16% in both groups had a very inadequate to inadequate performance for run 1, whereas 8% of interns and 4% of residents had such a performance for run 6. Although individual scores for both groups tend to increase over the six runs, this increase seems to be of no significance (Table 1; Friedman test for time; interns, $p = 0.332$, residents, $p = 0.175$). Between groups, there is no difference in sum scores for each run (Table 2).

Figure 3 shows a visual representation of the unclustered performance scores. As can be seen, there is a large standard deviation for both groups for this parameter, narrowing over runs. Residents did not seem to be consistent in improvement of scores over runs, and no consistent "jump" in score after the BSSC was established. Table 1 shows no significant improvement for score between the last run of the second series (after the BSSC) and the last run of the first series.

Questionnaire

Table 4 shows the frequencies of the scores on the questionnaire presented to each participant. In general, residents believed that they performed better in the second series of Xitact. Also, they were more secure after performing one series of exercise on Xitact. How-

Table 3. Comparison of interns and residents over runs between groups: distribution of sum

Sum score	Label	Category of performance	Intern run (%)						Resident run (%)					
			1	2	3	4	5	6	1	2	3	4	5	6
0–20	I	Very inadequate performance	12	8	0	12	4	8	16	4	8	4	4	0
21–40	II	Inadequate performance	4	8	8	4	8	0	0	4	0	8	4	4
41–60	III	Questionable performance	24	4	20	4	16	8	4	20	20	12	12	12
61–80	IV	Adequate performance	16	28	20	20	20	16	28	28	28	20	16	4
81–100	V	Highly adequate performance	44	52	52	60	52	68	52	44	44	56	64	80

Table 4. Questionnaire for residents

Statement	Rating: 1 = disagree, 5 = agree (%)				
	1	2	3	4	5
The *first* series of exercises on the Xitact (before the laparoscopic part of the Basic Surgical Skills Training) went well	4.2	29.2	20.8	33.3	12.5
During the *first* series of exercises on the Xitact (before the laparoscopic part of the Basic Surgical Skills Training) I felt secure	4.2	29.2	25.0	37.5	4.2
The *second* series of exercises on the Xitact (before the laparoscopic part of the Basic Surgical Skills Training) went well	4.0	4.2	29.2	50.0	12.5
During the *second* series of exercises on the Xitact (before the laparoscopic part of the Basic Surgical Skills Training) I felt secure	0.0	4.2	16.7	62.5	16.7
I feel my performance on the *second* series of exercises on the Xitact is better than my performance on the *first* series of exercises	12.5	8.3	29.2	20.8	29.2
I feel the laparoscopic part of the Basic Surgical Skills Course is an essential part of the course	0.0	8.3	16.7	12.5	62.5
I learned a lot from the laparoscopic part of the Basic Surgical Skills Course	0.0	14.2	8.3	41.7	45.8
I learned a lot from the exercises on the Xitact laparoscopy simulator	8.3	20.8	20.8	25	25
I think I will feel more secure in my future clinical laparoscopic performance after participating in the Basic Surgical Skills Course	0.0	8.3	16.7	45.8	29.2
I think I will feel more secure in my future clinical laparoscopic performance after practicing on the Xitact laparoscopy simulator	12.5	16.7	20.8	41.7	8.3
I feel the Xitact laparoscopy simulator should be an integral part of the training in the Basic Surgical Skills Course	4.2	20.8	16.7	29.2	29.2

ever, approximately one-fifth believed that they did worse the second time on Xitact compared to their first series of runs. More than 70% agreed with the statement that the laparoscopic part of the BSSC is an essential part of the course; approximately 60% believed that the Xitact laparoscopy simulator should be an integral part of the course. More than 80% indicated that they learned a lot from the laparoscopic part of the BSSC, and 50% believed they that learned a lot from the exercise on Xitact.

Table 5 shows that both interns and residents agreed on the use of Xitact for training and educating surgical residents, specialists, overall error reduction and laparoscopic skills enhancement capacities. It is considered to be most useful for surgical residents by both groups. Interns believed it was also useful for medical students; surgical residents did not value this purpose of the simulator equally, nor did they seem to agree on this ($p = 0.006$).

Discussion

The BSSC was designed to introduce surgical trainees to safe surgical practice within a controlled workshop environment. Furthermore, it aims to teach, assess, and certify trainees' ability to use safe surgical techniques. Until recently, it was unclear if the course was able to meet this objective. Formal course assessment was performed using one assessment form for all three modules. Participants are scored on a 3-point ordinal scale, and overall assessment is divided into the the categories of satisfactory/not satisfactory. The criteria by which assessments are stated are poorly defined and subjective[34]. Furthermore, participants are scored by the same surgeons who are their mentors during the course. It is obvious that many flaws are inherent in this subjective means of assessment of score. Technical competence as judged by the mentor will always be subjective [20]. The lack of validated, reliable objective tests of surgical technical MAS competence has long been a problem in the assessment of MAS trainees. So far the Minimally Invasive Surgical Trainer Virtual Reality (MIST-VR), another validated PC-based laparoscopic surgical trainer, is the only system used to assess performance objectively before and after the BSSC. In one study, a group of 12 residents' scores for time to complete the MIST-VR task and the number of errors were significantly improved compared to those of a control group of non-BSSC-trained medical students [32]. However, another study showed no significant difference in performance between MIST-VR and non-MIST-VR trained students on a simulated appendectomy in a live animal model [1].

Table 5. Usefulness of Xitact's clip-and-cut scene for skills training/error reduction

Rating	Total (mean)[a]	Intern[a]		Resdent[a]		p value[b]
		Mean	SD	Mean	SD	
Medical student trainings/education	3.90	4.56	0.65	3.24	1.23	0.006
Surgical residents training/education	4.45	4.43	0.63	4.45	0.72	1.000
Surgical specialist training/continuing education	3.87	3.95	0.85	3.83	1.09	0.998
Overall laparoscopic error reduction	3.92	4.07	0.59	3.83	0.82	1.000
Overall laparoscopic skills enhancement	4.12	4.07	0.80	4.17	0.64	0.993

[a] Rating: 1, not useful; 5, very useful
[b] Kolmogorov–Smirnov test, two-tailed

In our study, there was no significant difference in score and time between the 25 residents and 25 interns before the BSSC. This seems plausible because both residents and interns have virtually no laparoscopic experience. It is logical that over runs, standard deviations of both groups for "time" and "score" tended to become narrower. Part of this phenomenon must be explained by the fact that the use of Xitact for multiple runs will narrow confidence intervals of both parameters, indicative of a growing acquaintance with the virtual reality interface itself. This is why the study was set up using a control group to account for Xitact's contribution to the outcome of the parameters of interest.

In our research setting, the BSSC did not seem to interfere with time or score generated by Xitact. There was a decrease in time over the six runs for both groups, but there did not seem to be significant decrease in time after the BSSC for the resident group. Also, there was no difference in time observed between residents and interns for the individual runs apart from run 2. Participation in the BSSC does not seem to increase residents' scores significantly compared to themselves (pre-versus post-BSSC scores) and compared with the scores of the control group of interns.

Although there is little dispute that special laparoscopic surgery training is necessary, the optimal format and training contents has not been established [18]. Concern has been expressed about short courses on medical education for surgical techniques [3, 6, 36]. Gadacz and others note that hands-on experience is essential and a 2- or 3-day minicourse is essential but not sufficient. Unfortunately, very few workshops or training programs that claim improvement have objective and validated means of assessment. It must be stated that the BSSC is not a course aimed at training residents for a specific procedure, it is merely a basic skills oriented course and it provides an introduction to the MAS techniques. Also, the Xitact laparoscopy simulator does not test the exact same tasks that are taught in the course. The scene featured is probably more complex and incorporates multiple skills taught during the course (aiming, grasping, translocating, cutting, and clipping) in one procedure.

The BSSC is likely to contribute to the understanding of and acquaintance with the most common principles of MAS, thus reducing insecurity for the resident before his or her first clinical MAS experience. This is supported by the outcomes of our questionnaire. Another positive effect of either being a mentor or a resident participating in the BSSC is the focus on the need for structured, repetitive training. Therefore, the BSSC may be seen as an introductory course in an ongoing need for training and educational courses for new MAS techniques.

Basic skills must be mastered prior to attempting more complex tasks, and faulty habits learned early are difficult to correct. It is suggested that the intern year is the most appropriate time to teach such skills [15], but this might be too early since only a few interns will become surgical trainees. Inexperienced surgeons may benefit the most from skills training [29] because they are learning a new technique and thus at the beginning of the learning curve. Also, inexperienced surgeons are usually eager for any means that can improve their performance and susceptible to novelties, as indicated by Table 5. It is also likely to increase confidence and involvement in MAS. Learning curves, as well as "performance curves" as described in the general motor skills literature, tend to be steep during the early part of the performance. A relatively small increase in the amount of practice provided during a course could substantially improve technical performance. No studies have compared simulated or clinical outcome following various schedules of training within the BSSC. No formal task analysis has been performed in which the training tasks presented were chosen. Also, no clear objectives and description of assessment have been developed by which participants can be assessed. Only when specific goals and objectives for each module of the BSSC are defined can accurate assessment and refinement of the course be provided.

Conclusion

The Xitact LS500 cholecystectomy simulator did not detect significant improvement in MAS performance among a group of surgical residents who attended the BSSC. Two explanations are possible. Either there was no significant improvement to detect, or Xitact did not measure the basic psychomotor skills that are trained in the BSSC. Probably, it is a combination of both.

It is unlikely that within the short, half-day time period for training laparoscopic basic skills during the BSSC a definite, stable improvement in laparoscopic

skill is achieved. Also, Xitact tests task performance presuming a certain degree of integration of various laparoscopic skills. The end point of research in performance studies using laparoscopic virtual reality training systems must be a detectable increase in performance in the laparoscopic operating room. Therefore, a valid virtual reality training system must mimic integration of various laparoscopic skills. It is likely that the BSSC does not increase such skills in novices in only one training session. Further research on integral laparoscopic skills training sessions using virtual reality simulation for training and assessment is necessary.

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