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Low cost simulator for acquiring basic laparoscopic skills

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A B S T R A C T

Introduction: Laparoscopic surgery requires a different set of skills than conventional surgery. The aim of this study was to evaluate the usefulness of a low-cost simulator and camera for the acquisition of basic laparoscopic skills.
Material and methods: This randomised trial involved 48 subjects (32 students and 16 surgeons). Two exercises were used, object transfer and cutting. Students were divided into 2 groups (n=8). One group performed the exercises in the operating theatre with the conventional laparoscopic camera. The second group performed the exercises in a classroom with a low cost micro-camera. Both groups were evaluated before and after 5 training sessions. Two groups of students were used as controls (n=8), and were evaluated 2 times without training. The surgeons were divided in 2 groups (n=8), one was evaluated in the theatre and the other one in the classroom.
Results: The trained groups showed significant improvements in the first exercise (P<.001) compared with non-trained groups. There were no differences in scores between the groups with different cameras. The surgeons had better scores than students (P<.001).
Conclusions: The improvements in laparoscopic skills on this simulator with a low-cost camera were not significantly different from those gained using the simulator with the conventional laparoscopic camera. This simulator was able to differentiate between experienced and inexperienced subjects.

Simulador de bajo coste para el entrenamiento de habilidades laparoscópicas básicas

Palabras clave:
Cirugía laparoscópica
Simulador
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R E S U M E N

Introducción: La cirugía laparoscópica requiere el conocimiento y tratamiento de un equipo e instrumental diferente al de la cirugía abierta. El objetivo de este estudio es observar si el entrenamiento con un simulador de bajo coste es de utilidad para adquirir habilidades en técnicas laparoscópicas básicas.

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Material y métodos: Estudio aleatorizado en el que participaron 48 sujetos (32 estudiantes y 16 cirujanos). Se diseñaron 2 ejercicios, uno de prensión y otro de corte. Los estudiantes se dividieron en 2 grupos (n=8), el primer grupo realizó los ejercicios en quirófano con la cámara de laparoscopia habitual y el segundo en un aula con una microcámara de bajo coste. Ambos grupos realizaron una primera evaluación, varias sesiones de entrenamiento y una segunda evaluación. Se utilizaron 2 grupos control con estudiantes (n=8) que realizaron las 2 evaluaciones sin entrenamiento. Los cirujanos se dividieron en 2 grupos y realizaron una evaluación, un grupo en quirófano y otro en el aula.
Resultados: En los grupos con entrenamiento, la mejoría entre la primera evaluación y la segunda para el primer ejercicio fue significativamente mayor que en los grupos sin entrenamiento (p < 0,001). Los cirujanos presentaron una puntuación significativamente mejor que los estudiantes en su primera evaluación (p < 0,001).
Conclusiones: El entrenamiento con este simulador de bajo coste ha demostrado ser de utilidad, de forma similar al entrenamiento en el simulador con un sistema de laparoscopia convencional, para adquirir habilidades laparoscópicas básicas. Este sistema de entrenamiento fue capaz de discriminar entre los sujetos con y sin experiencia en cirugía laparoscópica.

Introduction

Minimally invasive surgery is, at present, broadly accepted to diagnose and treat different diseases.[1] Laparoscopic surgery requires knowledge and handling of equipment and instruments different from those needed for conventional surgery. These differences cause a series of difficulties to the surgeon starting training in laparoscopic surgery:

1. Introduction to an enhanced, but monocular, vision system that affects both depth perception and three-dimensional vision.[2]
2. Utilisation of long instrumental tools that reduce tactile feedback and increase tremor.[3]
3. Hand-eye dissociation (*fulcrum effect*) and reduction of movement-range of instrumental due to access through fixed trocars.[4]

At present, there are various training models in experimentation animals and different types of simulators, as well as computing applications that emulate even complex situations in surgical interventions, all of which have proven to be effective in order to acquire laparoscopic skills. However, these possibilities are not available for every one, due to their high costs and difficulties in accessibility and infrastructure.

As is the case with other disciplines, such as air or sea navigation, the automobile industry or the army, simple simulators allow acquiring basic technical skills, which seems to be useful for further learning into more complex techniques.[5] Reviewing medical literature we find different simulators and training programmes that provide low-cost learning to be carried out in hospital facilities.[6-8] These low-cost tools may become important in acquiring certain skills when learning laparoscopic surgery.

The aim of this study is to see whether training with a *videotrainer* system using a low-cost camera is useful to learn basic laparoscopic techniques.

Material and methods

Participants and study design: randomised prospective study involving 48 subjects arranged as follows: thirty-two second-phase medical students from the Faculty of Medicine of Rovira i Virgili University, with no experience in laparoscopic surgery, and 16 surgeons with experience in laparoscopic surgery (for this study, experienced surgeons, who at least had performed 30 laparoscopic cholecystectomies, were considered). The students received initial knowledge on laparoscopic surgery and were then divided in 2 groups by simply randomised allocation and through a table of randomised numbers. The first group (n=16) performed the exercises in a simulator with a surgical camera and the second group in a classroom with a low-cost camera. Each group underwent an initial evaluation of the exercises and a final evaluation 5 days afterward. Eight students from each group took part in five 30 min-training-sessions prior to the second evaluation. The surgeons were also randomly divided in 2 groups (operating theatre and classroom) and took a first evaluation (Figure 1).

Simulator: the simulator consists in a translucent (4 mm-rigid copolymer) 40×30×18 cm frame that allows working with direct vision without the need of a light source. When the exercises are being performed, the camera stands in the way of the simulator thus blocking direct view, but not the light admission from other angles. It has 3 orifices, 2 lateral ones for instrumental uses and a central one for the camera. There is a lower draw-out tray to place the exercises (Figure 2).

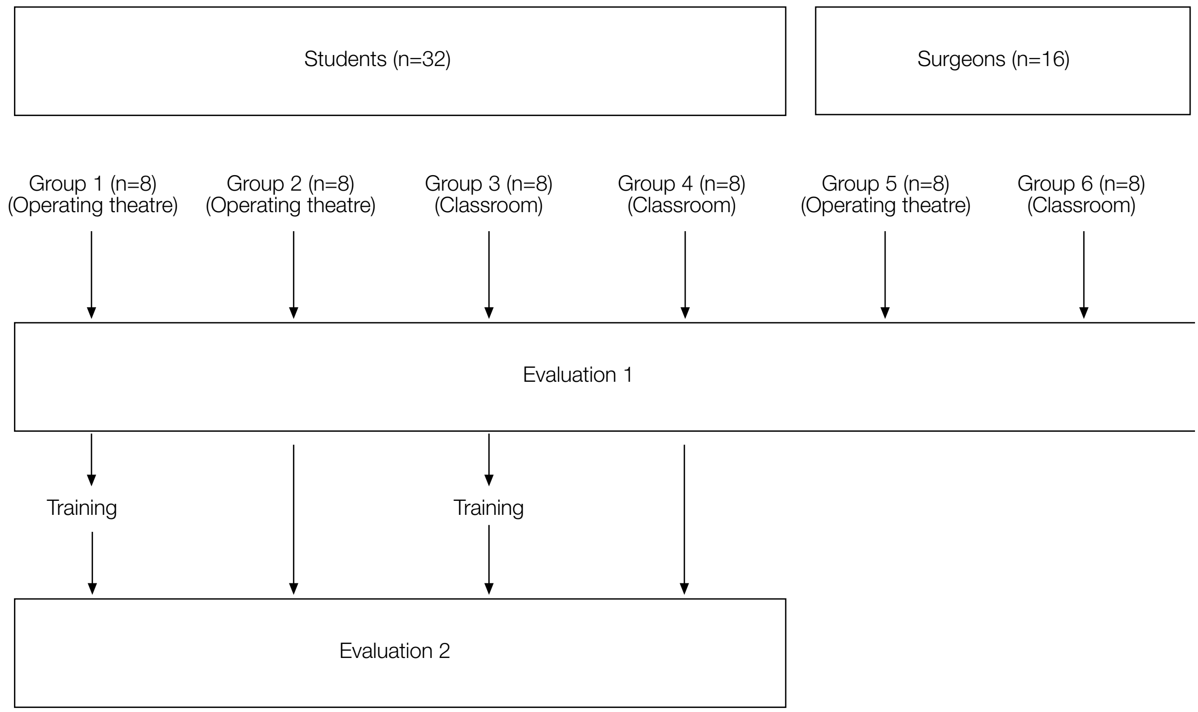

Figure 1 – General design of the study.

Figure 2 – Low-cost simulator.

Cameras

- Low-cost micro-camera: we used a micro-camera (image sensor CMOS [*complimentary metal oxide semiconductors*], definition 380 line colour, Ref. LAS3022) fitted to the end of a 30 cm tube that stimulates optic movements in laparoscopic surgery.[6] The camera is placed over a tubular structure at a 30° angle, connected to a 19" TV by a RCA-type connection and to the electrical net through a transformer.
- Operating theatre camera: a laparoscopic Storz® (Tricam SL pal) camera was used, with a Storz® (Xenon nova) light source, and a 30° optic. The camera was connected to a monitor, approved for electro-medicine, a 19-inch Sony Trinitron PVM-ZONGE®, part of the operating theatre laparoscopic equipment.

Instruments: graspers Endo Clinch II® (Covidien Autosuture) type were used and Conmed® scissors, both 5 mm long.

Exercises and score: two exercises were performed, one consisting of grasp and object transfer and the other was a cutting exercise. Based on score systems from other studies with other simulators[8,9] and in preliminary experiences with these exercises using this simulator, the following formula was set to score the exercises:

- Score = total time in seconds + (20 × number of failures).
- Grasp and object transfer exercises (*exercise 1*): the participant practiced right-hand grasping and left-hand camera handling. Eight objects sitting on the platform to his/her right had to be grasped and transferred over to a tray on his/her left side. Any object dropping outside platform or tray was computed as a failure.
- Cutting exercise (*exercise 2*): the participant took a grasper with his/her left hand and a pair of laparoscopic scissors with his/her right. The camera remained fixed on its supporting structure. A piece of cloth was placed over the simulator with a trajectory printed on it along which the participant had to cut. Cutting away from the lines setting the trajectory was computed as a failure.

Statistical analysis: Student *t* test was used for independent variables to compare mean scores obtained by both students and surgeons; score variations before/after training have been analysed by Student *t* test for paired data. The results are expressed by mean (standard deviation). Differences between variables were evaluated by a $P<.05$ statistical signification limit. SPSS 15 application was used for statistic treatment of data.

Results

Of the 32 students that participated in the study, 25 (78%) were in sixth year of their careers at the moment of the study, 1 was in fifth, 3 in fourth, and 3 in third year. Thirty (94%) of the 32 students were right-handed and 2 were left-handed. Their general characteristics are shown in Table 1.

The surgeons scored better than the students in the first evaluation for 2 exercises and in 2 scenarios. In *exercise 1* (grasp and transfer) the students in the classroom scored a mean 165.5 (32) versus 58.2 (14) of the surgeons; in the operating theatre the students scored a mean 132.3 (40) versus 77.0 (18 of the surgeons). In *exercise 2* (cutting) the students in the classroom scored a mean 151.5 (32) versus 62.6 (20) of the surgeons; in the operating theatre the students scored a mean 147.5 (39) versus 64.8 (25) of the surgeons. Differences were statistically significant in all the cases ($P<.001$) (Table 2).

When comparing scoring differences between trained students versus untrained students, the improvement mean in scoring was significantly higher in the trained group for the first exercise (87.6 [30] vs 33.3 [29]; $P<.001$) and for the second exercise (65.1 [41] vs 33.8 [39]; $P<.001$) (Table 3).

When analysing the difference in improvement between the trained/untrained groups in both 2 scenarios and for both exercises, a significantly higher improvement was observed in the trained groups, in the classroom as well as in the operating theatre for *exercise 1* (107.6 [14] vs 45.2 [39] in the classroom [$P<.001$] and 67.6 [38] vs 21.3 [38] in the operating theatre [$P<.001$]). In *exercise 2*, the trained students improved their score significantly over the untrained students at the operating theatre (85.8 [28] vs 15.3 [34]; $P<.001$); however, no changes were observed in the classroom between the trained-untrained groups (Table 3).

Discussion

The use of simulators in laparoscopic surgery aims at improving training for surgeons and efficiency and safety for patients, although it is not as yet totally clear which are the best methods and equipment for each phase of the training. At present, it is considered that training in laparoscopic surgery has to be phased, thus undergoing a series of stages prior to practice in the operating theatre.[10,11] However, while assistantship and tutorised interventions are possible in any centre authorised to train residents, other tools such as simulators and interventions on animals or cadavers are more expensive, less available and, on occasion, they require a more complex infrastructure. There has been certain improvement in availability in the last years due to proliferation of minimally invasive surgery centres imparting courses of various duration and complexity.[12,13] Furthermore, there is a tendency to set up skill laboratories for this type of training, where physical simulators and virtual reality are combined in accordance with the principle of replacement.

Table 1 – Student allotment in different groups and their main characteristics

Characteristics	Group 1[a]	Group 2[b]	Group 3[c]	Group 4[d]
Mean age, y	24	25	24	22
Right/left handed	8/0	7/1	7/1	8/0
Videogames, yes/no	5/3	4/4	4/4	2/6
DIY activities, yes/no	2/6	2/6	2/6	1/7
Man/woman	2/6	3/5	3/5	2/6

[a]Operating theatre with training.
[b]Operating theatre without training.
[c]Classroom with training.
[d]Classroom without training.

Table 2 – Results from students versus surgeons

	No.	*Exercise 1* (grasp and transfer), mean (SD)	*P*	*Exercise 2* (cutting), mean (SD)	*P*
Classroom					
Students	16	165.5 (32.7)	<.001	151.1 (33.0)	<.001
Surgeons	8	58.2 (14.5)		62.6 (20.5)	
Operating theatre					
Students	16	132.3 (40.1)	<.001	147.5 (39.3)	<.001
Surgeons	8	77.0 (18.7)		64.8 (25.8)	

Table 3 – Mean scoring difference of students between first and second evaluation

Exercise	Group	No.	Mean (SD)	P	Group	No.	Mean (SD)	P
Difference in score (1st-2nd evaluation) Exercise 1	Without training	16	33.3 (39)		Classroom without training	8	45.2 (39)	<.001
					Classroom with training	8	107.6 (14)	
				<.001	Operating theatre without training	8	21.3 (38)	<.001
	With training	16	87.6 (30)		Operating theatre with training	8	67.6 (38)	
Difference in score (1st-2nd evaluation) Exercise 2	Without training	16	33.8 (39)		Classroom without training	8	52.2 (37)	.706
					Classroom with training	8	44.3 (44)	
				<.001	Operating theatre without training	8	15.3 (34)	<.001
	With training	16	65.1 (41)		Operating theatre with training	8	85.8 (28)	

The usefulness of training with physical simulators has been shown in various studies, in which improvement in developing exercises over the simulator is observed so as to tell surgeons with experience from those without it.[9,14] In our study the group of surgeons scored significantly higher than the students, which indicates that the simulator discriminates between experienced/inexperienced individuals. Regarding the usefulness of the simulator as a teaching tool, we observed that students in the training groups in both scenarios scored better in object transfer than those that did not train. However, no differences were found in the cutting exercise between trained/untrained groups, although we observed that the students find it difficult to orient the cutting line properly, which makes us consider that the second exercise design was not right, and in light of the results it does not seem a valid exercise to train in this surgical skill. Hence the importance of a good design for the practice exercises.

Simulators allow training in certain manoeuvres and steps along the process of a surgical intervention. They appear as an interesting alternative or complementary means to reduce the need to experiment with animals, given the ethical problems that this last practice implies. With regards to type of simulator, it seems that when training novel surgeons for basic skills, virtual reality simulators do not present great differences with respect to *videotrainers*.[15] Both systems have proven their usefulness in several studies when compared against untrained control groups. According to studies comparing training with *videotrainer* against virtual reality, as we observed in a recent systemic revision,[16] there does not seem to be differences with respect to time in order to perform exercises and the number of failures, although more precision and economy of movements in groups trained with virtual simulators can be observed .

Virtual simulators have the main advantage of recording scores, which also allows checking surgeon's progress and working individually, as an assistant is not necessary to work, given that the programme itself works as an instructor. However, apart from differences of economic nature, the *videotrainer* system offers a feeling of reality and of a sense of touch that many virtual simulators lack. Although it seems that realism in exercises and tactile feedback do not reduce effectiveness of training significantly, development of programmes gradually closer to reality and utilisation of devices with haptic technology will surely result in more widespread use of virtual simulators and more satisfaction from surgeons training with them.[17] In any case, given that both methods have their own advantages, it seems logical that their combination lead to a better learning than using either one separately.[18,19]

Apart from initial training for novel surgeons, simulators are valued as a tool to accelerate the learning curve in laparoscopic surgery. They offer the opportunity to acquire a number of skills, such as perception of depth with two-dimensional vision or enhancement of movements of instrumental introduced through trocars, in a stress-free, more relaxed environment than in the operating room, and without risking patients' health. Various simulators have proven useful to acquire basic laparoscopic skills, and their use has even been proposed to evaluate surgical competence, through using this skill acquisition as part of a standardised and approved surgical curriculum, although this would be a complex task due to the scant objective tools accepted and approved that we have available.[20,21]

The final approval for a simulator requires corroboration of transference onto the operating theatre of those skills acquired in the laboratory.[22] Medical students participated in our study, with the objective of studying a population with the same experience background in laparoscopic surgery. Studies with this simulator, including participation of residents and surgeons with no laparoscopic experience, could be interesting to assess the influence of practice of this simulator over the evolution of skills in real interventions.

Simulators in laparoscopic surgery are excellent training tools, although both time and economic resources may limit their usage. In our study we did not find differences between students, nor between surgeons performing the exercise in different scenarios, which leads us to suppose that this simulator, with a low-cost camera, apart from being portable and of easy set-up, will allow for training at the right moment and place, be it classroom, surgical skill laboratory, home, etc. Training with this simulator equipped with a low-cost camera seems useful, as it does similar training with a conventional laparoscopic system simulator, to acquire basic laparoscopic skills.

Finally, it is worthy of note that this study arose great interest in endoscopic surgery among the participating students. Most of them regarded the simulator as a very useful instrument to understand the difficulties involved in laparoscopic surgery, as despite having had contact at the operating room with this type of surgery, only with direct surgery assistance or additional audio-visual material projection it is difficult to understand how to work using a two-dimensional system and material as that used in laparoscopic surgery. Various authors have proposed the application of new teaching models in surgical subjects for undergraduate courses, which will result in a better communication between students and surgeons and foster larger participation from both.[23,24] The presence of a "virtual campus" is the needed infrastructure to develop and manage these new teaching needs.[25] The department of surgery of the Faculty of Medicine of Reus (Rovira i Virgili University) is developing a surgical skills programme as obligatory practice within which this simulator practice is included. It seems that a brief introductory session with this simulator might be useful for students of medicine, with the objective of making them aware of the particularities of endoscopic surgery and stimulate and foster their interest in surgery specialties.

Conflict of interest

The authors affirm that they have no conflicts of interest.

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