A Comparison of Human Cadaver and Augmented Reality Simulator Models for Straight Laparoscopic Colorectal Skills Acquisition Training

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BACKGROUND: The aim of this study was to compare the human cadaver model with an augmented reality simulator for straight laparoscopic colorectal skills acquisition.

STUDY DESIGN: Thirty-five sigmoid colectomies were performed on a cadaver (n = 7) or an augmented reality simulator (n = 28) during a laparoscopic training course. Prior laparoscopic colorectal experience was assessed. Objective structured technical skills assessment forms were completed by trainers and trainees independently. Groups were compared according to technical skills and events scores and satisfaction with training model.

RESULTS: Prior laparoscopic experience was similar in both groups. For trainers and trainees, technical skills scores were considerably better on the simulator than on the cadaver. For trainers, generic events score was also considerably better on the simulator than on the cadaver. The main generic event occurring on both models was errors in the use of retraction. The main specific event occurring on both models was bowel perforation. Global satisfaction was better for the cadaver than for the simulator model ($p < 0.001$).

CONCLUSIONS: The human cadaver model was more difficult but better appreciated than the simulator for laparoscopic sigmoid colectomy training. Simulator training followed by cadaver training can appropriately integrate simulators into the learning curve and maintain the benefits of both training methodologies. (J Am Coll Surg 2010;211:250–255. © 2010 by the American College of Surgeons)

Advantages of the laparoscopic approach in colorectal surgery are now well-documented.[1-4] The inherent loss of 3-dimensional perspective and tactile feedback has created a prolonged learning curve for this approach.

Laparoscopic skills training appears to be a valuable method to reduce the learning curve for laparoscopic colectomy. It fosters basic and advanced laparoscopic skills. But little evidence exists to support the use of skills training and simulation to accelerate learning in colorectal surgery.

Traditionally, animal and human cadaver training models have been used to improve spatial perception of surgical anatomy with similar tissue planes and organ consistency.[5,6] Recently, laparoscopic training simulators have demonstrated an ability to enhance the technical skills required for basic laparoscopic procedures in several trials.[7-10] For advanced laparoscopic colorectal surgery, no studies have compared training models for laparoscopic skills acquisition or demonstrated skills transfer to patient care after laparoscopic training.

The aim of this study was to compare the human cadaver model with an augmented reality simulator for straight laparoscopic colorectal skills acquisition.

METHODS

Protocol

This comparative study, approved by the Institutional Review Board at University Hospitals Case Medical Center,

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took place during an annual colorectal training course organized by the American Society of Colon and Rectal Surgeons. Trainers underwent training on the simulator several weeks before the course and the day before the course to standardize training methods and simulator use. Trainees received instruction on laparoscopic colon surgery and on training models use. Then, 35 straight laparoscopic sigmoid colectomies on fresh human cadavers (n = 7) without prior bowel preparation, and on an augmented reality simulator (ProMIS 2.5; Haptica; n = 28) were performed and compared.

Simulator

The ProMIS simulator is composed of an anatomical plastic mannequin linked to a laptop computer (http://www.haptica.com). The peritoneal cavity is replicated by a disposable plastic tray, with plastic layers replicating different tissue planes. Use of real surgical instruments on a real physical model provides tactile feedback to trainees.

Surgical technique

The laparoscopic sigmoid colectomy technique was standardized for both models as follows: medial to lateral dissection of the Toldt's fascia; proximal ligation (clips) of the inferior mesenteric vessels; lateral peritoneal incision and mobilization of the splenic flexure; intraperitoneal linear stapled rectal transection; extraction of the sigmoid specimen and intraperitoneal circular stapled colorectal anastomosis. Trainees used the same real laparoscopic instruments, including access devices, laparoscope, scissors, graspers, staplers, and energy devices on both training models. A standard 0-degree laparoscopic camera was held by an assistant to perform the procedures in 2-dimensional vision.

Assessment

Before the training, surgeons' prior training course and laparoscopic colorectal surgery experience was collected on a standardized form. During the training, generic and specific technical skills and events (scores, no unit) were assessed using validated Objective Structured Assessment Technical Skills forms completed independently by trainers and trainees.[11,12]

Generic skills included respect for tissues, time and motion, instrument handling, knowledge of instruments, retraction, and flow of the operation. Each generic skill criterion was scored from 1 to 5.[12] Specific skills included port insertion, vessels exposure and division, Toldt's fascia dissection, left ureter identification, rectal transection, specimen extraction, and colorectal anastomosis. Each specific skill criterion was scored from 2 to 10.[12] For technical skills, higher scores were given for better performance. Generic events included appropriate incisions, planes of dissection, instruments and diathermy use, retraction, hand-to-eye coordination, tissues handling, suturing technique, bleeding control, and speed of procedure. Each generic event criterion was scored from 1 to 2.[12] Specific events included artery control, material fallen in abdomen, bleeding, colonic ischemia, and organs injury. Each specific event criterion was scored from 1 to 24 according to event gravity.[12] For events, lower scores were given for better performance. After the training, a global satisfaction grade (no unit) on a 10-point Likert scale was given by each trainee for training models. Data were compared between each training model.

Table 1. Prior Laparoscopic Colorectal Surgery Experience and Courses

	Cadaver group		Simulator group*		
	n	%	n	%	p Value†
Prior LCRS procedures‡					0.647
None	2	28	4	16	
<30	4	57	13	54	
>30	1	14	7	30	
Prior LCRS courses					0.114
No	5	71	7	29	
Yes	2	28	17	71	

*Missing data.
†Chi-square test.
‡Performed as first surgeon.
LCRS, laparoscopic colorectal surgery.

Statistical analysis

Data were recorded in Excel (Microsoft). Results were expressed as mean ± SD. Analysis was carried out with SPSS software statistical package (SPSS, Inc). All technical scores were compared with the Mann-Whitney U test. Satisfaction grades were compared with Student's *t*-test. Distributions were compared with chi-square test. A p value <0.05 was considered as significant.

RESULTS

Cadaver and simulator surgeons had similar levels of laparoscopic colorectal experience and course experience (Table 1). On the cadaver model, generic skills and generic events were considerably better scored by trainees than by trainers (Fig. 1). On the simulator, skills and events scores were similar between trainees and trainers (Fig. 1).

Generic (p = 0.008) and specific (p = 0.028) skills and generic events (p = 0.001) were scored better by trainers on the simulator than on the cadaver model (Fig. 2). In contrast, for trainees, only specific skills were scored better

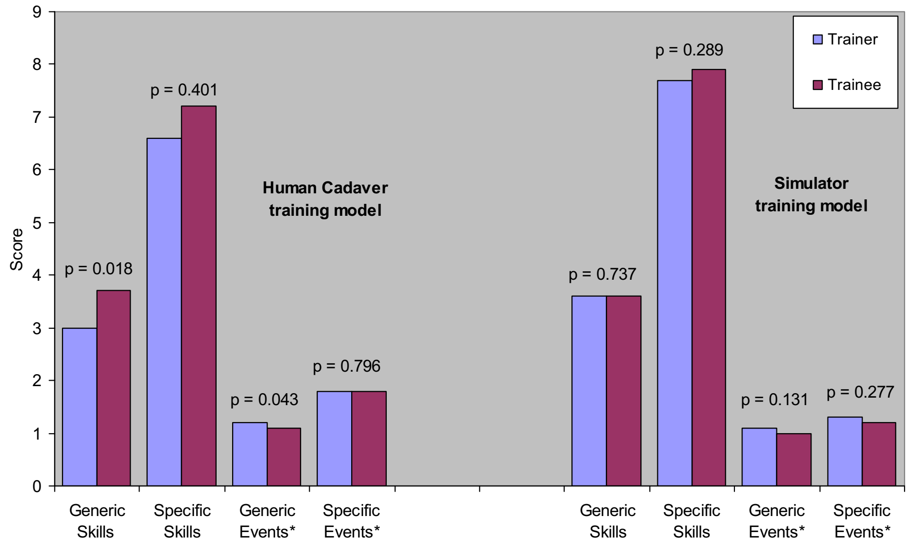

Figure 1. Comparison of laparoscopic sigmoid colectomy training scores between trainers and trainees. *For events, a lower score is better; Mann-Whitney U test.

(p = 0.038) on the simulator than on the cadaver (Fig. 2). The most frequent generic event recorded by trainers on both training models was inefficient use of retraction (Table 2). The most frequent specific event on both training models was perforation of the bowel (Table 3). The rate of bowel perforation was 28% (2 of 7) and 10% (3 of 28), respectively, on cadaver and simulator models. No injury to the left ureter was recorded. The global satisfaction grade was significantly better for the cadaver model (n = 7) than for the simulator (n = 24) (9.7 ± 0.7 versus 6.8 ± 2.2; $p < 0.001$).

DISCUSSION

This is the first study comparing the human cadaver model with an augmented reality simulator for laparoscopic colorectal skills assessment and satisfaction. Intuitively, the human cadaver model appears to be the best anatomic and clinical-like model for surgical procedural training.[13] Ross and colleagues,[5] reporting on the adoption of laparoscopic colectomy training courses, suggested that the cadaver model was the most important factor of course choice for participants. Levine and colleagues[14] demonstrated a substantial improvement in generic technical skills for resi-

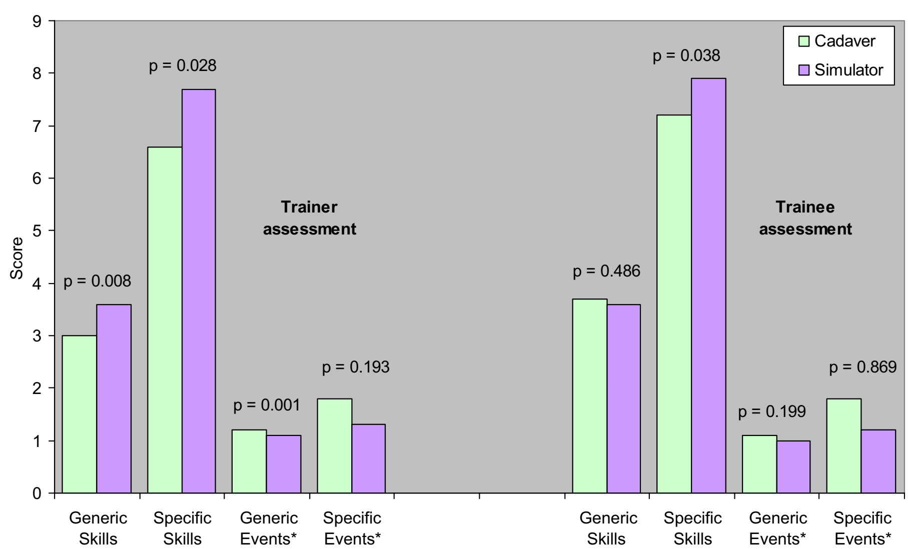

Figure 2. Comparison of laparoscopic sigmoid colectomy scores between both training models. *For events, a lower score is better; Mann-Whitney U test.

Table 2. Generic Events Recorded during Laparoscopic Sigmoid Colectomy Training

	Trainer assessment		Trainee assessment	
	Cadaver (n = 7)	Simulator (n = 28)	Cadaver (n = 7)	Simulator (n = 28)
Inappropriate incisions	2	0	1	0
Incorrect planes dissection	2	3	1	3
Inefficient instruments use	3	3	1	0
Inefficient retraction use	4	8	1	2
Bad hand-to-eye coordination	1	6	1	3
Bad tissues handling	3	4	1	6
Unreliable suturing techniques	0	1	0	1
Inappropriate diathermy use	0	0	0	0
Incorrect bleeding control	NA	1	NA	2
Hurried or too slow procedure	1	2	1	2
Total	16	28	7	19

NA, not assessable.

dents exposed to laparoscopic gynecologic trainings on cadavers. Availability of human cadavers is limited, and their use is expensive ($3,000 each) and requires operative facilities and equipment and a funeral service. The augmented reality simulator offers the potential for expanding training access to alternative high-fidelity models, the ability to use real clinical instrumentation, easier transport, reusability, and measurement and recording of training performance for objective evidence of skill acquisition. The approximate price to acquire a ProMIS simulator is $25,000; however, it can be used repeatedly, with a cost of approximately $200 per disposable plastic tray.

To assess technical skills on both models, objective structured assessment forms were used. In a prospective study, Sarker and colleagues[12] showed that this tool was reliable between trainers and trainees for laparoscopic colectomy performed on patients. In our study, generic skills and events were scored better by trainees than by trainers on the cadaver model, and skills and events were scored similarly by trainers and trainees on the simulator. These data might suggest that scoring is more variable and difficult on the cadaver than on the simulator model or, alternatively, trainees believe their skills are better than they actually are. In addition, the reliability of this tool might be different between a clinical skills assessment and assessment in a training course. Simulators should be less subjective because they are able to automatically record performances over

Table 3. Specific Events Recorded during Laparoscopic Sigmoid Colectomy Training

	Trainer assessment		Trainee assessment	
	Cadaver (n = 7)	Simulator (n = 28)	Cadaver (n = 7)	Simulator (n = 28)
Spleen minor injury	0	0	0	1
Unsecured artery	0	1	0	2
Material fallen in abdomen	0	1	0	2
Bleeding	NA	1	NA	2
Left ureter not identified	1	0	0	0
Colonic ischemia	NA	1	NA	2
Bowel perforation	2	3	2	3
Left ureter injury	0	0	0	0
Other viscus injury	1	1	1	2
Total	4	8	3	14

NA, not assessable.

time, instrument path length, and economy of movement during a procedure without human intervention. These measurements were demonstrated by Neary and colleagues[15] to distinguish between novice and experienced laparoscopic colorectal surgeons on the ProMIS simulator.

When scored by trainers, the technical skills and generic events were better on the simulator than on the cadaver. Scored by trainees, the specific skills were also better on the simulator than on the cadaver. No prior study has compared the technical difficulties between both laparoscopic colorectal models. These data suggest that the laparoscopic sigmoid colectomy was more difficult on the cadaver than on the simulator model. This can be explained by either a poor tissue planes replication on the simulator or some differences between human cadavers, such as anatomic variations or quality of tissue preservation. Examining the generic events in more detail, the trainees had difficulty maintaining adequate retraction on both training models, suggesting that the simulator is able to replicate difficulties of dissection as seen in the cadaver model.

Consistently in both models, the most frequent major complication was perforation of the bowel (>9%). This highlights the importance and the difficulties associated with mastering technical skills for appropriate tissue handling during a laparoscopic colorectal procedure. This might be an unrecognized learning curve issue, as the overall incidence of bowel perforation during laparoscopic procedures is about 0.22% and up to 7% in laparoscopic bowel resections, or simply related differences in approach of the trainee to a simulated colectomy whether on cadaver or virtual simulator.[16] Neary and colleagues[15] identified similar issues on the ProMIS simulator with a higher risk for organ injuries, including bowel perforation, for novice than experienced surgeons. The rate of bowel perforation was very high (28%) on the cadaver model. This can be explained by either increased exposure difficulties or increased intestinal fragility in this training model in comparison with the ProMIS simulator.

Overall satisfaction was considerably better for the cadaver model than for the ProMIS simulator, suggesting better face validity. A high satisfaction for the cadaver laparoscopic training model has already been reported in several studies.[13,17,18] The main cadaver model qualities reported were tissue consistency and preservation of anatomic planes, making the understanding of surgical anatomy, laparoscopic technique, and laparoscopic instruments use easier.[13,18] The single comparative study, comparing a cadaver with a porcine laparoscopic model for urologic procedures, also found a substantial preference for the cadaver model for the same reasons.[6] These data suggest that improvement of replication of human tissue planes on the ProMIS simulator might better convince trainees of the reliability of simulator training for complex procedures. Newmark and colleagues[19] demonstrated that a low-fidelity box trainer can be equivalent to a virtual reality simulator to measure time of completion and number of errors for basic laparoscopic tasks.

In conclusion, using similar surgical instruments, the human cadaver model seemed more difficult and was better appreciated than the ProMIS simulator for laparoscopic sigmoid colectomy training. These data suggest that simulator training followed by cadaver training can provide optimal integration of simulators into the learning curve.

Appendix: Colorectal Surgery Training Group

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Drafting of manuscript: Leblanc
Critical revision: Champagne, Augestad, Neary, Senagore, Ellis, Delaney
Final approval: Leblanc, Champagne, Augestad, Neary, Senagore, Ellis, Delaney

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