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Telementoring for Minimally Invasive Surgical Training by Wireless Robot

S. Sereno, MD, D. Mutter, MD, PhD, FACS,
B. Dallemagne, MD, C. D. Smith, MD, FACS,
and Jacques Marescaux, MD, FACS, FRCS

Hands-on training courses with local mentoring are excellent educational tools in laparoscopic surgery; however, the need for the physical presence of specialized instructors represents a limitation because of costs, time, and geographic constraints. Remote robotic telementoring using a wireless videoconferencing mobile robot could represent an alternative to local instruction. The authors compare local active and passive mentoring with remote robotic telementoring using the wireless RP-6 Robot that worked through a WiFi 802.11b connection during a hands-on laparoscopic training session. Surgeons were mentored once in France from the United States. Robot mentoring was well received and appreciated (assessment score of 2.65; scale, 0 to 4). There was no statistical difference in the different mentoring sessions (active, passive, and remote). Mobile wireless robot is a valuable tool in laparoscopic telementoring. Robotic-assisted telementoring may not replace onsite mentoring, but it may enhance educational opportunities and the quality of hands-on training courses by implementing tutoring with expert assistance from remote locations.

Keywords: education; surgery; robot; training; laparoscopy

Introduction

Today, surgical education is, for the most part, based on conventional teaching methods that include theory and practical exercises. Although proficiency in surgery was historically acquired mainly by apprenticeship, the restricted access to the operating room because of legal reasons and the new skills needed for laparoscopic surgery have drastically modified the methods of training surgeons. A consensus has emerged that specialized training courses may improve the technical skills required for performing new surgical procedures.[1-3] Many studies have demonstrated that the rate of complications associated with the clinical learning curve decreases significantly after dedicated surgical training.[4,5]

Surgical simulators are not yet ready to fulfill the actual training requirements. Hands-on educational programs on living animals under the supervision of experts remain optimal methods of teaching. The value of such courses is very dependent on the quality of the mentoring that is provided by the expert surgeon assisting the trainees. The limitations of these educational programs are often availability of mentors and costs. Many expert surgeons do not know how, do not like, or do not have the time to participate in animal laboratories. Travel expenses and the absence of the experts in their own institution increase direct and indirect costs for mentors.

One of the solutions of these difficulties is to use telemedicine. Technologic advances in video and computer communications have made the concept of telemedicine in surgical education possible.[6-8] It can be used for telementoring, which refers to the possibility for an expert surgeon to assist another surgeon from a remote location[9-11]; however, conventional videoconferencing systems are not appropriate for surgical mentoring: the expert is only able to watch and comment on the video image. The organization of the operating room; the position of

From the IRCAD/EITS, University Louis Pasteur, Strasbourg, France (SS, DM, BD, JM); and the Mayo Clinic, Jacksonville, Florida (CDS).

Address correspondence to: Jacques Marescaux, MD, IRCAD/EITS, 1 Place de l'Hôpital, 67091 Strasbourg Cedex, France; e-mail: jacques.marescaux@ircad.u-strasbg.fr.

the operators, nurses, anesthesiologists; the placement of laparoscopic ports; and the surgical steps are significant factors in the execution and quality of a surgical procedure. To achieve this remote presence requires multiple cameras throughout the room, a video router that controls the various images and sounds, interactivity tools, and a dedicated connection between the sites to handle the video and audio signals.[10,12] This expensive and disruptive setup creates a different manner of human communication. Ideally, the mentor should have access to the surgical pictures but should also be able to move and interact more closely within the surgical environment. Mobility, interactivity, and audio and visual requirements might be fulfilled by a mobile remote presence system simulating a human-type physical presence.

The aim of this study is to compare onsite mentoring with robotic telementoring using a wireless videoconferencing mobile robot during hands-on laparoscopic courses on living animal models in a center with extensive experience in surgical training.

Methods

The RP-6 Robotic System

The RP-6 is a remote presence robot (RP-6; Intouch Health, Santa Barbara, California) that uses wireless technology for remote control and videoconferencing. It consists of two parts: the robot and the control station.

The robot is a 5 feet–4 inches tall, wireless, wheeled machine that can rotate its head (flat monitor) and body separately and can travel at a speed up to 2 miles per hour. Circumferentially distributed on the bottom and middle part of the "body," the RP-6 has a sensor-assisted driving system consisting of 29 infrared sensors that detect possible collisions and slow or stop the robot's motion. The robot has a camera attached on the top of its head and a speaker on the front of the body, providing videoconferencing in real time. The person who stands in front of the robot will see the face of the "driver" on the screen and hear his or her voice. This person can also see himself or herself with a picture-in-picture modality. The RP-6 has an 8-hour rechargeable battery.

The robot is remotely controlled from a control station (version 3.0.3) that includes a computer console with a double-screen display (video version 1.84), camera, microphone, telestration, and picture-sharing capability. Telestration has a capability that allows the "driver" to freeze an image shown on the screen of the robot and make annotations or drawings.

The movements of the robot are controlled by a joystick (Logitech Extreme 3D Pro; Logitech, Fremont, California) at the control station. When an obstacle is detected, infrared sensors transmit the information to the computer. A signal appears on the control station that simultaneously indicates the position of the obstacle and prevents any movement of the robot in that direction. The control station and the robot are linked via broadband Internet through an 802.11 wireless network.

Experimental Room Setup and Surgical Model

All animals used in the experiment laboratory were managed according to French laws for animal use and care and to the directives of the European Community Council (number 86/609/EEC).

Surgeons included in the study were established surgeons participating in a continuing medical education (CME) surgical program on laparoscopic procedures. They worked on anesthetized 30- to 35-kg pigs, which were intubated and ventilated. The laparoscopic setup was a conventional 3CCD digital camera (Storz, Tüttlingen, Germany) with a 0-degree straight telescope. As a routine, 2 surgeons assisted by a nurse had to perform an usual surgical operation. This procedure was detailed step by step in a PowerPoint slideshow that included short videos, which were continuously displayed on a dedicated 19-inch flat screen facing the surgeons. The 2 trainee surgeons reproduced successively the same procedure under the proctorship of an expert surgeon. The procedure selected for the study was a small-bowel resection and anastomosis. It involved dissection of a segment of small bowel after vascular division with clips, resection, and side-to-side small bowel stapled anastomosis with intracorporeal suturing of the enterotomy sites where stapling jaws were introduced.

Mentoring

Two types of onsite mentoring were used: the standard assistance called "active onsite mentoring," where the expert surgeon provided assistance with verbal instructions and practical support by manipulating or changing the position of instruments and camera when necessary. They gave advice orally but could also take 1 or 2 instruments themselves to demonstrate a procedure. They could also correct the performance of a task by modifying the position of the arm or the hand of a trainee. In the second type of onsite mentoring, called "passive onsite mentoring," the expert limited his or her support to verbal assistance without using hands to correct the positioning of instruments or camera. This mode of assistance would reproduce more closely the type of assistance provided remotely by the robot.

Robotic telementoring was performed with the RP-6 robot. In this study, the expert was remotely located at the control station in the same building and used all the technical features of the robot to provide verbal assistance to the surgeons (Figure 1).

The same expert provided successively both onsite and remote mentoring. The mentors all had extensive experience in surgical mentoring in animal laboratory sessions and were familiar with the Intouch robot technology.

The objective was to evaluate the quality of the mentoring and not the result of the surgical procedure, as its conduct would depend on other factors such as surgeons' level, assistance, and so forth. Thus, the final outcome of the surgical procedure was not evaluated because the same procedure was not repeated twice.

To avoid significant bias in the evaluation, onsite mentoring was alternatively provided in passive and active mode, and the surgeons were randomly assigned either to robotic telementoring followed by onsite mentoring or to onsite mentoring followed by robotic telementoring.

Intercontinental Mentoring

One experiment was carried out with an expert located on another continent (C. D. Smith, Department of Surgery, Emory University School of Medicine, Atlanta, GA). The aim of this test was to evaluate distant robotic mentoring in terms of quality of image, sound, and mobility of the robot and the value of the assistance through a real intercontinental communication. France–United States appeared as a significant demonstration.

Evaluation

The trainees were divided into 4 series, based on the sequence of the mode of mentoring and the type of onsite mentoring (Table 1). Evaluation was performed using a Likert-like bipolar scaling method in which the trainees had to answer 2 predetermined questionnaires (Table 2). These questionnaires evaluated the quality of the mentoring and the performances of the robot in terms of image, sound, mobility, and interference.

Figure 1. RP6 robot during laparoscopic telementoring.

All the participants were free to add comments in their evaluation sheets.

Statistical Analysis

The 2-tailed Fisher's exact test and 2-tailed unpaired *t* tests were performed using GraphPad Instat (GraphPad Software, Inc, San Diego, California) as appropriate. Significance was $P < .05$.

Results

Forty surgeons were assisted onsite and remotely. Two surgeons were submitted to the "intercontinental" experiment. Surgeons included in the study had different personal experience in laparoscopic surgery. They were asked to self-evaluate themselves within 1 of the following 4 groups: complete beginner (there were no complete beginners), beginner (17%), intermediate (79%), and advanced (4%). All trainees successfully completed the surgical tasks during the course.

Performance of the Robot

Ranking of the global performances of the robot (sound-image-mobility-interference) was not statistically different between groups. The mean score was 2.65 (range, 2.42-2.94) (Figure 2). The disturbance caused by the presence of the robot was not a significant issue for the trainees.

Table 1. Sequences of the Modes of Mentoring for the Different Series of Trainees

	Series A	Series B	Series C	Series D
Mentoring	1st, active mentoring 2nd, robotic telementoring	1st, robotic telementoring 2nd, active mentoring	1st, passive mentoring 2nd, robotic telementoring	1st, robotic telementoring 2nd, passive mentoring

Table 2. Questionnaire

Mentoring	Bad 0	Poor 1	Regular 2	Good 3	Excellent 4
Active onsite mentoring					
Passive onsite mentoring					
Robot-assisted telementoring					
Robot Performance	**Bad 0**	**Poor 1**	**Regular 2**	**Good 3**	**Excellent 4**
Image					
Quality					
Sharpness					
Color					
Interference					
Sound					
Quality					
Sharpness					
Movements					
Smoothness					
Appropriateness					

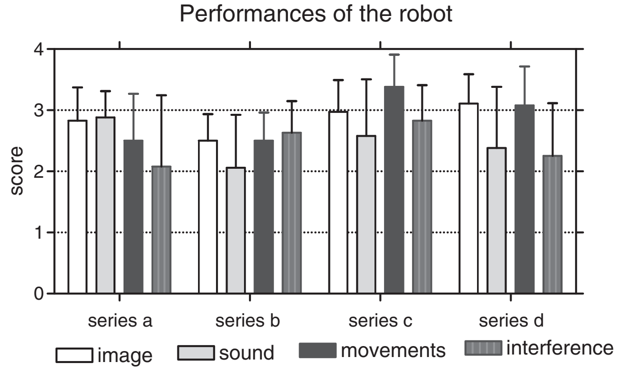


Figure 2. Performances of the robot (series a: n = 12; series b: n = 8; series c: n = 12; series d: n = 12).

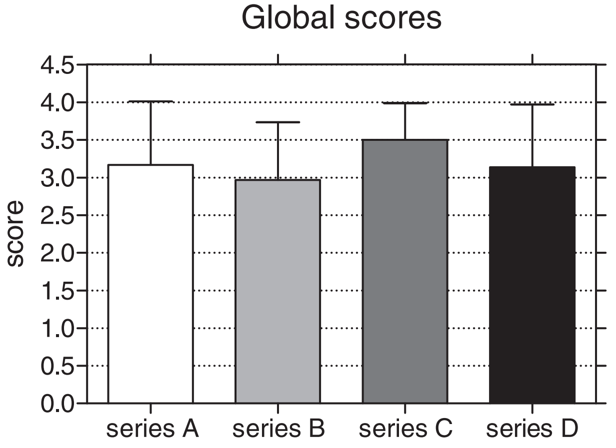


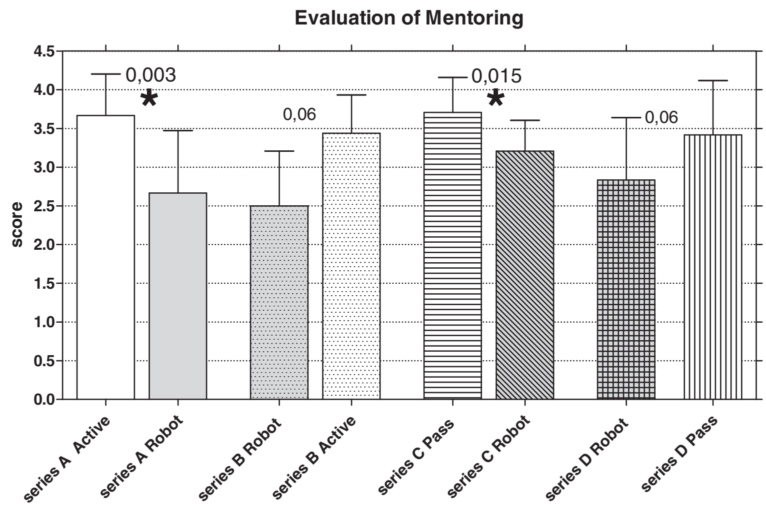
Figure 3. Scores of mentoring of the 4 series of trainees (mean score + SD); (series A: n = 12; series B: n = 8; series C: n = 12; series D: n = 12).

Quality of Mentoring

There was no statistical difference in the mean score of the different groups (Figure 3), demonstrating that the sequence and type of mentoring did not affect the global score of the teaching session.

Within the series, however, onsite mentoring (active and passive) was statistically superior to robotic telementoring when it was applied as the first mentoring

A



B

	Interaction Mean Score (SD)			Quality of Teaching Mean Score (SD)		
	Local	**Robot**	***P***	**Local**	**Robot**	***P***
Series a	**3,66 (0.49)**	**2,75 (0.75)**	**< .01**	**3,66 (0.65)**	**2,58 (0.99)**	**< .01**
Series b	3,5 (0.53)	2,5 (0.75)	.12	3,37 (0.51)	2,5 (0.75)	.06
Series c	**3,75 (0.45)**	**3,16 (0.57)**	**.03**	**3,66 (0.49)**	**2.91 (0.79)**	**.04**
Series d	3,41 (0.66)	2,75 (0.86)	.06	3,41 (0.79)	2,91 (0.79)	.12

Figure 4. (A) Evaluation of mentoring (quality of mentoring + interaction with the expert) with a comparison between site and robotic telementoring. Data are shown as mean + standard deviation. *$P < .05$. (B) Mean scores of the 2 parameters of evaluation of mentoring: quality of the interaction with the expert and quality of the teaching. Results in bold are statistically significant.

method of the sequence, but there was no significant difference if it was applied after robotic telementoring (Figure 4A).

The 2 parameters of mentoring (interaction with the expert and quality of mentoring) confirm these observations (Figure 4B). Onsite mentoring was systematically better than robotic telementoring. It was not significant when robotic telementoring was used before onsite mentoring.

The evaluation of active compared with passive onsite mentoring was not statistically different: simple verbal assistance was equivalent to active assistance. This was observed whatever the sequences of teaching.

The type of sequence did not affect the evaluation of robotic telementoring. Its didactic quality was statistically equivalent if it was used before or after onsite mentoring.

Quality of the Transmission

No interruption of the video signals during the robotic telementoring session was observed. This allowed continuous interactivity between the surgeons and the experts.

Intercontinental Mentoring

The intercontinental robotic telementoring session was carried out without any adverse event. The quality of pictures, sound, and mobility of the robot was comparable to local remote mentoring.

Free Comments

It appeared clearly that the trainees were very quickly comfortable with the presence of the robot. They had very realistic interactive exchanges with the experts controlling the robot. They did not take into account the fact that the mentor was not physically present in the room.

Discussion

In this period of emerging technologies and surgical techniques, practical training programs are essential to develop surgical skills and expertise.[13] Education based on conventional tutorial and apprenticeship during live surgery is increasingly difficult. Consequently, hands-on courses represent an essential way for acquiring surgical skills. This system of education requires onsite mentoring with all its constraints: the availability and know-how of the expert, direct and indirect costs related to experts' travel, and time out of practice.

One option to solve these constraints is telementoring, which is an advanced application of telemedicine. Telemedicine has been defined as "the practice of medicine and/or teaching of the medical art without direct physical physician-patient or physician-student interaction, via an interactive audio, video communication system employing electronic devices."[14] Telementoring is real-time and live interactive mentoring in which the mentor can help the student without being physically present. In laparoscopic surgery, a conventional video and sound transmission may be insufficient to allow the mentor to observe all the parameters of a surgical procedure that includes video images, positioning of the operating table, trocars, surgeon, assistant, and nurse. Advances in technology and the availability of new wireless mobile robots today offer the possibility of sharing a telementor who will communicate in real time during the session with the students.[15] The RP-6 robot appears as a well-designed and original system able to fulfill the requirements of telementoring in surgical education. It makes images and sound transmission possible, allowing interactivity between the operator and the remote mentor.

Analysis of the study questionnaires filled out by the trainees confirmed that the technical qualities of the RP-6 robot's sound, image, mobility, and interactivity were considered sufficient for live mentoring. The presence of the robot was well accepted by the operating nurses and not viewed as a problem in the working space. No technical problem was encountered during the sessions, neither locally nor in the transatlantic location, and the wireless communication system was always sufficient. Furthermore, the questionnaires revealed that the trainees became comfortable with the presence of the robot very quickly. This confirmed the observation made in other applications.[16]

The mobile robot has been evaluated in several hospitals by surgeons using it to provide supplemental "face-to-face" communication with patients from the surgeons' homes and offices. Patients and practitioners interacted with the RP-6 robot, which displayed a live video image of the physician's face on its monitor/head.[17] The general acceptance of this new monitoring is good. Such a remote proctoring system has infrequently been used for teaching purposes. Nonetheless, in another study, robotic telementoring appeared effective to proctor medical students during an anatomy class of cadaver dissection.[18] The system was considered very effective, and students felt that they were interacting with a person rather than with a video screen display and quickly forgot that the surgeon was not located in the same room.

As the feasibility has been demonstrated, there were still questions about the quality of this remote mentoring compared with onsite mentoring. The objective of our study was to evaluate whether experts are as effective mentoring remotely as when they do so onsite. Although the expert was considered more effective when he or she taught onsite before robotic telementoring, this was not the case when robotic telementoring preceded the expert's onsite mentoring. More surprising, there was no difference observed between onsite active mentoring and onsite passive mentoring, regardless of the sequence. Nevertheless, robotic telementoring was never considered more superior than onsite mentoring.

This study shows a superiority of onsite "human" mentoring over remote "robotic" mentoring, but the difference is not as large as we would have expected. Analysis of the comments by trainees, experts, and nurses comments showed that the major drawback of the robotic mentoring is the lack of a "hand actor" on the robot. This makes it impossible for mentors to demonstrate actively a procedure using their hands. Besides, the mentors' experience in animal laboratories probably limited the drawbacks of this limitation. Finally, the development of such robots must be a choice between more complex robots with specific man/machine interfaces or simple robots allowing the use of available reliable teletransmission systems, avoiding mechanical or technologic failures.

The option of remote mentoring opens many possible applications in the field of teaching and training in surgery. Experimental surgery is a unique possibility to acquire dedicated skills for new laparoscopic procedures, and its quality is ensured by the expert correcting or validating the surgical techniques. No other training method currently available, such as computer training or "virtual reality" simulation, offers an equivalent possibility to acquire comparable surgical skills. Hands-on training sessions have been attended by more than 15,000 surgeons at the IRCAD Institute since 1994. Such high-quality courses require tremendous involvement of the experts. We can now imagine an expansion of the panel of participating experts thanks to remote robotic telementoring technology. Nevertheless, remote mentoring might not replace onsite mentoring, but we think that the concept may be useful in many situations: limited number of local experts, unavailability of external experts, the need for prompt and updated teaching of specific surgical procedures, remote assistance for distant training centers, or collaboration among local and remote experts. Using remote control to observe surgical procedures might also become one method to evaluate the capability of a surgeon to perform specific procedures and perhaps to deliver accreditation.

The cost of the robot could limit worldwide use of the system as its purchase price is about US$100,000. Yet this expense must be compared with the real cost of an expert, including travel expenses and loss of personal in-hospital working time. For example, the participation of Professor Dan Smith in the local work would include travel costs (flight tickets: $3500) as well as 3 days of personal in-hospital working time (estimation: $1000 per day), representing a total of $ 6500. This would mean that the robot would be reimbursed after 15 remote training sessions. If one considers the use of this robot on a regular basis, the cost would not be a major drawback considered over a long period.

Conclusion

Although it is clear that a mobile wireless robot may not replace the local mentors, it has been shown that it is a valuable tool in telementoring minimally invasive procedures. Robot-assisted mentoring may amplify the quality of education and proctoring in hands-on training courses by increasing the availability and specificity of experts tutoring from any remote location.

References

1. Olinger A, Pistorius G, Lindemann W, Vollmar B, Hildebrandt U, Menger MD. Effectiveness of a hands-on training course for laparoscopic spine surgery in a porcine model. *Surg Endosc.* 1999;13:118-122.
2. Wolfe BM, Szabo Z, Moran ME, Chan P, Hunter JG. Training for minimally invasive surgery: need for surgical skills. *Surg Endosc.* 1993;7:93-95.
3. Deziel DJ, Millikan KW, Economou SG, Doolas A, Ko ST, Airan MC. Complications of laparoscopic cholecystectomy: a national survey of 4,292 hospitals and an analysis of 77,604 cases. *Am J Surg.* 1993;165:9-14.
4. Moore RG, Adams JB, Partin AW, Docimo SG, Kavoussi LR. Telementoring of laparoscopic procedures: initial clinical experience. *Surg Endosc.* 1996;10:107-110.
5. Schulam PG, Docimo SG, Saleh W, Breitenbach C, Moore RG, Kavoussi L. Telesurgical mentoring: initial clinical experience. *Surg Endosc.* 1997;11:1001-1005.
6. Ballantyne GH. Robotic surgery, telerobotic surgery, telepresence, and telementoring: review of early clinical results. *Surg Endosc.* 2002;16:1389-1402.
7. Eadie LH, Seifalian AM, Davidson BR. Telemedicine in surgery. *Br J Surg.* 2003;90:647-658.
8. Marescaux J, Rubino F. Telesurgery, telementoring, virtual surgery, and telerobotics. *Curr Urol Rep.* 2003;4:109-113.
9. Latifi R, Peck K, Satava R, Anvari M. Telepresence and telementoring in surgery. *Stud Health Technol Inform.* 2004;104:200-206.
10. Lee BR, Moore R. International telementoring: a feasible method of instruction. *World J Urol.* 2000;18:296-298.
11. Cubano M, Poulose BK, Talamini MA, et al. Long distance telementoring: a novel tool for laparoscopy aboard the USS *Abraham Lincoln*. *Surg Endosc.* 1999;13:673-678.
12. Link RE, Schulam PG, Kavoussi LR. Telesurgery: remote monitoring and assistance during laparoscopy. *Urol Clin North Am.* 2001; 28:177-188.
13. Emken JL, Mcdougall EM, Clayman RV. Training and assessment of laparoscopic skills. *JSLS.* 2004;8:195-199.
14. Guidelines for the surgical practice of telemedicine: Society of American Gastrointestinal Endoscopic Surgeons. *Surg Endosc.* 2000;14:975-979.

15. Friedman AA, Zibit M, Coote M. Telementoring as a collaborative agent for change. *J Tech Learn Ass.* 2004;3: 1-41.
16. Zhang C. Robot "nurse" puts a human face on elderly health care. *The Salt Lake Tribune.* June 19, 2003.
17. Stephenson G. *Dr Robot tested at Hopkins.* Johns Hopkins Office of Communication and Public Affairs, Baltimore, MD: August 2003.
18. Smith CD, Skandalakis JE. Remote presence proctoring by using a wireless remote-control videoconferencing system. *Surg Innov.* 2005;12:139-143.