The RoboConsultant: Telementoring and Remote Presence in the Operating Room During Minimally Invasive Urologic Surgeries Using a Novel Mobile Robotic Interface

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OBJECTIVES Remote presence is the ability of an individual to project himself from one location to another to see, hear, roam, talk, and interact just as if that individual were actually there. The objective of this study was to evaluate the efficacy and functionality of a novel mobile robotic telementoring system controlled by a portable laptop control station linked via broadband Internet connection.

METHODS RoboConsultant (RemotePresence-7; InTouch Health, Sunnyvale, CA) was employed for the purpose of intraoperative telementoring and consultation during five laparoscopic and endoscopic urologic procedures. Robot functionality including navigation, zoom capability, examination of external and internal endoscopic camera views, and telestration were evaluated. The robot was controlled by a senior surgeon from various locations ranging from an adjacent operating room to an affiliated hospital 5 miles away.

RESULTS The RoboConsultant performed without connection failure or interruption in each case, allowing the consulting surgeon to immerse himself and navigate within the operating room environment and provide effective communication, mentoring, telestration, and consultation.

CONCLUSIONS RoboConsultant provided clear, real-time, and effective telementoring and telestration and allowed the operator to experience remote presence in the operating room environment as a surgical consultant. The portable laptop control station and wireless connectivity allowed the consultant to be mobile and interact with the operating room team from virtually any location. In the future, the remote presence provided by the RoboConsultant may provide useful and effective intraoperative consultation by expert surgeons located in remote sites. UROLOGY 70: 970–974, 2007. © 2007 Elsevier Inc.

The invention of the telephone in 1876 provided a basic means of communication over long distances. The telecommunications industry has since advanced greatly with the perfection of radio transmissions, wireless communications, and satellites in orbit that have not only made long-distance communication highly efficient, but also facilitated communication with remote areas around the world.

The rise of telecommunications has strongly influenced medicine, leading to the development of an entirely new branch of medicine known as telemedicine, the use of telecommunications technology to provide medical services from a remote location.[1] One of the first recorded instances of telemedicine was in 1906 when Einthoven, the father of electrocardiography, made a trans-telephonic transmission of an electrocardiogram from his laboratory to a hospital 1 mile away.[2] An early example of long-distance use of telemedicine was in 1967 in Boston, when a medical station at Logan International Airport was linked to Massachusetts General Hospital in downtown Boston using a two-way microwave audio-video link.[3]

In the decades since, teleconferencing has become the predominant form of telemedicine and it has been used during minimally invasive procedures for telementoring and telesurgery. One of the first cases of telesurgical mentoring was in 1996 when an endoscopic specialist at a remote site offered guidance to a surgeon doing a

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laparoscopic procedure at a hospital 3.5 miles away.[4] The two sites were connected via a single point-to-point digital transmission link. The consulting surgeon successfully guided the junior surgeon through seven laparoscopic procedures without any connection failures or interruptions.

Similarly, between September 1998 and July 2000, 17 procedures were telementored between two sites 9230 km apart: an operating room at the Policlinico Casilino "Tor Vergata" University of Rome and a remote site at the Johns Hopkins Medical Institutions in Baltimore.[5] Discussions between the two teams were carried out using a system that included a dial-up Internet connection, real-time audio-video, an external video camera with a panoramic view of the operating room, and a remote control for electrocautery and telestration. Ten cases were telementored successfully, but in five cases the operating room team was unable to establish a connection with the remote site. A similar research was conducted in 2000 when a less experienced laparoscopic surgeon in Singapore was telementored by a senior laparoscopic surgeon located remotely in the Johns Hopkins Medical Institutions in Baltimore. In this study, both cases were accomplished successfully.[6]

These studies demonstrated the feasibility, safety, and effectiveness of telementoring during laparoscopic procedures performed anywhere in the world.[4–6] However, these studies used conventional teleconferencing techniques that do not allow enough direct interaction between the consultant and the client (any recipient of the telementoring) because of requirements for space and equipment and dependence on skilled camera placement on the client end for detailed views of the operation which leave the remote consultant seemingly detached from the operation.[7,8] Although the consultant is able to provide effective guidance and advice, he is dependent on the recipient end for garnering information and cannot himself roam about the room and investigate points of interest (e.g., patient positioning, x-rays, anesthesia monitors, operative views).

One breakthrough for establishing a sense of remote presence has been the invention of the RemotePresence-7 robot (RP-7; InTouch Health, Santa Barbara, Calif). This robot has a small footprint comparable to the size of a human being and it allows an individual to project oneself from one location to another to see, hear, roam, talk, and interact in real time just as if that individual were actually there. Most important, little preparation or additional equipment is needed to use the RP-7 robot. A consultant operates the robot from a remote location using a joystick and a specially configured laptop computer to control robot movement and camera views respectively with minimal training.

The RP-7 robot has been used experimentally for telerounding, which has been linked to increased patient satisfaction in postoperative care.[9,10] A survey of patients in the intensive care unit revealed that telerounding with the RP-7 robot increased examination thoroughness, strengthened the continuity of contact between patient and physician[11] and provided opportunity for more frequent face-to-face discussions, and improved the coordination of postoperative care.[8] The RP-7 allows the physician to do almost everything that he would have done in an actual bedside visit including looking at all charting information, test results, scans, and x-rays.

The robot has also been used for teleproctoring of medical students during an anatomy class cadaver dissection.[7] The robot is operated by a senior surgeon in a remote location to monitor students' dissections and advise them as needed. The most compelling aspect of teleproctoring has been the sense of physical presence of the proctor in the operating room.[7] The robot's human footprint and ability to move around and interact in a human way through face-to-face audio-visual communication establishes remote presence of the proctoring physician and provides students with efficient, timely advice.

In the current study, we examine the impact and feasibility of telementoring using the RP-7 robot in live, minimally invasive urologic surgeries. In addition, we evaluate the potential of remote presence in the operating room and the efficacy of the InTouch RP-7 robot as an intraoperative consultant—thus, the nickname "RoboConsultant."

MATERIAL AND METHODS

The RP-7 Robot

The RP-7 is a sophisticated remote presence robotic system that can be controlled by a portable laptop control station linked via broadband Internet connection. Its dimensions are 165 cm in height and 63 × 76 cm at its base, comparable to the size of a human (Fig. 1A).

The head of the robot is fitted with two advanced digital cameras, an audio microphone, and amplification circuitry allowing for real-time, two-way audio-video communication (Fig. 1B). In addition, the robot head is moveable, allowing it to pan, zoom, and tilt, thus replicating similar motions to a human and allowing for more flexibility to see, evaluate, and investigate. Real-time video allows for detailed viewing and image capture of items of interest as well as telestration. The power supply in the form of a rechargeable battery is estimated to last between 5 and 6 hours.

The control station consists of a laptop computer, a headset with earphones and a microphone, and a joystick control (Fig. 2). The control station is linked to the robot via broadband Internet connection (either wireless or a wired ethernet connection), allowing the consultant to be mobile and link to the robot from virtually any location including the office, operating room, patient ward, clinic, or even from home. The laptop computer has a built-in camera that allows the receiver to view the consultant on the robot screen.

The RP-7 is equipped along the perimeter of its waist and base with advanced infrared sensors that detect when the robot is nearing an object, thus preventing unwanted collisions. The robot is controlled by a joystick, allowing for rotation as well as forward, backward, and strafe movements. The buttons atop the joystick toggle between control of the robot's base and rota-

Figure 1. (A) Front view of the RP-7 robot demonstrating key components such as speaker, collision avoidance sensors around waist and base, and **(B)** view of the robot head including the screen, one camera for general purposes such as driving and another camera for zooming, and a microphone.

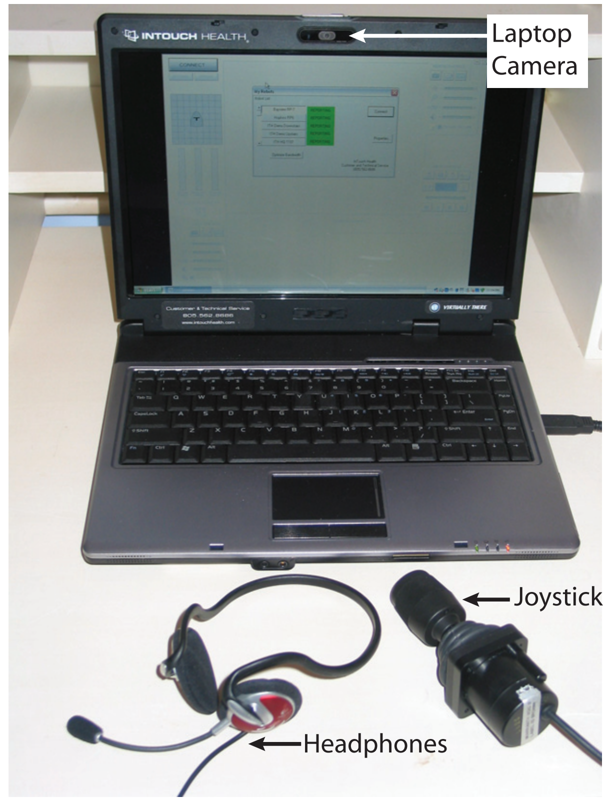

Figure 2. The laptop control station including a built-in camera, headphones, and a joystick to control robot movement.

tional and tilt movements of the robot head. The zoom feature of the robot camera is easily controlled by pointing to an area of interest using touchpad controls on the laptop and dragging the cursor to expand the view, a feature that allows the consultant to interrogate areas of interest such as x-ray films in greater detail (Video Clip 1). A video input jack located along the back of the robot allows for connection of any video source such as an endoscopic camera or fluoroscopy, thus allowing the consultant to view directly the images seen by the recipient surgical team. In addition, using the image capture feature, the consultant can capture still images and telestrate items of importance directly back to the recipient on the robot screen. The total cost of RP-7 is approximately $150,000.

The RoboConsultant Study

In this pilot study, we investigated the utility of the RoboConsultant for telementoring in the operating room. To determine the functionality of the robotic interface at different distances and sites, the robot was operated from a remote location by a senior surgeon during endoscopic and laparoscopic urological procedures in an adjacent room, an adjacent building, and a hospital 5 miles away. The senior surgeon was mentoring a junior attending in each case.

The operating team evaluated the subjective effectiveness of the telementoring and telestration experience. The criteria for evaluation included the impact of the presence of the robot in the operating room and the efficacy and ease of communication with the consulting surgeon. The consultant evaluated the ease of using the control station, the overall handling of the robot, and any interface connection failures. Both teams also evaluated overall robot functionality, including navigation, zoom capability, examination of external and internal endoscopic camera views, and telestration.

RESULTS

The RoboConsultant was easy to operate and performed without connection failure or interruption in each case. The consulting surgeon successfully immersed himself within the operating room and provided effective communication, mentoring, telestration, and consultation to a junior attending. The following two cases will highlight the utility and efficacy of RP-7 in the operating room setting.

The first case was of a laparoscopic radical nephrectomy for tumor in a morbidly obese patient. This case highlighted the mobility of the robot in the operating room, effective two-way, real-time, audio-visual communication between the consultant and the operating room team (Video Clips 2, 3), and the ability of the robot to evaluate external monitor and internal camera views in the operating room (Video Clips 4, 5).

The second case was of a laparoscopic partial cystectomy for a urachal mass. This case highlighted the robot's ability to evaluate external trocar positioning (Video

Clip 6), image capture and telestration, and picture-in-picture projection format (Video Clips 7, 8).

The operations were not disrupted in any way owing to the presence of the robot. The small footprint of the robot allowed for easy maneuvering inside the operating room. The high-magnification capabilities of the built-in cameras captured clear, detailed images of the operation and the robot was easily linked to the internal camera views via a video input jack, allowing the consultant to view the same images as the operating team.

COMMENT

In our experience, the RP-7 RoboConsultant provides clear, real-time telementoring and telestration by submersing the consultant into the operating room environment. The greatest advantages of the RoboConsultant over conventional teleconferencing techniques are its small footprint and human-like dimensions, maneuverability, versatility, and ease of use, all of which give it a feeling of just another human being in the operating room. The RP-7 can be moved promptly from one room to another depending on where it is needed. The mobile, built-in camera acts as the eyes of the consultant and the built-in audio capabilities function as the consultant's voice. The real-time images of the operating room and the image of the consultant on the robot screen provide direct face-to-face communication between the recipient surgeon and the remote consultant. Most important, no additional staff support is needed to use the RP-7, except to open a door or plug in after a procedure.

In addition to enhancing a sense of remote presence, the RoboConsultant's ability to capture and telestrate images makes consultations more detailed, informative, and educational. The consultant can magnify certain portions of an image and telestrate them back on the robot screen and explain to the recipient any significance or feature of that image. During live surgery this feature allows for improved planning of an operation and appropriate course correction by the consultant during technically difficult steps. An additional advantage of the RoboConsultant with endoscopic procedures is its ability to link to the internal camera views. With this feature, the consultant can view the precise images as the recipient surgeon and provide more informed and comprehensive consultations.

The RoboConsultant can potentially be used to provide mentoring and consultation worldwide. Because it can be used for telementoring in the operating room from any remote location that has broadband Internet capabilities, the location can be an adjacent room, an adjacent building, or even in medical centers hundreds to thousands of miles away. Although broadband wireless connections are not without fault, we experienced no signal drops during our study.

The RoboConsultant is particularly beneficial in time-sensitive situations such as problems during an operation that require immediate consultation from an expert.[10] In such cases, instead of waiting for a consulting surgeon to come to the operating room, the consultant can connect to the RoboConsultant using the laptop control station from his or her current location and provide prompt advice. Already the RP-7 has been effectively used in the setting of intensive care units and emergency rooms.[9,10]

The RoboConsultant has the potential to bring medical services to developing countries that lack medical expertise or experience. An expert surgeon can mentor or demonstrate to another surgeon in an underdeveloped country who has limited experience with a certain disease or surgical procedure. In some cases, the resources and technology may be available in the host country but the physicians are not experienced enough and require more training or guidance. The RoboConsultant may help shorten the learning curve for novice surgeons[7] and reduce the number of patients who would have to travel abroad to seek expert care.

A major shortcoming of this study is the lack of quantitative assessment to evaluate the robot's efficacy. Our primary goal was to test the feasibility of using the RP-7 teleconferencing robot in the operating room setting. Further multi-institutional studies and consideration of medico-legal issues are certainly required to assess RP-7's utility and role.

Although the Roboconsultant proved effective in our pilot study, the RP-7 in its current form is only a means of expanding heath care delivery, but by no means can completely replace the presence of a human being. This is especially evident by the lack of ability to examine a patient physically or participate in surgery. However, telesurgical interventions have already been demonstrated and haptic feedback technology can likely be incorporated into this robotic interface in the future.

CONCLUSION

The RP-7 RoboConsultant provided clear, real-time telementoring and telestration and allowed the consultant to experience remote presence in the operating room environment as a surgical consultant. The portable laptop control station and wireless connectivity allowed the consultant to be mobile, interacting with the operating room team remotely from virtually any location with broadband connectivity. In the future, the remote presence provided by the RoboConsultant may provide useful and effective intraoperative consultation by expert surgeons located in remote sites.

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Video Clips cited in this article can be found on the internet at: http://www.goldjournal.net