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Technical Report

Laparoscopic Telescope with Alpha Port and Aesop to View Open Surgical Procedures

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ABSTRACT

Laparoscopy has advanced surgery by allowing the surgeon to operate within a patient's abdominal and pelvic cavity with minimal trauma and scarring. The coupling of a video camera to the laparoscopic telescope has had the secondary effect of allowing others to view the surgical field either on color video monitors or by watching the video feed over the Internet at a remote location. These advancements have allowed better teaching and mentoring of operations. Open procedures can benefit from this technology as well but have suffered in the past from inadequate methods to depict the open surgical field. We used the Alpha Port and Aesop robot to position a sterile laparoscopic telescope near the surgical field to view open cholecystectomies performed on five pigs and to send the video feed over the Internet to remote physicians. Viewing the video on the monitor, the surgeons performed the operation in a comfortable ergonomic upright position. Both the surgeons and the remote physicians found the quality of the video to be excellent, and the remote physicians felt comfortable learning and mentoring surgical procedures using this technique.

INTRODUCTION

LAPAROSCOPY HAS ADVANCED SURGERY by allowing the surgeon to operate within a patient's abdominal and pelvic cavity with minimal trauma and scarring.[1] In addition, the coupling of advanced CCD video cameras to the telescope permits the surgeon to share the operative field with others. Surgical assistants, medical students, and surgical nurses alike are afforded the view that was once rather exclusively the surgeon's. Thus, both surgical care and education have improved. With computer networks available in many operating theatres, the boundary imposed by the very walls of the room can be transcended. Surgical cases have been streamed over the Internet to distant locations for the purposes of education and consultation.[2] These advancements rely absolutely on a small camera during laparoscopic procedures.[3] During traditional open surgical procedures, on the other hand, sharing the operative field has been limited. Teaching during open cases has suffered as a result of the limited visibility of the surgical field by assistants or observers, the view dropping off sharply as distance increases from the surgical field.

In the past, several attempts have been made to view the open surgical field, including head-mounted, wall-mounted, and overhead light-mounted cameras, as well as cameras mounted on overhead booms that can be extended over the surgical field. This report explores the use of the laparoscopic telescope attached to an Alpha Port and Aesop robot (Computer Motion, Inc., Santa Bar-

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bara, CA). The hypothesis was that the surgeon would have the same optical advantage as in laparoscopy and that the field could be shared. Using a sterile camera in the operating field in this fashion, video from the surgical field can be viewed on a television monitor or sent over the Internet to a remote location for proctoring or teaching.

MATERIALS AND METHODS

Five 30- to 40-kg Yorkshire pigs were anesthetized and prepared for open cholecystectomy. A 10-mm flat laparoscopic telescope was fixed distally into an Alpha Port, a rigid fixation arm that acts as the extracorporeal pivot point for the laparoscope in lieu of the traditional trocar port. This arrangement allows the telescope to remain near the surgical field, with pivotal motion in the expected fashion. The telescope was attached proximally to an Aesop robot affixed to the operating table on the left side at the foot. The robot was controlled by the surgeon's voice and continuously adjusted for optimum viewing by the surgeon approximately 5 cm caudally and 7 to 10 cm above the surgical field. The telescope was attached to standard laparoscopic video equipment (Stryker Endoscopy, Santa Clara, CA), and the images were displayed on a Sony 20-inch medical color video monitor Model PVM-20M2MDU (Sony Corporation, Tokyo, Japan). The monitor was placed at the head of the table so that both the surgeon and the first assistant could view the screen during the procedure. The video was also sent via S-VHS-quality cable to an Intel Teamstation 384 videoconferencing unit (Intel, Inc., Santa Barbara, CA). The Teamstation was connected point to point over a 10baseT local area network (LAN) to an identical Teamstation unit in a remote location. The connection was established via H.323 using the H.263 FCIF/QCIF video CODEC (COder/DECoder) at approximately 400 kbps bidirectionally and 15 frames per second (fps).

The surgeons performed open cholecystectomy on each of the five pigs. The three participating surgeons all had extensive training in laparoscopic and minimally invasive surgical techniques. The mechanical skills needed for laparoscopic surgery are different from those required for open surgery,[4] and the surgeons were encouraged, but not restricted, to view their actions on the video monitor as if performing laparoscopic surgery, as opposed to viewing the surgical field directly. They all had corrected or uncorrected distance visual acuity of 20/20 and normal color perception. The live video feed of the surgical field was simultaneously transmitted to three physicians viewing in a nearby conference room. The remote physicians all had corrected or uncorrected distance visual acuity of 20/20 and normal color perception. The video in this conference room was projected on a screen using an NEC Multisync MT1035+ projector (NEC, Tokyo, Japan), as well as a 29-inch PictureTel CRT monitor model SM-72DVX2N (PictureTel Corporation, Andover, MA) at a resolution of 800 × 600 pixels with 24-bit color depth.

RESULTS

Open cholecystectomies were performed on each of the five pigs by a surgeon and a first assistant. The Alpha Port and Aesop apparatus were used with the laparoscopic telescope for viewing during the procedure. After establishing the surgical field, but during the cholecystectomy dissection, the surgeon and first assistant were asked to perform the surgery as much as possible by looking at the video monitor (Fig. 1). During each procedure, a handheld Richardson retractor provided sufficient retraction for visibility using the telescope. The telescope was adjusted an average of three to five times using the voice-operated Aesop controls to maintain adequate visibility. The procedures were performed without complication. Afterward, the operators stated that they felt comfortable performing the dissection by viewing the monitor and actually felt that they were in a more comfortable ergonomic position fully upright. They completed a survey to qualify their experience (Table 1). The responses indicated that not only did the surgeons feel the quality of the video was excellent but that they were comfortable performing the dissection while viewing the monitor and that the apparatus was unobtrusive.

Three physicians viewed the procedures in a remote conference room. A screen capture of the remote video image is shown in Figure 2. The physicians viewing the operation remotely also completed a survey (Table 2). Their responses indicated the video quality to be excellent and that they would feel comfortable learning the procedure, as well as remotely mentoring the procedure from the video feed.

DISCUSSION

The Alpha port and Aesop robot apparatus with a laparoscope constitutes a novel way to view an open surgical field. In contrast to minimally invasive laparoendoscopic surgery, which depends on a video camera for viewing, open surgical procedures have been difficult to view by individuals other than the surgeon and the first or second assistant. Since the days of the early operating theatre, where students of surgery would pack into steep arrays of seats to catch a glimpse of surgical anatomy, many attempts have been made to improve the visibility of the traditional surgical operation. The simplest solution involves the use of mirrors, an approach that has

FIG. 1. Surgeons performing open cholecystectomy while viewing video provided by laparoscopic telescope fixed to Alpha Port/Aesop apparatus.

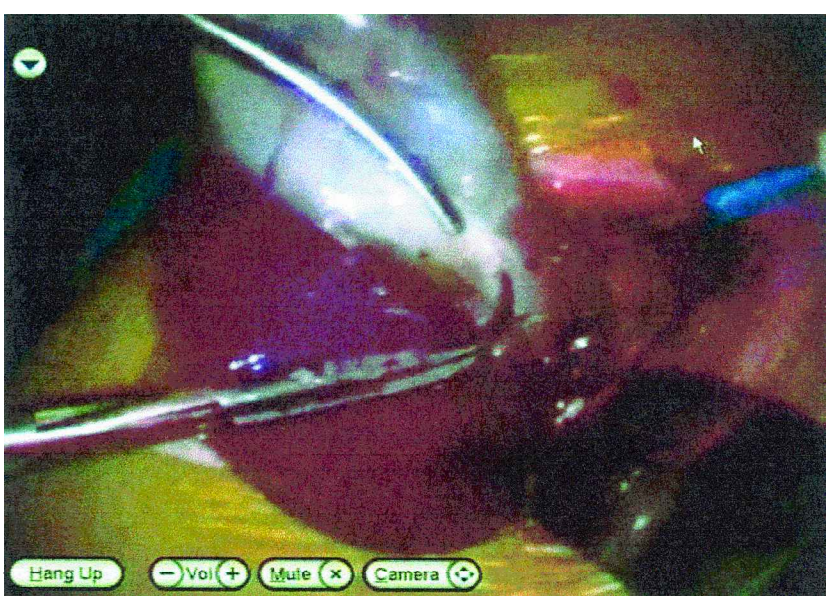

FIG. 2. Remote video feed frame grab of open cholecystectomy as seen by remote physicians.

Table 1. Survey of Surgeons Performing Operation

Questions	*Average*	*Range*
How would you rate the overall quality of the demonstration?	8.7	8–10
How would you rate the quality of the video you viewed on the monitor?	9.3	8–10
How would you rate the quality of the color reproduction?	9.0	8–10
I felt comfortable operating while viewing the monitor video image.	9.3	9–10
I felt that I could see every structure just as well on the video monitor as I could viewing the surgical field.	9.3	9–10
I felt comfortable operating with the telescope in place, that it was not obtrusive to the operation.	8.3	6–10
I feel that surgical education would benefit from this technology.	10.0	10

Graded Likert scale: 1 = poor or strongly disagree; 10 = excellent or strongly agree. (N = 3).

been used in few surgical procedures. Video cameras have advanced shared optics significantly; however, they may suffer from the fact that they usually must lie beyond the sterile field. Several vantage points for these cameras have been explored. Cameras mounted on the surgeon's head have been useful for teaching some surgical procedures, particularly in pediatric surgery, where the operative field is very small. The main problem with head-mounted cameras is movement of the surgeon's head, causing the image to be jittery or to slip in relation to the surgeon's gaze, necessitating frequent adjustment. Overhead light-mounted and light-handle cameras have been used with good results, as they are fixed and not prone to jitter and can be remotely controlled. These cameras have an acceptable vantage point from overhead but may still be rendered useless if the surgeon bends over the surgical field, blocking the view of the camera. The perspective also may change when the overhead lights are moved and adjusted. Use of an overhead boom-mounted camera during open procedures has had considerable success in our laboratory. This camera requires extra personnel to control the camera but has been found to be somewhat useful in teaching open surgical procedures. Obviously, microsurgical procedures that employ a surgical microscope can be outfitted with a beam splitter and a C-arm-mounted camera to obtain video footage that is nearly identical to what the surgeon views.

After reviewing all the various modalities for viewing the open surgical field that have been used to date, a list of minimum requirements was developed, along with an apparatus and logistical approach that would meet these requirements. The first requirement was to use state-of-the-art optics, lighting, and video equipment. A 10-mm flat laparoscopic telescope with a CCD camera and light source was chosen. This equipment has been well tested and proven to provide high-quality video during laparoscopic procedures, and it is widely available. The second requirement was to place the camera close to the operating field, which required the equipment to be incorporated into the sterile field. This arrangement permits high-quality detailed close-up images, as well as allowing the surgeons to interact and adjust the camera to optimal positioning.

The third requirement was to have the telescope and camera apparatus fixed to avoid unnecessary motion. Aside from creating a better image for the surgical team to view, fixing the camera is very important when sending the video feed digitally to a remote location using the Internet Protocol (IP) or an ISDN connection. Modern videoconferencing hardware and software, such as the Intel Teamstation, use CODECS that maximize the quality of video transmission within a specific bandwidth. To increase speed of transmission and improve the smoothness of the video, the CODEC compresses the video by not sending redundant information about each pixel in related frames.[5] Every 15 seconds, a full frame (with in-

Table 2. Survey of Physicians Viewing Operation Remotely

Questions	*Average*	*Range*
How would you rate the overall quality of the demonstration?	8.7	8–9
How would you rate the digital video quality?	8.0	7–9
How would you rate the quality of the color reproduction?	8.6	8–9
I feel that I had a good view of the operation.	8.0	7–9
I would feel comfortable using the video to learn surgical procedures.	7.6	6–10
I would feel comfortable mentoring someone from a distance using this video feed.	7.6	5–10
I feel that surgical education would benefit from this technology.	8.3	7–9

Graded Likert scale: 1 = poor or strongly disagree; 10 = excellent or strongly agree. (N = 3).

formation about every pixel in the frame) is transmitted as a means to refresh and maintain the image fidelity. Between full frames, only information about pixels that change beyond a particular threshold is transmitted. These "delta" frames stem from the temporal compression technique used by the CODEC.[6] For example, if one pixel contains the same color value in two consecutive frames, no new information is sent regarding this pixel, and on the receiving end, the pixel remains the same color value during the second frame. In practical terms, a very still image, with little of the overall image moving or changing, is necessary. With fewer pixels in the image actually changing, a smaller portion of the allowable bandwidth is used to transmit information about the changing pixels, and more information can be transmitted to produce a higher-quality, smoother video image. If the camera is not fixed, however, pixels that would normally remain unchanged may take on different values as the picture jitters or moves, requiring more information to be transmitted to reflect these changing values.[5] This may result in a pixilated image or choppy video stream. Fixing the telescope to an Alpha port maintains a steady image, with minimal motion artifact. To improve the quality of the video image further, a 15fps rate was used instead of the 30 fps typical for full-motion video. When half as many new frames are sent per second, the available bandwidth is instead employed for sending higher-quality images for each individual frame. The trade-off for smoother motion is negligible considering that the camera was rigidly affixed to the table, reducing the overall motion in the field, as mentioned in the discussion above. The remote-site physicians observing the procedures felt that the frame rate was sufficient for mentoring purposes.

The fourth requirement was to give the surgeon control of the camera and place ownership of the image with the surgeon in defining the surgical field. The telescope and camera were fixed to the Aesop robot. The robot is voice controlled by the surgeon, allowing control of the field of view hands free and without the assistance of other personnel. The camera has an optimal viewing position without interfering with hands or instruments. All movement is intentional, whether by voice command or use of the surgical instruments.

Operators competent in laparoscopic surgery felt comfortable operating while viewing the procedure on the video monitor. This offers many advantages to the operator. The images obtained are close-up, well lit, and magnified. This is the equivalent of bringing the surgeon's eyes to within 10 cm above the surgical field, without consideration of the surgeon's visual acuity or refraction. At the same time, by allowing the surgeon to operate in a fully upright comfortable position viewing the operation from the monitors, strain and fatigue that can result from a stooped position over the surgical field is reduced. Improvements on the visualization system, including a suspended imaging system based on projection of the image by parabolic mirrors and advanced beam-splitter technology, may also help visual perception and reduce fatigue.[7,8] The second benefit is affording everyone in the operating room the same view as the surgeons. This allows operating room personnel such as assistants, nurses, perfusionists, anaesthesiologists, or surgical technicians to keep pace with the events of the operation and to act preemptively and cooperatively as the surgical procedure progresses. In addition, students of surgery and nursing students can learn by watching the procedures on the monitors. Furthermore, once the video stream is digitized with readily available teleconference equipment, it can be sent to remote locations via the Internet or ISDN connection. Laparoscopic surgery has long taken advantage of these technical advancements in the improvement of surgical education and training.[9,10] The Alpha Port and Aesop apparatus have the potential to open the door to remote surgical teaching and remote surgical mentoring of the open surgical procedure from anywhere in the world.

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