Bilateral open inguinal herniorrhaphy was performed in Cuenca, Ecuador, and monitored via low-bandwidth (128 kilobits per second [Kbps]) satellite communication by consultants in Richmond, Va, for consensus regarding identification of standard surgical landmarks.

When telemedicine emerged in the late 1950s, the innovative and sophisticated technology used at the time was quite expensive. Historically, the use of telemedicine applications was limited to institutions that either had funding through government-sponsored grants or could afford the cost of the technologic tools. This hindered the broad use and expansion of telemedicine. Today, the use of this technologic method is still cost-dependent; however, the advent of the Internet as well as a broader expansion of telecommunication to remote areas make the concept of globalization more feasible.

In recent years, several groups have experimented with less expensive telecommunication resources that are capable of handling less bandwidth, while nonetheless establishing safe and effective telemedicine applications. Access to specialized medical attention by those in remote areas has traditionally limited adequate patient care. The feasibility and effectiveness of mobile health care delivery to remote areas has been demonstrated. However, the sense of remoteness and isolation in certain medical scenarios could limit the potential of this service.

Laparoscopic tools make it possible to share the surgical visual field with the rest of the surgical team, with the benefit of superior optics. Endoscopic visualization techniques recently applied to open surgery facilitate surgical performance and add a new tool to the armamentarium of today’s surgeon.

Transmission of such visualization techniques, especially with current compression software, may be severely limited by motion artifacts resulting from both intentional and inadvertent human manipulation. While small movements within the visual field may have no adverse effects, moving the entire field causes severe pixelation of the transmitted images. Stabilization of the camera to eliminate motion artifacts allows compression of laparoscopic images with the H.323 protocol for Internet transmission, with minimal pixelation. Open surgery should also be amenable to compression and Internet transmission with the advent and application of similar camera stabilization techniques. We report the first international telepresence and consultation for open surgery using camera stabilization and video compression via the Internet and a low-bandwidth connection.

See Invited Critique at end of article

METHODS
Audio and video were transmitted via an international mobile satellite telephone (Inmarsat, London, England) point-to-point from a computer in Cinterandes Foundation’s mobile surgical facility in Cuenca, Ecuador (latitude 2°, 53 minutes; longitude 78°, 59 minutes) to an Integrated Services Digital Network videoconferencing system in the Medical Informatics and Technology Applications Consortium (MITAC) laboratory at Virginia Commonwealth University in Richmond. The system uses 2 separate 64-Kbps satellite chan-
nels, for a total capability of 128 Kbps. Each satellite channel had 16 Kb dedicated to voice and 48 Kb dedicated to video, for a total throughput of 32 Kb of voice and 96 Kb of video.  

The cost of the satellite telephone equipment is approximately $15000. The usage is based on rates of $7.50 per minute per 64-bps channel. However, rates are currently being packaged so that fees are based on actual time used and data packets sent rather than simple connection time. Critical time for consultation via videoconferencing is approximately 15 minutes. The 2 portable satellite dishes were placed on the roof of the mobile surgical facility, allowing transmission to an Inmarsat satellite, the Atlantic Ocean Region–East, which is in orbit over the Atlantic Ocean.

The 2 portable satellite phones were integrated together with a Pentium III (Intel, Santa Clara, Calif), 500-MHz processor with 128 MB of RAM (random access memory) and a zc206 video digitizer (Zydacron, Manchester, NH), which transmitted half-frame (320 × 240) video to Richmond over Integrated Services Digital Network. The conference used G.722 audio protocol and H.263 video protocol, with a frame rate of 15 frames per second. Consultants viewed the operation on an Intel Teamstation Videoconferencing System, with a Pentium III 500-MHz processor and 128 MB of RAM.

Composite video output from the laparoscope was transmitted via British Naval Connection to the telecommunications computer. A wireless lapel microphone clipped to the surgeon's scrubs provided audio transmission from the remote site and was received by a built-in speaker in an MITAC consultant computer.

Standard laparoscopic equipment (Striker Endoscopy, Santa Clara, Calif) was used for the procedure. A 10-mm, 0° laparoscope paired to an Alpha Port (Computer Motion Inc, Goleta, Calif), a rigid fixator arm for stabilizing the laparoscope, was incorporated on one side of the operating room table within the sterile field, allowing stationed positions to be selected during surgery for video capture of the operative field. The surgeon could move the camera to maximize the field of view. As shown in Figure 1 and Figure 2, placement of the laparoscope with the Alpha Port is easily accomplished and provides local as well as distance viewing of the surgical field. Similar work, performed in the MITAC laboratory using the robotic surgery arm, Socrates (Computer Motion, Goleta, Calif), has demonstrated a more accessible view of the open surgical field.14

The telecommunications equipment used to support this research was packaged in such a way that it could easily fit into carry-on luggage, thus permitting ease of transportation, storage, and rapid deployability. The endoscopic equipment was also packaged in luggage. However, the ability to deploy such technology in many cases depends on the availability of the existing infrastructure. During the course of this research, a technical expert was indispensable in helping the attending surgeon. Once these technologic tools and methods become integral to surgical service, dependence on technical support will subside. It is not necessary to physically bring remote-site surgeons to the United States when they can gain immediate access technologically.

The project took place in May 2001; the procedure was a bilateral open inguinal hernia repair with mesh performed on a 28-year-old woman with symptomatic herniation. The patient agreed to participate in the project and consent was obtained. The surgical observers in Richmond were located in the MITAC laboratory and included 2 board-certified general surgeons, 2 surgical residents, and 3 medical students. Each observer was asked by the operating surgeon in Ecuador to identify 9 anatomic structures correctly and comment on the technical aspects of the operation. The remote team included R.C.M., local surgeons, anesthesiologists, and nurses who routinely provide care to underserved populations. The participants in the MITAC laboratory viewed images using an IKON Team Board (Malvern, Pa). The images were projected on the board using a Sanyo MT103S+ liquid crystal display projector (Sanyo, Chatsworth, Calif).

Real-time video was successfully transmitted via low-bandwidth satellite communications from Cuenca, Ecuador, to Richmond, Va. Video transmission of open herniorrhaphy exhibited sufficient resolution for faculty surgeons and surgical residents observing in Richmond to correctly identify 9 anatomic landmarks. Additionally, still images were captured both locally and remotely, allowing direct comparison of image quality. Figure 3A and B compare views of the hernia sac interior—3A from Ecuador and 3B from Richmond—with zero loss of quality.

The actual speed of the connection was 128 Kbps. The total connection time was 2 hours, including the connection time before the surgical incision. The surgical procedure lasted 1 hour 45 minutes. No loss of communication was encountered during the entire transmission. There were brief episodes of pixellation but no discontinuity in the audio and video interaction between the consultant and the remote site. If the camera or Alpha Port is shaken or moved, pixellation is inevitable. It is crucial to hold the

Figure 1. Adjusting the camera for visualization of the open herniorrhaphy. The device holding the camera can be seen in the center of the surgical field.

Figure 2. Performing surgery with the Alpha Port camera support (Computer Motion Inc, Goleta, Calif). Standard laparoscopic equipment and monitors provide local visualization of the surgical field while transmission hardware provides distance telementoring and consultation.
camera still to permit transmission. The Alpha Port was used for the entire surgical procedure, and no technical difficulties were encountered during its use. The use of this device provided a wide view of the operative field and close-ups of the procedure when needed.

Bilateral repairs were performed with resection of the round ligament. The Table presents the anatomic structures identified during transmission of the surgical procedure. Start and end points during placement of the mesh were also identified. The consulting surgeons (n = 2) and medical students (n = 3) concurred on all of the 9 anatomic points. Thus, we are the first, to our knowledge, to show identification of anatomic structures in open surgery using endoscopic-assisted imaging.

The transmission also served as a teaching session for the 3 medical students, as they were able to interact with both parties and actively engage in questions and discussions during the surgical procedure. While a technical expert was essential during this research, dependence on technical support will subside as these methods become more widely known and used.

With increasing global accessibility to the Internet, low-bandwidth telemedicine capabilities are made available, providing network infrastructure that requires little or no investment after the initial cost of the on-line set-up. The surgeons performing the surgical procedures in this research were board certified. On the international scale, surgery is not always performed by “board-certified” surgeons. The application of telemedicine and the many-faceted possibilities permits physicians with less skill to be mentored from afar or to participate in educational activities from remotely located sites.

Several aspects of low-bandwidth telemedicine were tested to validate the use of current technology to provide effective sharing of the open surgical environment. Telepresence, telementoring, and telesurgery are feasible and should be applied more broadly. The feasibility of telementoring of laparoscopic procedures has been shown. However, telementoring during open procedures has not been broadly applied, in most part due to the lack of adequate visualization.

The use of the Alpha Port to support the laparoscope during the transmission of open surgical procedures clearly enhanced visualization by magnifying the operative field and anatomic structures. Additionally, this apparatus minimizes camera motion and involuntary human motion, thus eliminating loss of resolution during transmission. The compression software only transmits that which changes from frame to frame. If only a small part of the field changes, such as a suture pass, the low-bandwidth transmission has excellent fidelity. If the entire field moves, the fidelity deteriorates and can only be restored by very expensive, high-bandwidth solutions. The laparoscope, paired with the Alpha Port, can constitute a standard tool during telementoring of open surgical procedures. Essential anatomic structures, vital to intraoperative surgical decision-making, could accurately be identified via low-bandwidth telemedicine capabilities.

By decreasing the costs of telemedicine with low-bandwidth connections, it is foreseeable that an increasing number of similar projects can be executed to provide specialized support and consultation in remote geographic regions of the globe. Stimulating the development of such projects can in turn increase the confidence and improve the capabilities of the remote medical personnel, positively affecting the spectrum of health care in underserved regions. Many countries of the world have little money available for health care. However, these same countries are making great strides in overcoming barriers to wide implementation by skipping over what the so-called West has done in the past (eg, the wide use and distribution of wireless telephony in the developing countries vs the dependence on copper wires in the 20th century in the United States and Europe). The costs of many initial projects will be borne by international funding agencies at first, but migration to health ministries will become the norm.
This type of connection can also be used as an educational tool in the medical field for students, residents, and physicians that are remotely located and do not have constant access to advanced medical expertise. The use of low-bandwidth telemedicine can be effectively exploited as a tool to provide support for on-site teams to enhance and expand the spectrum of current health care delivery systems.

This work was funded by a grant from the National Aeronautic Space Administration, Washington, DC.

We acknowledge the efforts by Anita Praba-Egge, MD, PhD, Edgar Rodas MD, Nathaniel Merriam, Azhar Rafiq, MD, and Brian King, MD, in completing this work.

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REFERENCES


The authors describe in exquisite detail the technologic strategies used to transmit, in wireless form, the performance of a bilateral inguinal herniorrhaphy on a woman over a great distance. Image stability is clearly an issue resolved by removing the human hand from the process. As presented by its ardent supporters, telesurgery is an interesting if not overly stated concept. Telepresence, telementoring, and telerobotics are terms that are creeping into the literature, at best describing feasibility studies to validate a concept.

In this exercise, medical personnel and medical students were able to identify specific gross anatomic structures from afar. The importance or even the existence of these structures in the repair of an inguinal hernia aside, what is the teaching point? Clearly, the fidelity of the images was valid. However, the validity of this approach to teach and educate medical students is questionable. Couldn’t these students go to an operating room and see these same gross anatomic structures?

‘Mentoring’ from afar pushes the envelope of logic. If the ‘novice’ is in difficulty, how does the mentor from afar really help? It is difficult enough to help in the operating room when residents get into tight spots and the attending is present across the table. We cannot assume that the novice will suddenly acquire the necessary skills to deal with complex, complicated, and unexpected findings. The novice’s training program is responsible for seeing that its graduates have the skills and experience to perform the necessary operations safely. How is it possible to supply the specific support to those who have not received the requisite training?

Technology has positively altered the face of medicine generally and surgery specifically in the past score of years. This report offers a technologic solution that appears to be in search of a problem when other solutions to the identified problem may be more appropriate.

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