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Is surgery a remote possibility? Robotic surgical system under development has telesurgery capabilities

Advances in robotic surgical technologies have spawned a multibillion dollar global industry since the da Vinci Surgical System (Intuitive Surgical, Inc., Sunnyvale, CA, USA) was first cleared for marketing in the United States in 1997 for use during thoracoscopic and laparoscopic surgical procedures. As surgical indications for its use have expanded, more hospitals and health systems are investing sizeable capital in these systems. Now one company is taking robotic surgery to the next level, not only enhancing the existing technology, but testing its system for remote use across hundreds of miles.

Robotic enhancements

Reiza Rayman, M.D., Ph.D., president and director of Titan Medical, Inc. (Flamborough, ON, CA), says that Amadeus—his company's "next-generation," four-armed robotic surgical system will eventually include technology currently not available, such as force feedback (i.e., haptic feedback). Robotic surgery systems available today currently lack tactile feedback, which many surgeons consider a significant obstacle related to its use.

The system is also being designed with a 16:9 format vision system that will eventually feature ultrasound vision in the scope. "This will enable surgeons to see not only the tissue surface, but to see through the tissue to see underlying structures such as blood vessels," Rayman explains. Another planned enhancement involves "multi-articulating" shafts. "Currently, the shaft of the robotic instrument that goes into the patient's body is essentially a straight, stiff shaft," explains Rayman, adding that this makes it difficult to navigate around healthy organs and tissue to reach the surgical target.

And then there's the telesurgery platform.

Telesurgery defined

"We define telesurgery as the performance of robotic surgery over a long distance, using a communication link," explains Rayman. "The definition includes surgery, as well as the actual manipulation of the instruments by the surgeon at a distance, not just telestration [drawn video images over a background image], which is passive," he stresses. "The Amadeus system has been designed in its core as an [Internet protocol (IP)] system, so whether it runs locally or by long distance, all the commands are programmed to be IP-compatible," offers Rayman.

Titan Medical completed its "Phase B" telesurgery testing in March 2009. "We wanted to find out whether the system could work on a real-world network at a long distance and produce acceptable response in terms of instrument commands and movements, in terms of transmission of the high definition [HD] video, and in terms of overall latency or delay feed seen between the time a command was given, and when it was seen back at the console by the surgeon," says Rayman.

The company worked with the communications provider Bell Canada (Montreal, QC, CA) to set up a virtual private network

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that spanned from Toronto to Vancouver and back, an estimated round-trip distance of 4,300 miles, or 7,000 kilometers. "It's an extremely long distance," says Rayman, "probably longer than one would practically expect when telesurgery becomes a day-to-day type of operation." However, he adds, "We wanted to test this extreme distance in order to push the envelope and to be able to say that if it worked at this distance, we could do it at shorter distances."

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During the test, Rayman said they had 45 megabits-per-second (Mbps) of bandwidth available. "Our goal was not only to test the response and latency, but also to test what amount of bandwidth would be acceptable for dual HD signals, plus the instrument commands." Video signals can take up the bulk of the bandwidth, from 70% to 75%, he explains.

Rayman says the results were "very acceptable, high-quality HD video, with low latency. The instrument responses were not a problem either," he added. Latencies were "in range of 300 ms total, end to end." Rayman says his past experience with telesurgery, coupled with what has been documented in the literature, indicate this is "quite acceptable for surgeons trying to do an operation." Still, Rayman hopes that by eliminating or refining some of the prototype components, the final version of the system will see even lower latency.

They also didn't need the full 45 Mbps of bandwidth. "We were able to pare down to about 10 Mbps total for both HD signals." Therefore, he concluded that 5 Mbps per channel, for a total of 10 Mbps, allowed for proper commands given at the console to be seen at the instrument site. "Having said that, we would recommend a buffer" to allow for demands above the 10 Mbps mark, Rayman suggests.

Patients at the other end

"What we did for these initial tests was simulate movement of dry lab objects that would simulate any generic surgery," explained Rayman. In addition, "In order to get visualization of tissue, we used an animal heart during the experiment with a simulated beat, in order to anticipate quick changes, which have more demand on the video."

Rayman says that "Phase C" testing would involve clinical cases, and the company has announced publicly that W. Douglas Boyd, M.D., head of the department of cardiothoracic surgery at Cleveland Clinic Florida (Weston/West Palm Beach, FL, USA), will be the principal investigator for Phase C. Titan Medical plans to complete this round of tests in the last quarter of 2010, in hopes of pursuing U.S. Food and Drug Administration marketing clearance for the Amadeus surgical system.

In terms of the surgical indications for this system, "We intend to launch initially in areas which are already being done, such as prostate surgery and parts of cardiac bypass procedures," explains Rayman. "But quickly, with the technology advancements," he adds, "we feel we can move into more complicated types of procedures such as heart valve surgery and bowel surgery."

According to Titan Medical, Boyd is a pioneer in cardiothoracic surgery who has collaborated with Rayman on robotic techniques in this field. In 1999, Boyd and Rayman performed the first closed-chest, beating heart coronary artery bypass surgery with the assistance of ZEUS Robotic Surgical System developed by Computer Motion, Inc. (Goleta, CA, USA). The company was acquired by Intuitive Surgical in June 2003.

Background on telesurgery

Rayman recalled an earlier robotic prototype that was telesurgery-capable. Computer Motion made a one-of-a-kind prototype that came out around 2001. Mehran Anvari, M.D., a laparoscopic surgeon at St. Joseph's Hospital (Hamilton, ON, CA), performed an estimated 30 stomach, kidney, and spleen surgeries using the system on patients 400 km away at North Bay General Hospital (North Bay, ON, CA).

"It was used in a single set of experiments from New York to France to demonstrate telesurgery feasibility," Rayman offers, referring to the minimally invasive cholecystectomy (gall bladder removal) in a 68-year-old woman performed September 7, 2001, by Jacques Marescaux, M.D. Marescaux was located in New York City and the patient was at a facility in Strasbourg, France. The distance

was 14,000 km and mean lag or latency was 155 ms on a high-speed, fiber-optic network. The procedure took 54 minutes to complete with no reported interruptions (*Ann Surg*. 2002 April;235[4]:487-492).

Rayman has several published papers on his dry and wet (animal) telesurgical lab experiments with ZEUS (the predecessor to the da Vinci system) using both wired as well as satellite connections, the latter an option in remote areas where no bandwidth is available. However, he explains, "That system is no longer being used. It's older and it's not supported right now, so there's currently no telesurgery going on in Canada or elsewhere."

"With telesurgery, you can virtually connect two surgeons, and have one surgeon operate and the other surgeon can actually move the extra arm, the 4th arm, and operate with the surgeon."

Not surprisingly, the U.S. military has invested in telesurgery research at the Telemedicine and Advanced Technology Research Center. However, unpredictable, dangerous battlefield conditions, coupled with issues of latency and interrupted transmissions remain barriers to advancement in this arena.

Still, Rayman says they've been in discussion with a consultant who represents some potential groups working with the U.S. military. "The aspect we're talking about with telesurgery is a field application that would support resuscitation and stabilization of a soldier injured in the field," he explains. "The idea is to use telesurgery to do the ABCs to assess the patient—airway, breathing, circulation—in order to get that patient stable enough to be transported to a back area and to be treated for the primary cause of their injury."

Telementoring with the robot

In addition to the technical aspects that make telesurgery a risky venture, the costs can be prohibitive. The argument that it eliminates patient transport will likely only justify its use if it can be established as a viable alternative for a sizeable population of patients in a given area (robotic systems are priced roughly at $1.5 million USD, excluding expenses for technical support and surgeon training).

However, Rayman argues, "Telesurgery has several aspects to it, all of which will accelerate the penetration and acceptance of robotic surgery." He believes that remote surgeon training is one of the main aspects, which could support adoption of the technology.

According to a paper published by Anvari, the penetration of advanced, minimally invasive techniques in Canada has been severely hampered by the inability to provide adequate training opportunities and support for community surgeons who live in remote regions. He describes his experience at The Centre for Minimal Access Surgery at McMaster University (Hamilton, ON, CA), where broadband Internet and telecommunication systems have been used for telementoring and robot-assisted remote telepresence surgery between a teaching hospital in Hamilton and two community hospitals in northern Ontario and Quebec (*World J. Surg*. 2007 Aug;31[8]:1545-50).

"Currently, surgeons need to travel from their hospital to a hospital with an expert in order to actually be in the operating room and see the expert work with the robotic platform," to observe, as Rayman puts it, "the tips, the tricks, and the little things that they do in order to feel comfortable enough to go back home and do it themselves. It takes a lot of time, effort and coordination," says Rayman of learning robotic assisted surgery. "With telesurgery, you can virtually connect two surgeons, and have one surgeon operate and the other surgeon can actually move the extra arm, the 4th arm, and operate with the surgeon."

Collaborative control of surgical robots would be a welcomed innovation that could foster remote consultation, evaluation, mentoring, and proctoring. But in addition to reimbursement issues and technical hurdles to clear for regulatory approval in the United States, surgical procedures practiced across U.S. state lines could raise licensing issues for physicians. Still, Rayman points to states like California with a strong existing telehealth network and high-quality Internet providers who could support this type of telesurgery.