ROBOTICS_TELESURGERY

In the Waiting Room

Robodocs may be here, but remote surgery remains remote

MOUNTAIN VIEW, CALIF.—"What this is allowing me to do is take my hands and literally put them inside a patient's body," says cardiac surgeon Mark Suzuki. He is peering into a video display and manipulating controllers on what appears to be a very expensive video game.

The device is no next-generation Nintendo, though. Inside a mock operating room at **Intuitive Surgical** is the user interface for a robotic surgery system named da Vinci. Though available for the past several years in Europe, it only recently won U.S. approval. Yet even as breakthroughs in medical robotics have greatly advanced minimally invasive surgery, the goal that has largely driven the research appears technologically out of reach: telesurgery—operations from a distance—has been put on the back burner.

The technology behind the robot-assisted surgery that Intuitive Surgical relies on was born circa 1989 at **SRI International**. After years of development work on microsurgery and laparoscopy, a eureka moment occurred, recalls retired Col. Richard Satava, professor of surgery at **Yale University** and former head of the Advanced Biomedical Technology Program at the Pentagon's **Defense Advanced Research Projects Agency** (DARPA). "A visiting medical student pointed out that if we could do surgery from a console across the room, why not set up the console at his house so he could practice at home?" Satava recounts.

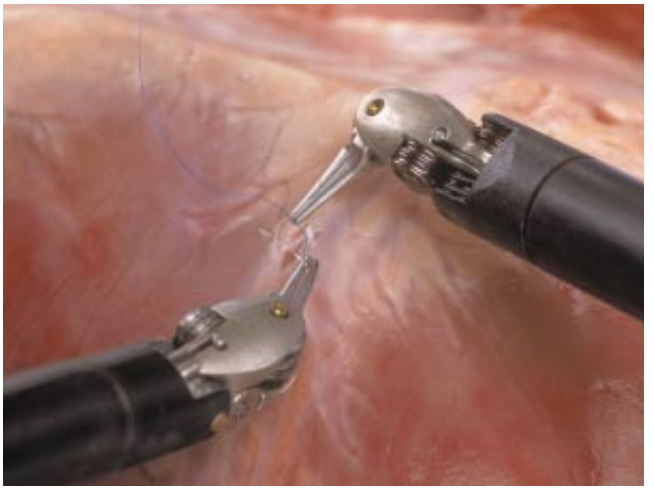
With physician Philip Green, inventor of the robot-assisted surgery system that eventually was licensed to Intuitive Surgical for commercialization in 1995, Satava coined the term "telesurgery." The goal that grabbed the Pentagon's attention and a DARPA grant became known as a doc-in-a-box. Imagine: An army ranger is riddled with shrapnel deep behind enemy lines. Diagnostics from wearable sensors signal a physician at a nearby mobile army surgical hospital that his services are needed stat. The ranger is loaded into an armored vehicle outfitted with a robotic surgery system. Within minutes, he is undergoing surgery performed by the physician, who is seated at a control console 100 kilometers out of harm's way.

Such a system would also prove immensely desirable in nonmilitary areas. Surgeons could operate on, say, astronauts, Antarctica researchers or residents of a remote village.

Satava succeeded in bringing that vision to light—for a moment, anyway. He impressed the Pentagon with numerous demonstrations, including one in which the secretary of defense remotely "operated" on pig intestines from a few hundred meters away via a wired connection. Then, in 1995, Satava's group introduced MEDFAST (Medical Forward-Area Surgical Telepresence), a prototype doc-in-a-box inside a tricked-out armored car. From five kilometers away, a researcher teleoperated on animal tissue over a line-of-sight wireless connection.

Though impressed, the army was noncommittal. "They did not think they could support from a logistical standpoint a large armored vehicle like our prototype," Satava remarks. "Instead they're focusing on [the] remote evacuation" of casualties, although the wearable vital-sign sensors have been used in military tests (as well as on a Mount Everest expedition).

The marketplace shares the military's misgivings regarding telesurgery. Mostly it boils down to bucks, Satava thinks. Even for robot-assisted surgery done in the same place, the cost is high: the systems not only contain pricey hardware, they require a trained support staff. Most medical facilities can't justify that kind of money for more minimally invasive procedures, even if they eventually include cardiac surgery [see "Operating on a Beating Heart," by Cornelius Borst; SCIENTIFIC AMERICAN, October]. The infrastructure for telesurgery would only jack up the already exorbitant price.



ROBOTIC SUTURING is done with video-gamelike controls.

Beyond the business barriers, a pressing technological problem prevents the doc-in-a-box from practicing: lag time in data transmission. According to Satava, the period from when a surgeon moves his hand to the moment the scalpel mimics that motion cannot be longer than 200 milliseconds; otherwise the surgeon risks slicing at the wrong spot. "You need to transmit data very efficiently to keep telesurgery real-time," notes Fred Moll, Intuitive Surgical's co-founder. "And the farther the surgeon is from the patient, the harder it gets."

Nowhere might that be truer than in space. Though proposed as a possibility, telesurgery is not on the foreseeable

INTUITIVE SURGICAL, INC.

time line of the **National Aeronautics and Space Administration**. The International Space Station will not be equipped for surgical procedures beyond the suturing of minor lacerations, says Sam Pool, NASA's assistant director for space medicine. "The rationale is that if there's a major need for a surgical intervention, we would come home," he explains. "The missions for which we would want, or really be forced, to do surgical interventions are still very far off in the future. And then the communication lags may almost be an insurmountable obstacle."

So far the greatest distance for which the lag time would not exceed the 200-millisecond threshold is 300 kilometers over a wire or 35 kilometers over a wireless, microwave connection, according to experiments. Improved technology could expand the range somewhat. (Telesurgery via geosynchronous satellite is physically impossible today: the round-trip signal time would be at least 480 milliseconds.)

The latency problem is "created by the video, not the control signals for the robot," according to Yulun Wang, founder and chief technology officer of Goleta, Calif.–based **Computer Motion**, Intuitive Surgical's main competitor (it has a similar robodoc called Zeus). Full-motion, high-quality video, he notes, requires about 90 megabits per second of bandwidth. Still, Wang believes that the world will soon be wired with enough bandwidth to handle the flood of information necessary for true remote surgery: "It's not a matter of yes or no, it's just a matter of when. If you had an open pipe, you could do remote surgery from anywhere on the planet." (Computer Motion is suing Intuitive Surgical for multiple patent infringements, claiming it beat Intuitive Surgical to the marketplace and that its competitor's technology resembles Computer Motion's.)

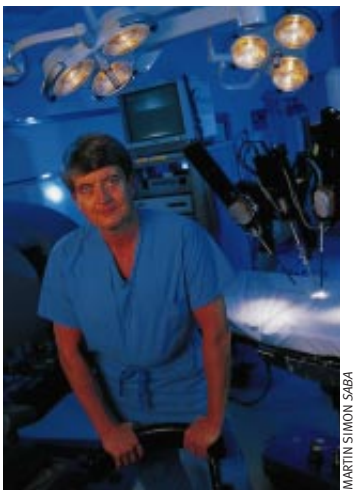
Where telesurgery might make inroads in the meantime is in the training of other physicians. Intuitive Surgical's Moll points out that surgeons are increasingly employing advanced videoconferencing and telepresence technology to "telementor" other physicians during various laparoscopic procedures (abdominal surgery accomplished by inserting a thin tube, outfitted with a camera and surgical instruments, through tiny incisions). Watching a video feed, marking the screen the way announcers do on TV sports broadcasts and even sharing control of the laparoscopic camera, the remote expert acts as a consultant for the on-site surgeon. In telementoring, "it doesn't really matter if it takes a second for the tip of the camera to move," Satava says.

Satava's colleague James Rosser, director of endolaparoscopic surgery at Yale, demonstrated the possibilities recently by guiding a surgeon at a Santo Domingo hospital through an operation to cure a patient's acid reflux. At his Connecticut home, Rosser watched the surgery from Computer Motion's voice-controlled robotic endoscope system and made verbal and on-screen comments. For unfamiliar procedures, surgeons can't "just dial up 1-900-OPERATE," Rosser quips. "We're developing the rigid rules of engagement for a participant conducting joint maneuvers who is not there. And remote interaction is an important building block that has to be refined before we can move on to true telesurgery." —*David Pescovitz*

DAVID PESCOVITZ (david@pesco.net), based in Oakland, Calif., is a contributing editor at Wired *magazine.*

Q&A_William E. Kelley

Paging Dr. Robot



MARTIN SIMON, *SABA*

Intuitive Surgical's da Vinci Surgical System consists of a cart outfitted with mechanical limbs that end in pencil-size, teleoperated surgical tools and a high-resolution camera. Inserted into the patient through tiny incisions, the instruments are controlled by a surgeon wielding joysticklike levers. The robot digitally mirrors the surgeon's hands while scaling down his or her motions and removing any tremor: to the surgeon at the helm, an artery is like a garden hose. The first person to put the $1-million da Vinci to work after its July clearance by the U.S. Food and Drug Administration was William E. Kelley of the Richmond Surgical Group in Virginia. He has since performed several dozen gallbladder removals, hernia repairs and other operations with robotic assistance. —*D.P.*

Q: What is the biggest benefit of robot-assisted surgery?

A: The biggest advantage is that it allows us to do complex and intricate surgical maneuvers much more precisely than we could do with either laparoscopy or open surgery. For instance, sewing is one skill in laparoscopic surgery that many surgeons have difficulty with. This enables me to make sutures in very difficult positions at awkward angles. You really can't reproduce the techniques with traditional instruments.

Q: Do you notice a resistance among your colleagues to sharing the operating theater with a robot?

A: My colleagues rejected it when I started taking out gallbladders with a laparoscope in 1989. There's always going to be that resistance. You have the people who will start very early, the majority who will wait until the kinks have been worked out and the people who don't want to ever do it. But ultimately, for example, if surgeons weren't doing laparoscopic surgery, they would have had to stop doing abdominal surgery in general.

Q: Are patients uncomfortable with the idea of a robot?

A: I've had a couple people say, "I don't want any robot doing the operation, Dr. Kelly. I want you doing it with your own hands." That's ironic because we don't use our hands directly. We use instruments. And this new technology is just an extension of the instruments. The most important thing is that we explain the options to the patient because their comfort level is every bit as important as what kind of instruments we use.

Q: What is the future of robot-assisted surgery?

A: We're really at the infancy of this technology. Everything is still evolving, and the operations will certainly become even easier. Of course, minimally invasive cardiac operations are the grand-slam home run of robot-assisted surgery. But this technology makes any surgeon better than before.