Surgery of the Future

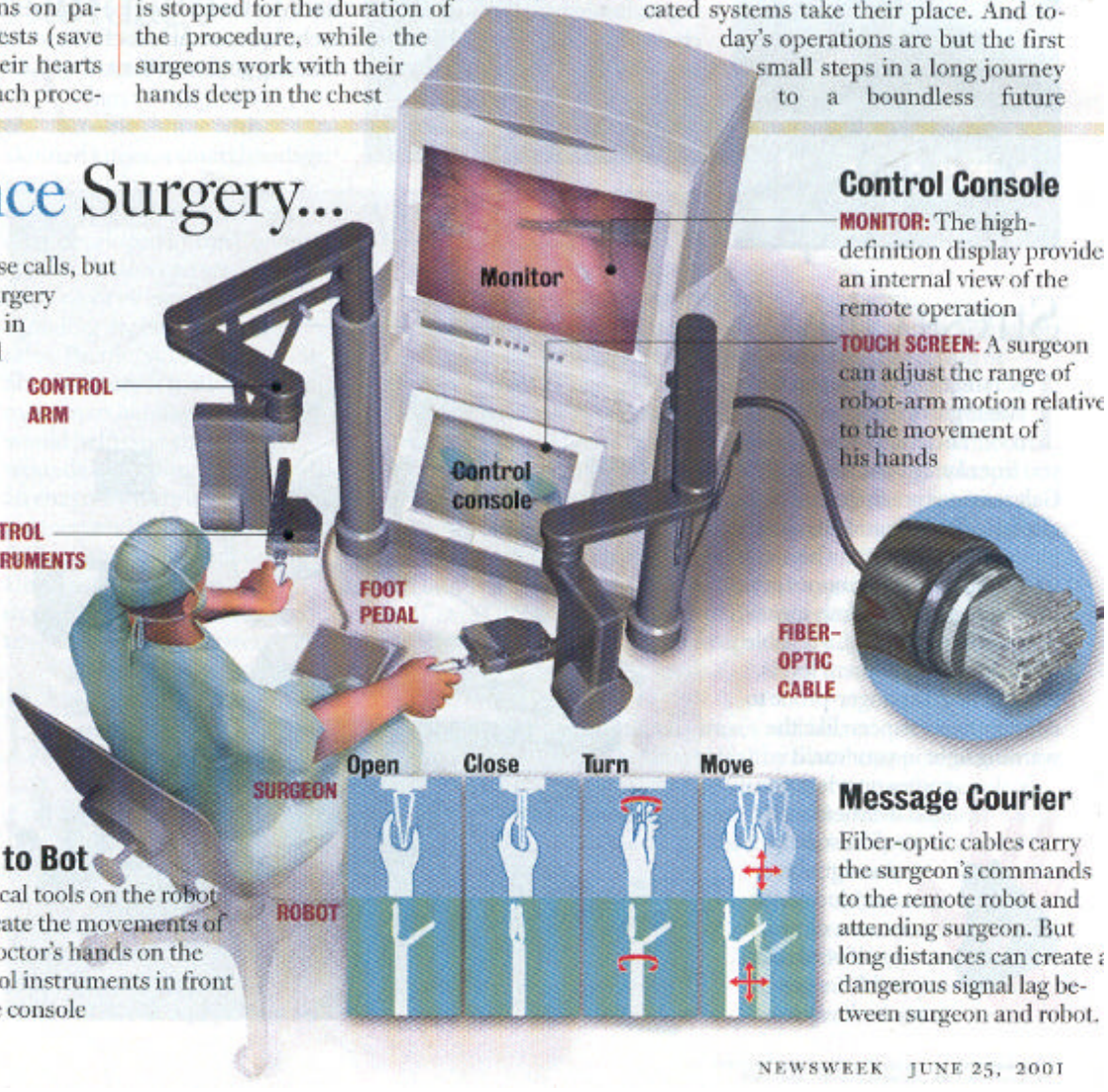
Imagine the day your surgeon performs your heart bypass while sitting at a computer thousands of miles away. That day may be coming. By David Noonan

The Ultimate Remote Control

DOUGLAS BOYD, A HEART surgeon at London Health Science Center in Ontario, is doing amazing things in the OR these days. Sitting across the room from the operating table, Boyd is using a surgical robot to perform bypass operations on patients without opening their chests (save for five tiny incisions), while their hearts continue beating. He's done 68 such procedures since the fall of 1999, with no deaths and far fewer post-op complications than he encounters in conventional operations. It's real state of the art, whiz-bang stuff, especially when compared with the controlled gore of standard bypass surgery, in which the chest is sawed open and the heart is stopped for the duration of the procedure, while the surgeons work with their hands deep in the chest cavity. But to hear Boyd tell it, his current OR feats and those of his fellow first-generation robosurgeons are a mere beginning. The million-dollar machines they're operating with today are "like the Model Ts of robots," destined for the junkyard, or maybe the Smithsonian, as more sophisticated systems take their place. And today's operations are but the first small steps in a long journey to a boundless future

Long Distance Surgery...

Doctors may no longer make house calls, but they may someday perform telesurgery with the robots they currently use in ORs, providing advanced surgical care to patients hundreds or thousands of miles away.



Control Console

MONITOR: The high-definition display provides an internal view of the remote operation

TOUCH SCREEN: A surgeon can adjust the range of robot-arm motion relative to the movement of his hands

At the Controls

- Tremor-proof hand controls eliminate the effects of shaky fingers

- The surgeon can adjust the robotic camera with his voice
- A foot pedal locks the controls, preventing accidents

Doc to Bot

Surgical tools on the robot replicate the movements of the doctor's hands on the control instruments in front of the console

Message Courier

Fiber-optic cables carry the surgeon's commands to the remote robot and attending surgeon. But long distances can create a dangerous signal lag between surgeon and robot.

where, says Boyd, "the only limitation is going to be people's imagination."

Robotic surgery is a reality. Today, less than three years after the first systems reached the market, more than 400 surgeons around the world are using surgical robots to fix hearts, remove gallbladders, repair fallopian tubes and remove prostates, among other procedures. Nearly bloodless and almost eerily precise, robosurgery makes some of today's standard operations seem nearly as quaint and crude as the early days of neurosurgery in the 1880s, when doctors operated in street clothes and scooped out brain tumors with their fingers. The pioneer robosurgeons are establishing the ground rules for the nascent field, figuring out the best way to use the technology. Practical by nature, disciplined by training, they are hyperfocused and locked into the present, making their way methodically through each operation. But, like Boyd, they are also dreamers, looking ahead to a time when almost anything will be possible, even long-distance surgery.

Robosurgeons don't have to wash their hands before they operate. The robosurgeon sits at a console a few feet from the operating table, watching a color video monitor and manipulating two control instruments. A computer links the controls to instruments held by robotic arms, which do the actual cutting and sewing inside the patient. The monitor is connected to a tiny camera that is held inside the patient by the robot, enabling the robosurgeon to see what he's doing. The instruments and camera enter the body through incisions as small as the width of a pencil. A second surgeon, scrubbed and gowned in traditional fashion, is at the table, changing the robotic instruments and ready to take over in the event something goes wrong.

"Scale means nothing to the machine," says Dr. Eugene Grossi, director of the Cardiovascular Research Laboratory at NYU Medical Center in New York City, as he conducts a demonstration of the Zeus Robotic Surgical System that he and his colleagues use to repair damaged heart valves. (The Zeus, manufactured by Computer Motion, and the da Vinci, made by Intuitive Surgical, are the two main robotic surgical systems currently in use.) What Grossi means, and enthusiastically explains while deftly using the robot to tie knots barely visible to the naked eye, is that surgical robots have built-in features that make them ideal for minimally invasive microsurgery. A computer program filters out the natural tremor that afflicts even the best surgeons. "I can have five Starbucks and be rock steady," jokes Boyd. Another program scales down the surgeon's motions, so a two-inch movement of the control instrument becomes, for example, a two-millimeter movement of the instrument inside the patient's body. It can also amplify range, so a 45-degree twist of the control becomes, say, a 90-degree twist of the operating instrument. And tiny endoscopic cameras with up to 25X magnification give robosurgeons microvision far greater than conventional surgeons using magnifying eyeglasses.

It's too soon in the history of robosurgery to say for certain exactly how or how much the high-tech operations benefit patients. At this point, the primary benefit seems to be less trauma to the body because of the minimally invasive procedures. This feature, which is also a benefit of laparoscopic surgery (in which surgeons stand at the table and manually

...The Game Plan

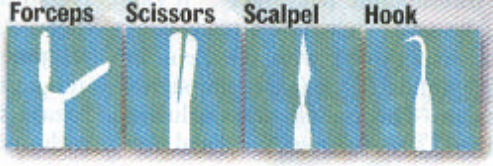
Once technical problems and regulatory issues are resolved, doctors will test the telesurgery on a simple procedure like a gallbladder removal.

The Surgery

- The on-site physician changes surgical attachments as requested by the distant doctor
- The robot arms operate through incisions as small as the width of a pencil
- Recovery time is shorter because of the minimally invasive procedure

Robot Tools

The robot can be fitted with about 40 surgical attachments used for clasping, cutting and suturing



Magnified View

The camera can zoom in 25x to enlarge hard-to-see features

operate long instruments through tiny incisions), usually results in faster recovery time. Boyd's robotic bypass patients spent an average of 2.8 days in the hospital after surgery, compared with an average of 6.8 days for patients undergoing conventional bypass. Such reduced hospital stays represent substantial savings for any health-care system and may prove to be one of the long-term benefits of robosurgery. Boyd says his patients also required one tenth as many blood transfusions and had far fewer post-op episodes of irregular heartbeat than conventional patients.

RIGHT NOW IN the United States there are seven clinical studies of robotic surgery systems underway, five involving the Zeus and two involving the da Vinci. Both systems have full clinical approval in Canada and Europe, where the regulatory environment is less constraining. Heart patient Richard Rome already knows everything he needs to know. "I would recommend this to anybody," says the 50-year-old photographer from Lynbrook, NewYork. "I feel great; my energy levels are awesome." Rome had the faulty mitral valve in his heart repaired last summer by Dr. Stephen Colvin, chief of cardiothoracic surgery at NYU Medical Center. "I didn't feel like having my chest bone cracked if I didn't have to," says Rome. He was out of the hospital in four days, walking in a week and cutting his grass in three weeks.

Perhaps the most intriguing aspect of robotic surgery is the potential for telesurgery—performing operations over long distances. "As soon as you're eight feet away you could just as easily be 80 feet or, with fiber-optic cable, 8,000 miles," says Boyd. Long-distance robotic surgery has been proposed as a way to treat patients in remote locations, such as Antarctica, or in more populated parts of the world where surgeons are scarce. In the latter case, a regional surgical center would be set up and outfitted with the working end of a robotic surgery system. Telesurgery faces lots of obstacles, including the technical problem of signal lag, those critical milliseconds between the movement of the control instrument and the movement of the operating instrument. Any delay exceeding 200 milliseconds, which can happen when the signal travels long distances, is considered a risk to the patient, since it decreases the surgeon's control. There are other questions as well. Is it ethical for a surgeon to operate on a patient in another city, or even another country, with no way to physically intervene if something goes wrong? And if something does go wrong—power failure, loss of signal transmission—who will the patient blame, and sue? The surgeon? The company that made the robot? The company that operates the communications system, the phone lines or cable? Can a surgeon operate by long distance in a place where he isn't licensed?

PHOTOGRAPH BY THOMAS HOEPKER

FROM A DISTANCE: Robots are changing the way surgery is performed. Seated at a control console, Dr. Eugene Grossi demonstrates the Zeus system at NYU Medical Center.

One person who thinks about these thorny issues is Dr. Michel Gagner, chief of laparoscopic surgery at Mount Sinai Hospital in New York City. Gagner is working with Prof. Jacques Marescaux at the University of Strasbourg in France on plans to perform transatlantic telesurgery. "It can be done," he says. They have already conducted an experiment with the Zeus in which they simulated a transoceanic signal transmission. "The results were conclusive and positive," says Gagner. The legal and regulatory issues are daunting, and Gagner cannot say when, or if, they will be able to carry out their plans. But he is confident about the equipment. "If you don't do anything crazy with the machine, nothing crazy is going to happen on the other end," he says. "The output is going to be exactly what you put in."

As their specialty evolves, robosurgeons are more likely to find themselves assisting or overseeing other surgeons from long distance, rather than operating themselves. In one scenario, the robosurgeon of record (and a scrubbed assistant) is at the console in the OR with the patient while the teacher or specialist observes and advises from another location via his or her own control console. If the robosurgeon on site is doing something wrong, or having difficulty, the specialist can help him through the crisis. In another, more complex example, the specialist would have the power to override the on-site surgeon's console and take over the procedure.

Doctors in the field are confident there will be other extraordinary developments in robotic surgery in the next 10 to 20 years. The key to many of them is "data fusion," which will merge the robotic surgery systems with diagnostic technologies, like MRI and CT scan. "Surgeons are used to seeing with their eyes, but there are other ways to see," says Grossi. He expects robosurgeons will eventually operate while looking at real-time diagnostic images of the patient's anatomy, and that the instruments will also have haptic feedback, a computerized sense of touch, so the robosurgeons will be able to "feel" the tissue they are operating on. Data fusion will also enable robosurgeons to load a patient's diagnostic imagery into the robot and practice the operation in advance.

Though he dreams of performing transoceanic telesurgery, Gagner sometimes worries that the distance between surgeon and patient has gotten too great. He recalls the old way of removing gallbladders. "You put your hands in the patient's body," he says. "And they spent seven days in the hospital recovering, so you really got to know them." And as he speaks, another future development suddenly looms, an affliction unique to robosurgeons, an occupational hazard they'll just have to learn to deal with—nostalgia for the human touch. ■