GOOGLE'S LARRY PAGE LOOKS AHEAD by Miguel Helft

PAGE 50

FORTUNE

THE FUTURE ISSUE

WILL.I.AM: WHY COKE, INTEL, AND OTHERS LOVE TO PICK HIS BRAIN

by Daniel Roberts

PAGE 66

Plus: MEET THE WORLD'S THIRD-RICHEST MAN

PAGE 74

THE HEALTH CARE CEO WHO LOVES OBAMACARE

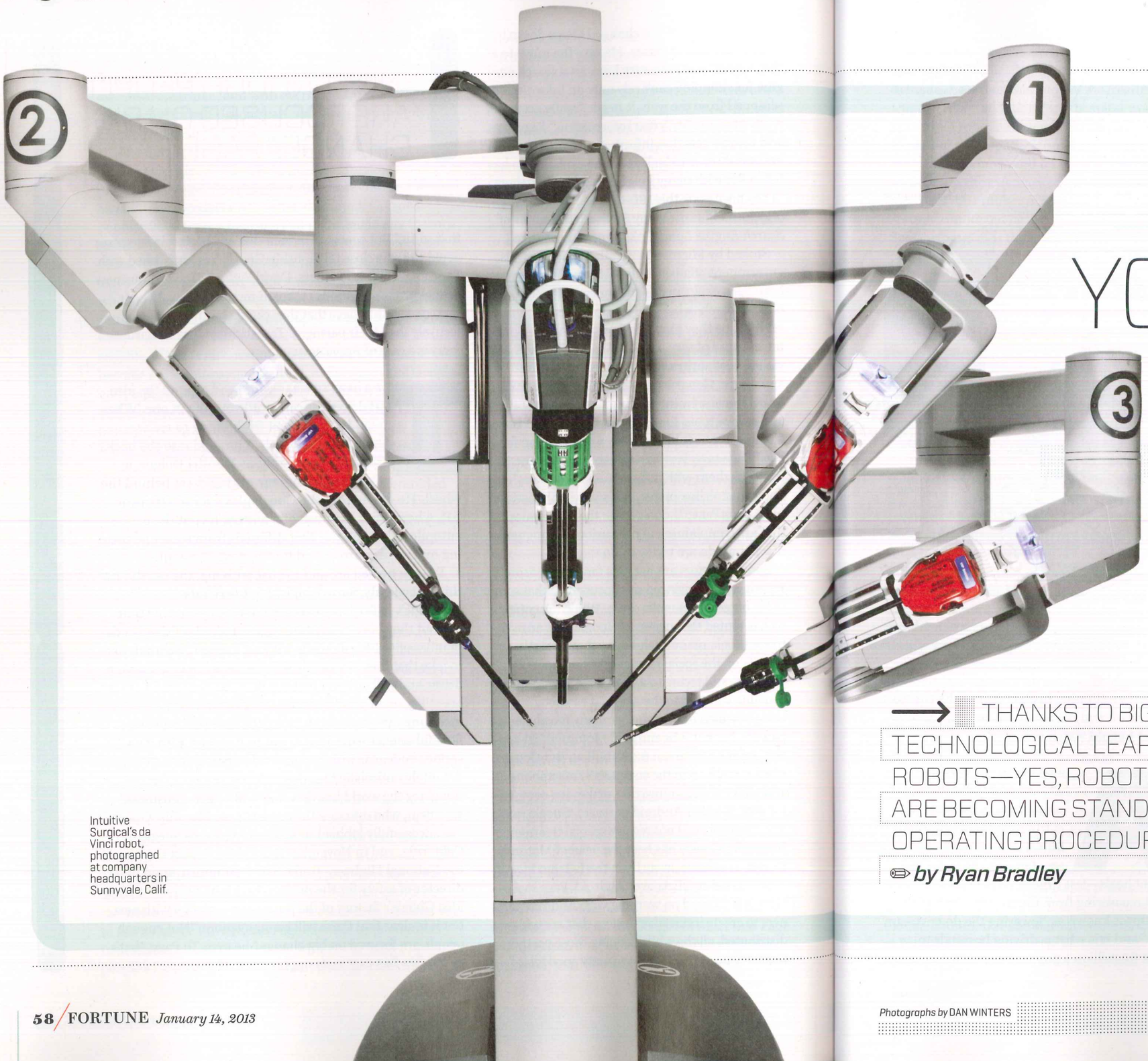
PAGE 80

THE RISE OF MACHINES

Drones, Surgical Robots, Supercomputers

PAGE 49

JANUARY 14, 2013
FORTUNE.COM



Intuitive Surgical's da Vinci robot, photographed at company headquarters in Sunnyvale, Calif.

MEET YOUR **NEXT** SURGEON

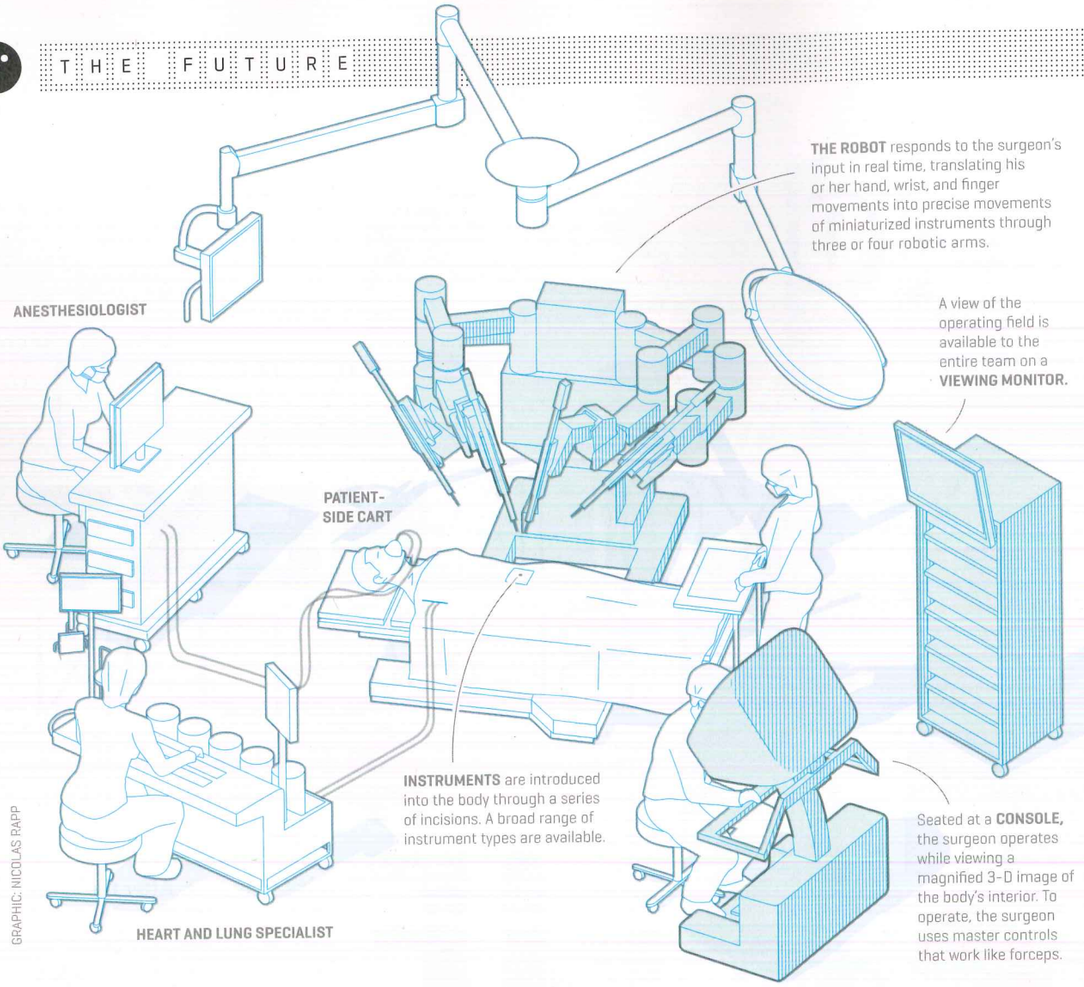
→ THANKS TO BIG TECHNOLOGICAL LEAPS, ROBOTS—YES, ROBOTS—ARE BECOMING STANDARD OPERATING PROCEDURE

✏ *by Ryan Bradley*

IF **RANK CLEMENT** glimpsed the robot only once. After the operating room attendant finished shaving his chest, she asked him if he wanted to be knocked out or if he would like to see the machine that would soon be inside him, navigating the space beneath his rib cage, cutting and cauterizing, and then sewing two of his arteries back into his heart. Clement wanted to see the machine. It was draped in plastic, its four jointed arms folded back toward its body. In a few months Clement would celebrate his 71st birthday, and the idea of submitting to such a device felt futuristic. He was fascinated. Then he felt a warm rush all over—the anesthesia kicking in—and he fell into a deep, drug-induced slumber.

Clement's body disappeared under a blue smock, his chest swelled from the CO_2 pumped in to keep it expanded, and his skin

Photographs by DAN WINTERS



GRAPHIC: NICOLAS RAPP

appeared an unreal yellow from layers of disinfectant painted on pre-op. The surgeon, Eric Lehr, grasped a scalpel and made three quick incisions on either side of Clement's rib cage, the cuts blooming open but hardly bleeding. Lehr placed three metal tubes, called cannulas, into the three wounds, twisting them into the chest until they were planted. An attendant wheeled the robot over to the operating table, positioned it alongside the patient, and took hold of the robot's arms, extending them over Clement while an assistant connected a camera, a cauterizer, and a clasping tool to three of the robot's appendages.

In a corner of the room, some 20 feet from Clement, two consoles the size of refrigerators displayed video feeds from a camera in Clement's chest. Lehr took a seat and leaned forward, staring at one of the screens for a beat before slipping his hands into the controls. Then he offered me a seat at the next console so that I could watch him work.

ADVANCES IN SURGERY usually attempt to ameliorate surgery's essential nature: cutting someone to cure him. The less severe the tissue damage, the faster the patient heals—less time in recovery, less money spent recovering from the wounds. In health care this is known as "lowering the downstream costs," and it is what is driving hospitals to invest $2 million a pop for surgical machines.

Surgeons—a particularly exacting bunch—have adopted robotics in droves. While physician buy-in is crucial, patients are also driving demand. Last year the *Journal for Healthcare Quality* reported that 41% of hospital websites advertised robotic surgery; of these, 37% did so on their homepage. Hospitals with robots are pulling in more and more patients, and in some cases, the existence of the robot actually increases the number of surgeries performed. A study conducted by the American Cancer Society found that the number of radical prostatectomies has "risen substantially" in the past decade, and patients travel great distances to be operated on with a robot. Today, four out of five prostatectomies are performed with a robot. The result is an industry at an inflection point. Robots have arrived, and hospitals, doctors, and patients are scrambling to adapt to this new technology.

The most popular of such surgical robots—the one used on Frank Clement during his operation last fall at Swedish Medical Center in Seattle—is the da Vinci. Patented and manufactured by Intuitive Surgical—a publicly held Silicon Valley–based company that posted revenue of $1.76 billion, a 24% increase over 2010—the system costs up to $2.3 million. It includes the console, the robot, and a tall server bay that connects them. It is, in more ways than one, the iPhone of its category: Surgeons say it is easy to use and elegantly designed. And like iPhone maker Apple, Intuitive has developed a closed model: Its software and hardware are proprietary, and the company controls all aspects of the da Vinci's production, bringing new meaning to the term "closed operating system."

Despite its dominant position (Mayo Clinic alone has seven machines), its success is far from assured. Another, just-formed robotics company's robot offers a competing vision of what might be possible in the operating room of tomorrow. Made by Applied Dexterity, a startup, and called the Raven, it is a smaller, cheaper experimental machine built on an open-source model, which makes it hackable, and more like Google's Android platform for mobile phones. Put another way, innovation at Intuitive tends to come from within the company, while nearly anyone can invent, add to, and study the Raven. Both models are pushing the field into previously unimagined territory. The $50 billion question for the future of surgery: Will there be (operating) room for more than one kind of robot?


A surgeon performs a hysterectomy with the da Vinci system.

CLEMENT'S CHEST CAVITY looked like the vast landscape of an alien planet—or that's how it appeared on one of Lehr's consoles. Occasionally, in the distance, another planetoid form came into view—rising and falling on the horizon. I asked Lehr what it was. "That's the left lung," he replied.

Lehr, who has been a cardiac surgeon at Swedish Medical Center for 18 months, navigated the camera toward the heart's casing. An artery emerged, a branch covered in a thick layer of pink and white jungle vines. The robot's tools—a cauterizer and forceps—were huge in the foreground. The forceps tugged at the vines, then the cauterizer swooped down and delicately fried bits of Clement's flesh. Tug, swoop, sizzle, tug, swoop, sizzle—again and again until the branch began to come free of the fleshy vines.

I leaned back, away from the screen, and watched Lehr's hands during this deft work. His delicate gestures called to mind a nun with a rosary. From his motions, billions of

bytes of information traveled through thick cords running from the consoles to the server, and back out and into the robot, which was moving its instruments mere millimeters.

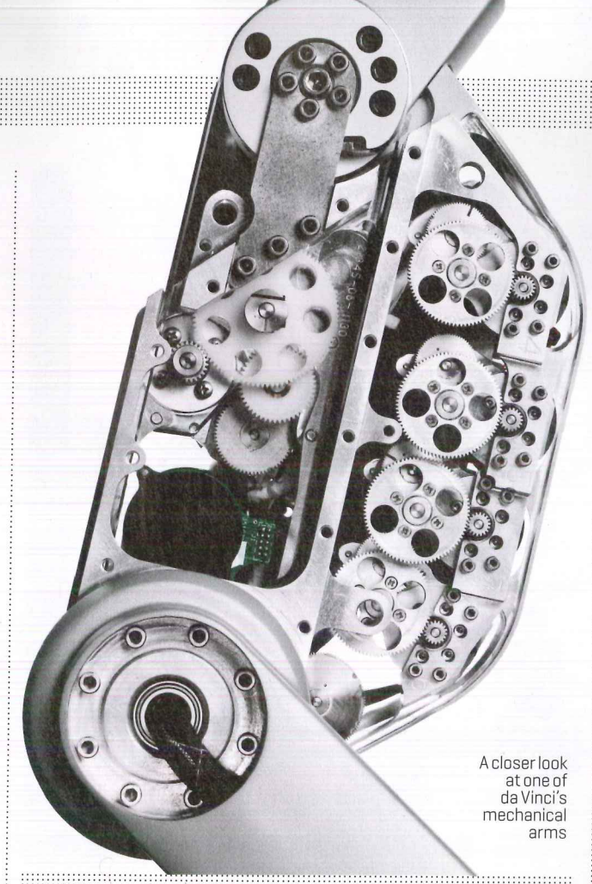
THE DA VINCI is an exceptionally intuitive system. In a recent study, researchers found that children who are adept at videogames are even better at using the system than most surgeons new to the interface. Seated at the console, a user hooks his thumb, middle finger, and forefingers through two controllers. The controllers move in every conceivable direction. Tapping on one of seven pedals engages different tools and controls the $63,000 endoscopic videocamera, which gives users a sense of depth. In place of tactile information, surgeons are immersed in stunning visuals and a remarkable sense of moving through space inside the body.

Intuitive builds all its robots at its Sunnyvale, Calif., facility. The company's CEO, Gary Guthart, is a mathematical engineer who used to work nearby at NASA's Ames facility, where he helped design interfaces for fighter pilots. Robotic systems for surgeons aren't so different. In both, he says, you are dealing with many sources of data, all possible distractions from the task at hand, or perhaps vital to it. And surgeons, like fighter pilots, must make snap decisions that can have fatal consequences. "There is a cognitive task that is time-critical, and a physical task," Guthart says. "It is a fantastically deep challenge."

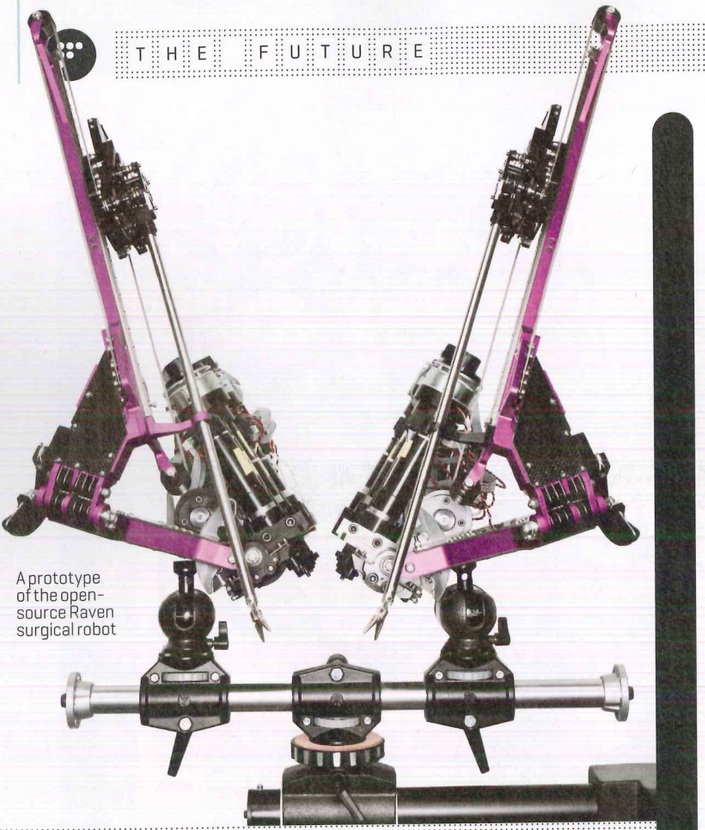
At Intuitive, the research team is constantly developing new techniques for the da Vinci. The company has just released what's called a single-site system, which uses curved tools to, as its name suggests, enter patients through a single incision in the bellybutton. A new project uses fluorescent imaging to identify cancer cells. On the da Vinci interface, the tumors appear bright green, making it easier for surgeons to identify and remove them, and harm little else.

Catherine Mohr, who oversees a small research team at Intuitive, says she believes robots will one day be used to treat ailments that are not traditionally considered surgical diseases. When you perform a gastric bypass, for example, you rid a patient of Type 2 diabetes. Hypertension can also be cured this way, via surgery. There are even experiments to fix forms of addiction via surgery. "What if, in the future, we can go in and tinker with the machine?" she says. "Do a little procedure, a little incision, and a lifetime of medical costs simply goes away."

Mohr is one of a few dozen people in Intuitive's research centers working on R&D to develop new products and users for the da Vinci. (Total R&D budget: $140 million a year.) Her competition isn't so organized. The Raven was developed out of robotics labs at the University of Washington and the University of California at Santa Cruz by two engineering professors who initially sought to understand the "language of surgery" by tracking physicians' movements. When the pair were unable to gain access to Intuitive's data, they set out to build their own machine. The result is smaller than a da Vinci—it can fit on an office desk—and sells for $300,000. At the UW lab it's hooked up to a Microsoft Kinect—the $150 motion-sensing device for gaming—to create a real-time 3-D map of the surgical area. A team at Harvard is using imaging and mapping software



A closer look at one of da Vinci's mechanical arms



A prototype of the open-source Raven surgical robot

that will allow the Raven to operate on a beating heart.

This loose federation of research projects underscores Raven's potential: It's a platform that anyone, from medical researchers to videogame enthusiasts, can build on. Its developers don't have to think about what's commercially viable, and so they can push the limits and dream up unexpected uses for the machine. At Johns Hopkins, for example, engineers are using Raven (and machines like it) to build systems that will soon "operate" on broken satellites. It is possible that even if Raven equipment doesn't find its way into hospitals, the research it enables will become commonplace in operating rooms.

LEHR HAD REACHED his favorite part of the surgery: He was grafting Clement's artery back to his heart—a stitch through the branch, followed by a stitch through the heart, again and again. When Lehr was done, he checked the blood flow, pinching the other still-open and unattached artery again and again as drops burbled out. He was concerned. There should have been more blood. He left his station and called the head cardiologist to discuss the situation. It was a little more than six hours since Clement had gone under. The average non-robot-assisted coronary bypass lasts about four hours. After Lehr hung up, he marched over to the table, an orderly entered with more tools, and suddenly the room was alive with activity. I sat and watched from a distance as the attendant removed the robot and the cannulas. Then I heard a loud rip, like a sword emboweling a couch cushion. When things settled, Lehr called me over.

He stood over Clement's chest, and I wedged behind a plastic partition a few feet from Clement's head, where the anesthesiologist worked. The chest was open in the middle, the ribs and skin held back with big metal clamps. "I told the patient going into this that there was a 15% chance of us having to open him up," Lehr said. To double-check the blood flow and perform the second bypass, Lehr had decided to go the traditional route. The ripping sound was Clement's sternum being sawed open so that Lehr could finish the procedure with his hands.

We waited beside Clement as his body warmed and his heart began to beat. Staring into his open chest, I found myself in awe of a different machine: the human body.

Clement woke up in the intensive care unit late that night. His wife was with him, and she told him there had been a problem, that they had had to open him up. Lehr came in and explained what had happened and why. "When I found out," Clement says, "it was just like, 'Oh jeez,' you know? I had more holes in me than a normal person would and, yeah, it was painful."

Clement celebrated his 71st birthday on Dec. 22. Aside from his heart troubles, he is a healthy man. Three weeks after the operation, he is upbeat. "I feel much better now," he says. He can walk for about 30 minutes. Before the surgery, Clement walked 45 minutes to his health club, where he spent about three hours lifting weights and taking yoga and spinning classes. Then he walked 45 minutes back. It was at his health club Clement first heard about the robot. "A guy at the club had his prostate removed by one," he says. "And another recently had his spleen sucked out through his bellybutton. Would I recommend surgery with a robot? Given all that happened? Oh, yes—definitely. It's the new, modern way." F