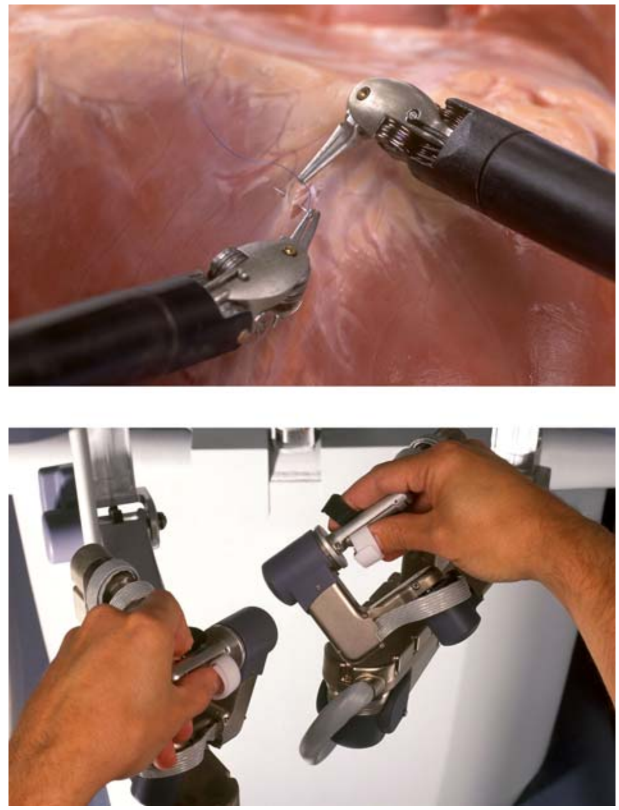
National Institute of Biomedical Imaging and Bioengineering

Adding Feeling to Robot-Assisted Surgery

Robot-assisted surgery moves minimally invasive surgery to a new level. Patients have less pain and scarring, reduced bleeding, and faster recovery times. Unlike conventional laparoscopic surgery, the robotic system provides unprecedented highly magnified, three-dimensional views of the operating field, eliminates tremors in the surgeon's hand movements, allows for greater freedom of motion for instruments, and all motion is intuitive – when the surgeon directs an instrument in a particular direction, it moves in that direction.

What's missing is a sense of touch. When surgeons operate on their own, their hands provide important tactile or haptic feedback. They can tell if their stitches are too tight and may damage tissue or if they're just right. Over the last decade a number of research groups have started investigating how to incorporate tactile feedback into robotic surgical systems. One team at Johns Hopkins University in Baltimore, MD, is partnering with Intuitive Surgical, Sunnyvale, CA, makers of a robotic system, the da Vinci Surgical System, to modify the system so that surgeons can experience the fine tactile feedback they get when operating with their hands.



Robotic surgical systems can improve patient outcomes, but surgeons can't feel the sutures or tissues involved. Johns Hopkins University researchers are developing visual feedback and force sensors to create a robot-assisted surgical system that allows surgeons to better experience the forces occurring within the operating field. *©2006 Intuitive Surgical, Inc.*

"Haptic feedback is necessary for a sense of telepresence – the feeling that there is a direct connection, not a robot, between the surgeon and the patient," says Allison Okamura, an associate professor of mechanical engineering at Hopkins and principal investigator on a 4-year grant from the National Institute of Biomedical Imaging and Bioengineering.

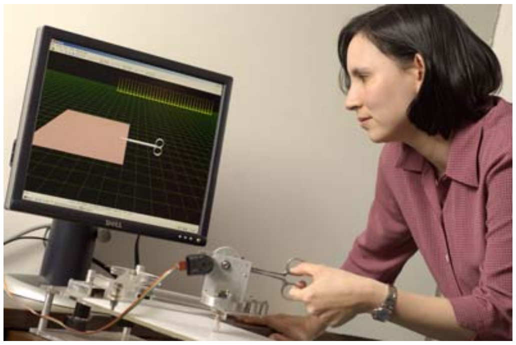
Although surgeons who currently use the da Vinci system cannot feel tissues and sutures, they do use their eyes to estimate the tightness of a suture knot. Building on this visual feedback, the Hopkins team is developing a display that overlays the 3-D view of the operating field. Small dots change color depending on the force used. A red dot indicates too much force, and a green dot, just enough. "This approach could get to the operating room faster [than force sensors] and it won't affect the robot's control system," says Okamura.

A Role in Cardiac Surgery

Although all fields of surgery could benefit from haptic feedback, cardiac surgery may have the most to gain. Okamura's group is working closely with Johns Hopkins cardiac surgeon David Yuh to create a robotic system that delivers the touch sensitivity required for conventional heart surgery. Because of the types and large number of sutures used, the delicate tissues involved, and the need for precise, efficient work, tactile feedback is essential. In lab studies surgeons who receive force feedback work more quickly and confidently, according to Yuh. A robotic surgical system with haptic feedback could mean fewer broken sutures, force that is applied more consistently, and suture knots that hold.

"Some people feel feedback is not important and they use other senses to judge force, but that judgment is not necessarily transferrable to new users of the device," says Yuh. "Without force feedback, subjects are more tentative and this reduces their speed." While the da Vinci robot has U.S. Food and Drug Administration clearance for some cardiac procedures such as mitral valve repair, it is not cleared for all cardiac surgeries. Because patients are often placed on bypass machines, cardiac surgeons have 1-to-2-hour windows to perform their operations. "You can't arrest a heart too long and expect it to come back well," explains Yuh. Retying suture knots several times can erase precious minutes from the clock.

To improve feedback long term, the Hopkins team is exploring the use of force sensors on the robot arms. These sensors could provide direct tactile feedback to the surgeon, but their development presents a challenge. To get to market, the sensors must be biocompatible, able to withstand the body's saline environment and electrical shocks from nearby electrocautery instruments, and hold up in a 150°C high-pressure steam bath during sterilization.



Johns Hopkins University researcher, Dr. Allison Okamura, demonstrates a haptic device that interacts with a virtual environment to display cutting forces to the user. *Courtesy of Will Kirk.*

"The sensors are the sticking point," says Christopher Hasser, director of applied research at Intuitive Surgical and co-principal investigator on the NIBIB grant. "We need a force sensor that can survive the environment and provides value at an acceptable cost." Despite the technical hurdles, Hasser anticipates that if all goes well the sensors may be available within the next 5 years.

Okamura is also interested in modeling the entire robot system to obtain a more accurate understanding of how much force is being applied to the patient. "In particular, we need to know the forces applied by the trocar [instrument portal] in the system," explains Okamura. Using mathematical equations, the team will be able to analyze all of the dynamic forces presented by the robot such as friction and inertia. By subtracting these from the overall model, the team will determine the force applied to the patient. The next phase of study should help illuminate these issues.

Better Surgeon Training

In addition to improving actual surgeries, a robot-assisted surgical system equipped with force feedback could also serve as an important teaching tool. Rather than following the current practice of teaching students on live patients, new surgeons could practice in the lab and be judged objectively on their readiness to perform live surgery. The robot's computer interface allows the system to translate hand movements into data that can assess technical competence. Using computer algorithms that recognize motion, a trainee's movements can be compared to a faculty expert's performance and assessed. "This is an amazing tool to use in academia," says Yuh.

References

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