Technology
PUBLISHED BY MIT Review

Thursday, March 27, 2008

Robotic Guidance for Knee Surgery

A robotic system enables minimally invasive knee replacements.

By Katherine Bourzac

Painful arthritis of the knee can make it difficult to take even a short walk. Knee replacements can give osteoarthritis patients a new lease on life. But some patients, particularly younger ones, don't need the entire joint replaced, and they may benefit from a minimally invasive, partial knee replacement. Patients have fewer complications and faster recovery times following such surgeries, but they're tricky to perform and not routinely done. The robotic guidance system helps orthopedic surgeons create and execute detailed plans for this complex surgery.

The surgical system was developed by MAKO Surgical Corp., of Ft. Lauderdale, FL, and approved by the Food and Drug Administration in 2005. Based on preoperative CT scans, the system generates a 3-D model of a patient's knee, which surgeons use to determine how much bone to remove from the tibia and femur, and where to place the implants that replace inflammed parts of these bones. Instead of removing the bone with a burr saw and working by eye, the MAKO system lets the surgeon manipulate a robotic arm that is equipped with a burr. The surgeon is free to remove bone until she reaches the boundaries prescribed during the planning stages. Haptic feedback creates a wall of resistance if the surgeon ventures outside the planned area, and if she persists, an audio alarm will sound, and the saw will turn off. This helps the surgeon minimize the trauma to the knee and preserve the maximum amount of tissue.

Andrew Pearle (http://www.hss.edu/physicians_pearle-andrew.asp) , an orthopedic surgeon and founder of the computer-assisted surgery center at the Hospital for Special Surgery in New York City, has been performing partial knee replacements with the MAKO system since June. He says that it's possible to perform these surgeries manually, by eye, but it's very difficult. The MAKO system makes this surgery "more precise and reproducible," says Pearle, who has no financial interest in the company.

During surgery, the system carefully monitors the doctor's progress as she works with the robot. Instead of looking at the bone itself to determine whether enough has been removed, the doctor follows her progress on an LCD depicting the bone and the saw position. Bone that needs to be shaved off is shown in green; when too much has been removed, the area appears in red. This allows for accuracy within about two

millimeters.

Crucially, the system also tracks the position of the leg throughout surgery. The leg cannot be immobilized during partial knee replacements because the surgeon needs to adjust and test it to make sure that she leaves the musculoskeletal system in proper alignment. Other robotics systems for orthopedic surgery, including one in use in Europe for hip replacements, are clamped directly onto the bone to make the cuts, so they don't face the problem of movement. Because the MAKO system is not fixed relative to the bone, it must remain oriented even when the patient's leg moves. An infrared camera tracks the position of the robot base and the position of reflective bone screws placed in the femur and tibia in preparation for surgery.

The robotic arm used in the MAKO system is based on one developed in the 1990s in MIT's artificial intelligence lab. "It was one of the first robotic arms developed to work specifically with people," says Rony Abovitz (http://www.makosurgicalcorp.com/08/company/management.htm) , chief technology officer at MAKO. Originally, MIT researchers had it throwing and catching baseballs. The arm is controlled by tension cables and low-friction bearings instead of gears. "This allows the arm to work in a humanlike way," says Abovitz. The arm is very sensitive to force and torque applied by the surgeon, and it feels weightless.

There are two other robotic surgery systems in use in the United States today, both for soft-tissue surgeries. The da Vinci robot (http://www.technologyreview.com/Biotech/17909/) , made by Intuitive Surgical (http://www.intuitivesurgical.com/index.aspx) , of Sunnyvale, CA, is controlled by a surgeon at a distance. It's designed for laparoscopic surgeries such as prostate removal. Another system, for placing catheters in the heart, is also operated from a remote console.

The MAKO system is unusual in that the surgery is performed collaboratively. "The surgeon's hands are on the robot, moving the arm," says Abovitz. Domenico Savatta (http://www.njurology.com/_physicians/savatta.php) , chief of minimally invasive and robotic adult urologic surgery at the Newark Beth Israel Medical Center, says that the MAKO system appears to offer "robotic assistance in a true sense" because it actually restricts the surgeon's movements. Savatta uses the da Vinci system in the operating room, and he says that it doesn't give the same level of feedback as the MAKO system. But the da Vinci robot isn't as specialized as the MAKO system, which is currently only approved for partial knee-replacement surgeries.

As of the end of 2007, 181 procedures have been performed using the MAKO guidance system. The company has patients who've been monitored for up to 20 months after surgery, with good results.

Maurice Ferré (http://www.makosurgicalcorp.com/08/company/management.htm) , CEO and president of MAKO, says that the company does hope to expand the range of surgeries that can be performed with its guidance system, but it's currently sticking with knees. Right now, MAKO's system is approved for replacing only one of the three compartments of the knee joint. The company is currently developing systems for surgeries to replace two compartments at once.
