THE BIG STORY

WITH TECHNOLOGY, BRINGING THE ACL TEAR TO ITS KNEES

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POSTING IN **CITIES**

EXPERTS IN MEDICINE AND ENGINEERING ARE USING NEW TECHNOLOGY TO LEARN WHY ACL TEARS, A DEVASTATING SPORTS INJURY TO THE KNEE, OCCUR –– AS WELL AS HOW TO

PREVENT THEM FROM HAPPENING.

Special Feature: The **Movement** Issue

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(http://i.bnet.com/blogs/kneeinjuries_movement_smartplanet_realgenius_sept2012.jpg)In 1987, Dr. Frances Sheehan-Gavelli was playing rugby for the All Pinks, a club team on Long Island, and watched as a teammate stuck her foot in a hole while running downfield. The woman's lower leg stayed in place, but her upper leg and body rotated about 90 degrees, tearing her anterior cruciate ligament, or ACL, the ligament in the knee that is supposed to prevent this kind of twisting motion. Sitting in her small, windowless office at the National Institutes of Health in Bethesda, Md., she can still remember the fall. "That planting and twisting," she said, grimacing. "It was painful to watch."

Today, Sheehan-Gavelli works as a research engineer in NIH's Rehabilitation Medicine Department and knows more than she ever expected to about knee malfunctions. It may seem unlikely to find an engineer working in rehabilitation, but by teaming up with clinicians and surgeons, she has helped pioneer new ways of looking at knee injuries and pain.

"Clinicians want to treat; engineers want to figure out what's wrong," said Sheehan-Gavelli's colleague, Dr. Katharine Alter, a clinician at NIH and the medical director of the institute's Functional and Applied Biomechanics Section. "Often, what we lose in clinic is, can we explain *why* is this happening? So we're trying to explain the underlying pathology and determine whether we're treating the right thing."

Using some cutting-edge technology, adapting some existing technology and using tools as low-tech as a slow-motion videotape, Sheehan-Gavelli has made significant progress in figuring out the oft-enigmatic knee. In some cases, her research has led her to results that may change the way athletes move on the field. "Our end product," she said, "is, how can you train athletes to protect themselves?"

Innovation in imaging

Long before Sheehan-Gavelli began studying how athletes tear their ACLs, she devised a new way to use an MRI to image moving bones and muscles in the knee. As any of us who have been subjected to an MRI remember, remaining motionless is key during the procedure -- move your hand to scratch an itch and you've blown it. But as a Ph.D.

candidate at Stanford University, Sheehan-Gavelli used Lego plastic toy blocks -- MRI stands for magnetic resonance imaging; metal inside the machine can interfere with its results -- to show that she could adapt an MRI program designed to capture an image of the beating heart for musculoskeletal imaging. (She found the MRI preferable to the CT scan because it doesn't share the same risk of radiation exposure.)

By adapting this cardiac technology, made by GE and Phillips, she essentially tricks the MRI machine into taking moving pictures. She then combines those with a conventional MRI image to create a three-dimensional representation. This allows her to see how the kneecap is moving, rotate the image 360 degrees and ultimately view how the cartilage is wearing and what might be causing the pain.

Today, she uses this dynamic MRI technique for athletes who suffer from chronic knee pain with an unknown cause. "It's not as sexy as an ACL injury, but it can still destroy someone's athletic career," Sheehan-Gavelli said. But while the exact cause remains elusive, she said the ability to create a realistic 3-D model of the cartilage is revolutionary. "It's as if I could open up your knee while it's in motion and see how the bones are moving against each other. Then we see that the kneecap isn't moving correctly, but it may not just be one reason. So we break the patients into groups for the types of therapy that will work best to correct it."

The current *modus operandi* for knee pain is that clinicians treat it based on a theory. "Right now, if you go in and have pain in your knee

and don't know the cause, they will start with general strengthening exercises, maybe even knee braces or taping the patella," Sheehan-Gavelli said. "And if it doesn't improve, eventually they'll treat it with surgery. The biggest thing we'll learn [with the 3-D models] is that we'll get to patient-specific therapy, so we know earlier on who should have surgery and who needs classic therapy."

Sheehan-Gavelli, a fast talker, has a habit of referring to others as "people much more clever than myself," while in the same breath referencing equations and formulas that make one's eyes glaze over. But she also has a talent for replacing theories with numbers. This has brought a new way of thinking to the clinical environment, where there are often unanswered questions.

Sheehan-Gavelli's colleague Alter may, for instance, look at the gait of children with cerebral palsy and note that the left side of a child's body isn't functioning very well. But Sheehan-Gavelli can put numbers on it, compare images of the gait to other gait images and analyze the difference. Using tools such as the moving MRI, she works with patients in clinical trials at NIH to figure out why the knee pain occurs. "I basically had a mousetrap," she said, "and [Dr. Alter] had a lot of mice."

Getting to the root of the injury

ACL tears, while not particularly common in the general population (about 100,000 each year, according to the Centers for Disease Control and Prevention), are more prevalent among athletes (and much more common among women). Medical experts also say they are some of

the most devastating injuries, usually requiring surgery and months of recovery and rehabilitation. The Chicago Bulls' Derrick Rose, for example, tore the ACL in his left knee during the playoffs earlier this year, which caused him to miss the rest of the season. After surgery in May, the recovery time was expected to be as long as a year. Those with ACL injuries often develop osteoarthritis in their knee faster than those without the injuries.

There is nothing new about using a device as low-tech as a videotape to learn how injuries occur and what we can do to prevent them. Decades ago, for instance, there were many more paralyzing compression injuries in professional football caused by “spearing” -- players essentially tackling with the top of their heads. After studying videos to determine that this particular type of tackling was causing the injuries, the NFL made it illegal, resulting in a reduction of paralyzing injuries.

Historically, we’ve understood very little about how ACL injuries happen. There have been plenty of studies that look at the shape and width of bones, but there hadn’t been much focus until recently on the way people were landing and how that was leading to injury.

Around the time that Sheehan-Gavelli was working on her thesis at Stanford, using the cardiac MRI to image moving bones, Dr. Barry Boden, now an orthopedic surgeon outside Washington, D.C., was at Duke University, starting to look at how ACL injures occur. “Seventy percent of these are non-contact injuries,” he said, “so I thought if we had a better understanding of how they happened, we could prevent

some of these injuries."

Several years ago, he began looking at videotapes of NBA and WNBA games during which athletes were tearing their ACLs and comparing them to videos of similar movements that weren't causing injuries. When he slowed the tapes, Boden was able to classify dangerous and safe landing positions. He could see that the injured athletes landed on their heel or flat-footed, and all the non-injured athletes landed on the ball of their foot.

The faulty position was causing a compression injury. It's like jamming your finger into a basketball. Or, to use a different metaphor, it's like the crumple zone of a car, which absorbs the impact of a collision so the driver doesn't have to. Similarly, the human calf muscles are designed to absorb the force of a jump when, say, you dunk a basketball and land on your toes. If you land flat-footed, the impact goes directly to your knees. The theory was that landing flat-footed causes the knee to jam and the femur snaps the ACL.

Boden teamed up with Sheehan-Gavelli to further study these injuries; he provided the gruesome videos of the injuries, and she offered an understanding of the knee mechanics, took measurements and provided statistics. They looked at patients in a standing MRI machine -- in both the safe and dangerous positions -- which offered insight into how the leg is aligned and how gravity affects someone in a fall. Combining that data with the videos, the duo was able to determine how the injury occurs.

"We now understand the forces involved," Boden said. "All that seems

common sense now, but believe it or not, five years ago, nobody was talking about compression injury at all."

So what does this mean? "The whole goal," Boden said, "is if you understand how it occurs, can you prevent it? There are numerous prevention programs out there, and they are all basically teaching people to land in the safe position."

Is prevention possible?

Dr. Bert Mandelbaum, an orthopedic surgeon at the Santa Monica Orthopedic and Sports Medicine Research Foundation and the team doctor for U.S. Soccer, has helped develop the Prevent Injury and Enhance Performance program. PEP consists of a warm-up, stretching, strengthening and plyometrics (fast movements to increase an athlete's speed) to strengthen and stabilize muscles around the knee and hip. In one study among 61 NCAA Division I women's soccer teams, use of the program significantly reduced injuries. The program also has been adapted for amateur and professional players internationally, through FIFA, soccer's governing body. FIFA's Medical Assessment and Research Centre reports that the program has led to a significant decrease in injuries during training and games.

"We know from a biomechanical standpoint that we can train these athletes to keep their legs from internally rotating when they jump and land," Mandelbaum said, taking a break from watching soccer at the Olympic Games last month. "There is a learning to it -- not only for the knee and hip but for the brain --neuroplasticity. It's like playing the piano. After six weeks, we can change the biomechanical variables

and change the brain waves."

Former U.S. soccer goalie Tony Meola, one of Major League Soccer's top goalkeepers, tore his ACL during a training session shortly after he was traded to the Kansas City Wizards in 1999. He was running after a ball and his foot was clipped from behind, causing him to misstep. His left knee snapped back, making a popping sound. "I had already played 11 years as a pro and had never had an injury," he said. "Back then, we were naïve about prevention -- it was all about bigger, faster, stronger."

Today, Meola coaches a girls soccer team on the Jersey Shore. He is using the PEP program, which he said may have prevented the injury he sustained 13 years ago. "You can do the exercises on the sideline as part of the warm-up," he said. "It really is a minimal effort for a huge reward." In his second year coaching this team, there have been no knee injuries.

A pilot prevention program also started this summer during basic training at the U.S. Army's academy in West Point, N.Y. A study of ACL risk factors and injuries was recently completed among 6,000 cadets and midshipmen at the Army, Air Force and Naval academies. The study is one of the few that looks at individuals before an injury, rather than only after the injury has occurred.

Lt. Col. Anthony Beutler, an Air Force sports medicine doctor who is one of the leaders on the Joint Undertaking to Monitor and Prevent (JUMP) ACL project, said those in the military are almost twice as likely to return from deployment with a musculoskeletal injury as a

combat injury, so learning how to prevent them is critical.

“Our evidence so far suggests that people can be taught to move differently,” he said, “and that these programs do work, for ACL and a wide variety of other injuries -- knee sprains, shin splits, stress fractures.

“The concept is simple,” Beutler said. “Teaching people to land softly, toe to heel, not heel to toe. Use your body as God intended you to use it -- keep your knees over your toes and use your knees as hinges. We like things to bend straight, not like corkscrews.”

Sheehan-Gavelli said for all the research findings, there are still various camps when it comes to the cause of ACL tears, and there are still people who question the effectiveness of prevention exercises. Dr. Kevin Shea, an orthopedic surgeon in Boise, Idaho, has conducted a study looking at female high school athletes and found that retraining them doesn't reduce the risk of injury; he said if it’s possible, the retraining may take years, not weeks.

But Sheehan-Gavelli has learned enough -- through her own research and anecdotally -- to believe in the prevention programs and the exercises that may have prevented her teammate’s injury 25 years ago. Today, when she talks to athletes, she tells them to practice landing on their toes. “If you’re falling,” she said, “just let yourself fall.”

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