3-D printing enhances complex orthopaedic surgery of upper extremities

Lisa Lattanza, MD – chief of hand, elbow and upper extremity surgery at the UCSF Orthopaedic Institute at Mission Bay – had seen these cases before.

After a fractured radius at age 7, the boy never healed properly. Over the next five years, the injured radius developed a secondary bow deformity, which blocked motion and prevented the radial head from articulating with the capitellum. The accompanying dislocation and grinding had worn away the radial head – and had become painful.

“Until recently, we probably wouldn’t have been able to fix this, but using 3-D technology and printing, we could model the radius that developed the secondary deformity,” says Lattanza. “The modeling enabled us to make a precision cut in the radius, so we could change the alignment and make sure the replacement radial head was pointing in the proper direction.”

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Innovation is an overused word, but there is no question that, as a profession, medicine is under more pressure than ever before to devise new ways to deliver care. Patients want better outcomes more consistently – and society wants us to deliver those outcomes as efficiently and cost-effectively as possible. These sometimes competing, sometimes overlapping demands drive the work highlighted in this newsletter.

Consider:

- We’ve begun to employ remarkable 3-D technology to do complex reconstructive surgeries of the upper extremities faster and with considerably more precision.

- We are participating in a Medicare demonstration project aimed at creating a more efficient joint replacement process.

- At our sports concussion clinic, we’re implementing the latest concussion protocols as part of an interdisciplinary team that is protecting athletes from lasting brain injuries.

- Our foot and ankle surgeons are pioneering procedures that often improve the results for complex deformities and misalignments.

- Finally, we are among the few centers in the country doing an exciting new fusionless spine surgery that has the potential to “cure” scoliosis.

We undertook each of these innovations with an eye toward thoughtfully meeting the demands of this remarkable moment in health care. By working closely with our community partners to extend these services to our patients, we are among those forging a path to a much healthier future.

Thomas Parker Vail, MD
Professor and Chair
Department of Orthopaedic Surgery
Lattanza is one of only a few surgeons nationwide using the 3-D technology, which fosters an innovative collaboration between surgeons and engineers to correct complex congenital and post-traumatic deformities in the upper extremities of both children and adults. “It makes the surgery more predictable, faster and more accurate,” she says.

**How It Works**

When an injury isn’t set correctly or doesn’t heal properly – or when a patient has a congenital deformity – the result can be a dislocated joint or misalignment that restricts motion. This puts the joint at risk for wearing out prematurely and becoming painfully arthritic.

“In the past, for complex cases, at best we would make a plan on paper and with X-rays, but sometimes this wasn’t possible due to the 3-D nature of the problem,” says Lattanza.

Now, however:

- Surgeons can do a 3-D computed tomography (CT) scan of the injured area, along with one of the normal hand, wrist or arm – and send the scans to Materialise, a 3-D printing company, which uploads the scans to its system.
- The surgeon and engineers from the company have a virtual meeting, where they view the scans to (a) plan one or more osteotomies and (b) choose appropriate fixation devices. The meeting usually lasts about a half hour per patient.
- The engineer finalizes the drawings that allow for precise cuts and placements of the fixation implants.
- The technology “prints” out 3-D versions of the bones, as well as guides and jigs that ensure proper placement of a standard plate and screws used to correct the deformity.

“The osteotomy jig tells us where to drill the holes for the plate and where to cut the bone,” says Lattanza, who in the past year has done multiple cases using this approach and says the surgeries usually take about an hour. When she turns the bone and the holes align, she knows she has corrected the deformity. “It’s all very exciting,” says Lattanza. “Now we can precisely correct complicated deformities of any long bone in the upper extremity that previously was difficult or impossible to correct – and we can use the 3-D modeling to gain a better understanding of how to treat these deformities in the future.”

**Dr. Lattanza can be contacted at (415) 353-2808.**

(1) Preoperative lateral X-ray of both bone forearm fracture malunion on the right side. Notice the abnormal bow of the radius. (2) Virtual image of radius showing the normal side superimposed on the injured side. (3) Intraoperative 3-D printed custom jig to guide plate placement and osteotomy for correction of bow. (4) Radius planned “virtual osteotomy correction” showing that injured and normal radii now completely overlap. (5) Postoperative correction of the radial bow and reduction of the dislocated distal radioulnar joint.
Private and public health care reform efforts have organizations across the country scrambling to meet the clear demand for higher-quality, lower-cost care, says Kevin Bozic, MD, vice chair of the UCSF Department of Orthopaedic Surgery.

“At UCSF, we’re focusing on better measurements of cost and outcomes, better coordination of care across providers, implementation of ‘lean’ methodology and participation in new payment methodologies,” he says.

Medicare Demonstration Project
Specifically, Bozic and the Department of Orthopaedic Surgery are spearheading a pilot program as part of a Medicare demonstration project.

“For more than two years, a team of representatives from anesthesia, nursing, case management, orthopaedic surgery, pharmacy and physical therapy has been working with hospital administration to analyze care episodes for hip and knee replacement and eliminate those aspects of care that don’t add value, because nobody benefits from repetitive, unnecessary steps,” says Bozic. “The goal is to improve outcomes and patient experience and reduce the overall cost of care for these potentially life-altering procedures.”

To help in the effort, the team adapted the lean methodology to the hospital setting. Lean was originally used in manufacturing to improve processes by identifying and removing waste in a system.

“We began by mapping all of the care patients receive – from referral, through evaluation in our office, hospitalization and care after they leave the hospital – so we could understand exactly how a patient flows through our system,” says Bozic.

Next, the group redefined the care process so each of the caregivers who touch the patient does everything possible to coordinate care with the goal of optimizing patient outcomes and experience – and reducing cost.

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According to the Centers for Disease Control and Prevention, each year at least 1.7 million Americans sustain a traumatic brain injury (TBI); about 75 percent of those are concussions or other forms of mild TBI. While many of these individuals do not suffer lasting complications, far more do than was previously believed.

Early diagnosis and treatment by a team of experts is the best way to avoid such damage, says sports medicine physician Carlin Senter, MD, of the Bay Area Concussion and Brain Injury Program at UCSF.

“It’s best if concussed athletes are seen by physicians who understand acute sports concussion and postconcussion syndrome and who can put a tailored treatment plan in place as soon as possible after injury,” she says.

Precise Diagnosis, Tailored Protocols
The program at UCSF, for example, deploys a team of nationally recognized experts in:
- Sports medicine
- Physical medicine and rehabilitation
- Neuropsychology
- Neuroradiology
- Neurology
- Neurosurgery
- Physical therapy

Located at the UCSF Orthopaedic Institute at Mission Bay, the program builds on the UCSF Department of Orthopaedic Surgery’s PlaySafe Program, which works with school districts and athletic trainers across the San Francisco Bay Area to treat and raise awareness about concussion and brain injury. Sports medicine experts and leading-edge imaging are available five days a week to evaluate and triage most concussions, as well as to do baseline neuropsychological testing for high school athletes.

Senter notes the majority of patients who are diagnosed promptly after their injury and who follow up-to-date, evidence-based protocols for sports concussion will enjoy a full recovery, usually within a month or two.

Treatment of sports concussion involves guiding patients through a recovery period of physical and cognitive rest. Clinicians work closely with patients, families – and, sometimes, teachers – to ensure they implement the

WHEN TO REFER
Consider referring your patient to the Bay Area Concussion and Brain Injury Program at UCSF if he or she has suffered a blow to the head, neck or body and is experiencing one or more of the following:
- Confusion
- Difficulty concentrating or remembering things
- Dizziness
- Headache
- Insomnia or excessive sleepiness
- Nausea
- Problems with balance or coordination
“The pain and functional challenges posed by complex foot and ankle problems often dramatically affect patients’ quality of life,” says Kirstina Olson, MD, chief of foot and ankle surgery at the UCSF Department of Orthopaedic Surgery. “But advances in components and surgical techniques are enabling us to better address these challenges.”

She says the problems – deformity and misalignment, accompanied by pain in the ankle, hindfoot or forefoot – are typically sequelae of poor surgery or injury or are attributable to changes in adults that progress over time. Many of these cases demand innovative solutions.

**Plantar Plate Repair**

“The forefoot – particularly the instability that occurs when the second toe rises and crosses over the great toe – is an extremely challenging area because patients want to walk pain-free but with a cosmetically acceptable result,” says Michael Coughlin, MD, also of the UCSF Department of Orthopaedic Surgery and chief editor of Mann’s Surgery of the Foot and Ankle, 9th Edition (Mosby, 2014).

Frustrated with previous surgical solutions, Coughlin was among those who redefined the evaluation and treatment of this condition and came up with a unique plantar plate repair. In this procedure, the surgeon makes an incision and pushes the metatarsal back by cutting it, before repairing the deficient ligament.

“IT brings the toe back to where it was, and the toe is aligned and pain is dramatically reduced,” says Coughlin.

**The Ankle and Hindfoot**

In the ankle, arthritis can be among the most vexing problems. Traditionally, many surgeons have opted to fuse the joint when the arthritis is particularly bad. The procedure eliminates the pain but, of course, limits motion and causes problems when patients need to walk on slopes or on stairs.

In the last 15 years, however, improvements in ankle replacement procedures have enabled surgeons to avert fusion by realigning the foot and replacing the ankle joint at the same time or in stages.

In the last year, the Scandinavian Total Ankle Replacement (STAR Ankle) system – which recently received FDA approval in the United States and which Coughlin helped introduce here – represents an especially important advance. It is the only three-part, uncemented ankle approved for use by the FDA.

As for the hindfoot, which is often the site of tendon and joint disorders that make walking difficult and unstable, Olson says restoring normal ambulation involves realignment, transferring tendons and stabilization. “Our familiarity with different choices of treatment and the experience we’ve developed over three decades is what helps us fit the right procedure to the right problem.”

Dr. Olson and Dr. Coughlin can be contacted at (415) 353-2808.
“Traditional scoliosis treatments are good, but not yet great,” says Mohammad Diab, MD, of the UCSF Department of Orthopedic Surgery.

“Bracing and fusion improve the condition, but both have drawbacks,” he says. Fusion takes away motion and irreversibly alters the function of the spine, while long-term bracing inflicts psychological costs, as Diab and his group recently demonstrated in a multicenter study.

In contrast, surgically tethering the spine modulates spinal growth and may allow for correction of scoliosis — something bracing cannot do — while maintaining the motion that fusion eliminates.

Diab is one of a few surgeons nationwide piloting a new fusionless tethering surgical technique, which he believes can be a better solution than anything currently available — and may even cure the condition.

Beyond Vertebral Body Stapling
A decade ago, Diab led a group of surgeons at UCSF Benioff Children’s Hospital in a study of the biomechanical effects on the spine of vertebral body stapling (VBS), which involves inserting staples across the growth plates of adjacent vertebrae. The procedure was a significant advance, but Diab was not fully satisfied, principally because the stapling technique was not viable beyond a certain age and curve magnitude.

In the last two years, he has turned to a screw-and-cable technique, in which he places titanium screws into the vertebral bodies on the convex side, where they integrate with surrounding bone via a hydroxyapatite coating. A flexible cable (polyethylene terephthalate) connects the screws. The cable resists stretching in the direction of convex growth but allows opposite motion as well as anterior and posterior motion.

“This stops curve progression and, if there is enough growth remaining, growth of the concave side will allow the curve to correct,” says Diab.

A Menu of Improved Options
The standard of care at UCSF is now:

- Monitor for progression any child with scoliotic curves between 0 and 30 degrees.
- After careful assessment, offer:
  - VBS to most children under age 10 with a curve between 30 and 39 degrees.
  - The screw-and-cable technique to a child age 10 or older with a curve between 40 and 50 degrees and open triradiate cartilage; girls should be premenarchal.
  - Spinal fusion surgery for a child with a curve over 50 degrees.

The fusionless operations take about six hours, with surgeons reaching the vertebrae through incisions in the chest or flank. Children typically get out of bed the day after surgery. Before discharge, they receive a custom spine brace, which they wear for three months to allow the implants to lodge securely in the vertebrae. Most return to unrestricted activity after a three-month check-in but are followed in annual visits through maturity.

“These are invasive procedures,” says Diab, “But spine surgery in the chest is well-established and relatively safe in experienced hands…. To date, we’ve had excellent success with no significant complications…and this is a one-time thing that can make a child brace-free for his or her entire childhood. That has incalculable value, particularly during the critical years around puberty.”

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Piloting leaner, better hip and knee replacement strategies

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Bundled Payment Provides Financial Incentive

The efficiency incentive is a so-called bundled payment, where all UCSF providers (hospital and physicians) receive a single payment for each episode of care for hip and knee replacement patients, beginning with the index hospitalization and extending through 30 days postdischarge; there is no additional payment for rehospitalization. The group decides how to divide that bundle among themselves – and all benefit if they efficiently achieve their goals.

Moving forward, the hope is to engage skilled nursing facilities (SNFs) and other posthospital providers in the bundle.

The team has been accepting bundled payments from Medicare through the Bundled Payments for Care Improvement (BPCI) initiative only since Jan. 1, but early outcomes are encouraging. “We’re definitely seeing improved patient satisfaction and a reduction in the number of patients being readmitted to the hospital. And we have much greater communication among providers across the entire care episode,” says Bozic.

In addition, as a founding member of the California Joint Replacement Registry (CJRR), the department is gathering data on patient-reported outcomes, pain, function, readmission, complications and emergency department visits. The CJRR will be making this information publicly available, to empower both patients and referring physicians to make value-based decisions regarding joint replacement procedures.

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