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SUCCESS AT THE HIGHEST LEVEL

Achieving Function and Aesthetics With an Interscapular-thoracic Prosthesis

By Sherri Edge

For 24 years, Sam Rosecrans relied on his right arm to do his bidding. When he cast his fishing line, ate dinner with his family, or headed out to work, his arm was there, effortlessly completing every task. Billions of neurons were sending electrical messages between his brain and nervous system, dictating the fluid motion of his shoulder, elbow, wrist, and fingers, a natural biomechanical process that functioned unnoticeably until July 1, 2015.


STAFF

Left: Lang palpates the patient's pectoral muscles to determine where to place the surface electrode on the front of the prosthesis.

Right: Baun shows Rosecrans how to position the prosthesis and maintain upper body alignment during basic daily tasks.

"I was running the wood chipper at a sawmill and watching the conveyor belts that moved the wood chips out to different bins," Rosecrans says. "One of the belts was clogging up so I was just pushing wood chips out of the way, and the edge of my right glove got caught on the conveyor belt. My hand was pulled into the conveyor belt, and as it kept moving, it pulled my arm up against the frame at the end of the belt. The force ripped my arm off above the shoulder, including the shoulder blade. I fell onto the floor and I guess I was in shock because I didn't realize my arm was gone. Then I turned around and saw it was hanging there in the machine. I remember thinking, 'I'm going to need that,' so I grabbed it with my left hand and waved my amputated arm at the guy who was watching from upstairs. Then I walked outside and I lost consciousness for several seconds. Two of the guys I work with came out to help me. They put a towel around my shoulder, got me some water, and talked to me until the ambulance got there."

Rosecrans' traumatic amputation is at the highest level of upper-limb loss, interscapular-thoracic. The humerus, the scapula, and a portion of the clavicle were separated from his body, resulting in the absence of the entire shoulder and arm. The most comprehensive research on rates of upper-limb loss by etiology and level illustrates the rarity of interscapular-thoracic, or forequarter, amputation. A dataset spanning nine years indicates an average of 18,496 upper-limb amputations occur annually ("Limb Amputation and Limb Deficiency: Epidemiology and Recent Trends in the United States," *Southern Medical Journal*, 2002). Out of that total, 65 were categorized as interscapular-thoracic amputations; the majority were cancer related (49) and dysvascular (15), and one was the result of trauma. Interscapular-thoracic amputation represents about 0.35 percent of all upper-limb amputations, which suggests that few prosthetists have direct experience with fitting an interscapular-thoracic-level prosthesis.

Upper-limb specialist **MacJulian Lang, CPO, FAAOP,** clinical director, Advanced Arm Dynamics' Northwest Center of Excellence, Portland, Oregon, identifies several factors that make this amputation level particularly difficult to fit. "Without any residual limb, suspension and stability of the prosthesis are of real concern," he says. "Also, we are replicating the form and function of the entire arm—all three joints and the hand—and that is a significant challenge."

AN INDIVIDUALIZED PLAN

On September 10, 2015, two months after his accident, Rosecrans met with Lang, rehabilitation coordinator **Kerstin Baun, MPH, OTR/L,** and technician **Cullen Hays**. "They wanted to be sure I understood what they could and couldn't do for me," Rosecrans says. "They explained the challenges of my amputation level and helped me understand what I could realistically expect from a prosthesis."

The prosthetic team began formulating a plan for a myoelectric system that could accommodate most of Rosecrans' daily needs like dressing, cooking, and eating, and also build his confidence and independence. An interscapular-thoracic-level prosthesis is an assistive tool that helps prevent overuse of the sound arm and hand, restores some structure and balance to the amputated side of the body, and makes many manual tasks easier. With three prosthetic joints and two EMG sensors for control, the functional capacity of the device is more lim-ited than that of transradial and transhumeral prostheses. This reality led Rosecrans to ask for a more robotic appearance: "Even if it can't operate like a Terminator arm, can it look like one?"

"We get pretty excited when someone wants their prosthesis to look bionic, and it's happening more and more," Hays says. "I think a lot of that has been inspired by seeing movie and video game characters with flashy robotic limbs. The prosthesis can become more of an extension of the patient's personality in the same way people customize a car, a computer, or even a phone case. It's part of how they show other people who they are."

SUCCESS AT THE HIGHEST LEVEL

Before he received his prosthesis, Rosecrans tried fishing with one hand and found it almost impossible. Now he's able to securely hold the pole with his prosthesis and use his left arm to reel.

Lang and Hays started with pencil sketches of what the finished prosthesis might look like. The next step was to sculpt a proof-of-concept miniature arm out of clay, a rapid way to create a 3D model that could be easily modified. "Based on our small sculpture, we moved into creating larger proof-of-concept models, taking what we had in our imagination and turning it into coverings or shells that could fit around and protect the prosthesis itself," Hays says.

The shell for the radial portion needed to cover the powered elbow without impeding its ability to flex and rotate, while the humeral shell needed to rotate on the shoulder joint and allow the upper arm to swing out. The humeral shell was built up at the shoulder to fill out Rosecrans' right shirt sleeve and visually balance it with the left shoulder. Fabricated from thin plastics, the shells were covered with woven Kevlar to add texture and visual interest. A matte-finish cutout frame was layered over the shells, adding structure that suggested underlying musculature. A small, silver disc centered on the humeral shell added a shiny finishing touch to the design.

FROM SHOULDER TO WRIST

Beneath the exterior shell of the prosthesis are the components that bring it to life. Lang designed a myoelectric system that consists of a Liberating Technologies passive locking shoulder joint, a Motion Control Utah 3+ Arm with wrist rotation, a Steeper bebionic hand, and a Motion Control Electric Terminal Device (ETD). The shoulder joint swings in a natural arc during ambulation and can be locked into 36 positions. "We customized the placement of the shoulder-locking lever on the medial side of the exterior shell, just above the elbow," Lang says. "When Sam gets the shoulder and elbow into the position he wants, he just operates the lever and the shoulder is locked."

Lang selected the Utah 3+ for several reasons, including its durability, since Rosecrans is an avid outdoorsman. The Utah 3+ also offers the capacity to add two additional electrodes in the future. "Sam is interested in targeted muscle reinnervation [TMR], which has the potential to significantly increase his control of the prosthesis by adding additional myoelectric control inputs," Lang says. "If he eventually gets TMR, it would be relatively easy to modify this prosthesis."

The suspension and stability of Rosecrans' prosthesis is achieved with a sleek, contoured interface that essentially does the work of a traditional socket. The frame is fabricated from smooth, lightweight plastic that is bonded to carbon fiber, and like any prosthetic interface, it is the foundation of Rosecrans' comfort. Lang says achieving the right contours on the frame has taken extensive design work and modification.

"The open areas are strategically

placed so that we're covering up as little of his skin as possible, but not sacrificing torsional rigidity or structure," Lang explains. "Where that really comes into play is when the shoulder is flexed or abducted so the arm is in front of him. The frame needs to be able to withstand that much torque without losing contact with either the anterior or the posterior electrode. The trim lines reach toward midline on both the anterior and the posterior to stabilize electrode contact. He needs to operate the device while sitting as well as standing, so interface length is a critical factor."

NOTHING CAN REPLACE THE HUMAN HAND

Rosecrans has always worked with his hands, whether it was on the job as an electrical lineman for several years, at the sawmill, or hunting and fishing in his native Idaho. During his brief time as a prosthesis user, it has become clear to him that nothing can replace the human hand, and having more than one type of terminal device is essential to being active. "The bebionic hand looks amazing," he says, "especially at the end of my bionic-looking prosthesis. I'm learning how to do the grip patterns and I like wearing it when I go out. When people see it, their faces light up, just like mine did when I first saw it. But you can't do everything with it. When I do anything work related, or if I go hunting, I switch to the ETD just because it's easier to use and stronger for those sort of situations."

As upper-limb specialists, Lang, Baun, and Hays hear this feedback from many patients. "I often compare it to having more than one pair of shoes," Baun says. "We don't wear athletic shoes for everything, right? So the terminal device really needs to match the situation or activity. The bebionic works better for holding certain items, things that are cylindrical like water bottles or soda cans. And in social situations where people are shaking hands, it's more appropriate to do that with the bebionic hand." The ETD has a higher grip force, making it especially suitable for holding and working with heavy items. Rosecrans says he has already used the ETD while hunting. When he's tying hooks to his fishing line, he uses his ETD and the rotator component of his wrist. The prosthetic team hopes to add some custom, activity-specific devices in the future, like a nonelectric device to use for fishing, and other tools for recreation.

THE NECESSITY OF OCCUPATIONAL THERAPY

Learning how to use a complex prosthetic system takes time and effort. Rosecrans has to control the hand, the wrist rotation, and elbow flexion and extension, and he has to manually pre-position and lock the shoulder. "There's a lot of cognitive demand associated with this high-level [prosthesis]. It requires more patience and practice time to really become a skilled user," Baun says. "The reality is that Sam may choose to wear the prosthesis for specific tasks rather than for everything he does. We explore this together so that he can really use the prosthesis to maximize his function."

Rosecrans believes that occupational therapy, which has been integrated into his care at each prosthetic appointment, has taught him how to slow down and better overcome frustrations with his prosthesis. "Without therapy, I'd get back home and end up spending hours trying to figure out how to do all this stuff by myself," he says. "Kerstin also showed me that I have a lot of spinal changes because my right side is elevated without the weight from my arm. So we've been doing some things that help to stretch my back and improve the alignment, and my back is not as sore."

Baun says that for many people with upper-limb amputations, wearing a prosthesis can help reduce scoliosis. "For Sam, the prosthesis potentially provides an anatomical and physiological benefit in terms of preventing pain and overuse syndromes, not only in his left arm and hand, but also in his core and his spine," she says.

SUCCESSFUL OUTCOMES

Besides the obvious physical changes from his accident, Rosecrans believes he's a different person on the inside too. He approaches life a little slower now and is more cautious about the choices he makes, thinking about how it could affect him and the people around him. He is close with his family and lived with his older brother for several months after the accident. "My family is my biggest motivator. I can't let them see me fail," he says.

Lang, Hays, and Baun believe that creating a successful prosthetic solution for a person with an interscapular-thoracic amputation takes a comprehensive team of specialists. Listening to the patient, formulating a detailed plan, introducing creative solutions that are based on sound theory, and integrating therapy are critical elements. Having a focused patient also increases the odds of success. "Sam has the right mindset, and by investing himself in this whole process, he's set himself up for prosthetic success. We're very excited to see where he goes with it," Lang says.

Living the rest of his life as a high-level upper-limb prosthesis user is something Rosecrans plans to approach one day at a time. "Having a prosthesis that looks this great makes me want to wear it. The only way to get better at it is to use it. And right there is the circle of life, basically." **O&P EDGE**

Sherri Edge is a writer and video producer. She has specialized in marketing and communications in the prosthetics industry for more than 20 years, and her work has appeared in numerous prosthetic journals, magazines, reference books, and websites.