The Toils of War

Battlefield innovations influence plastic surgery—and vice versa

By William Payton

From wound care in the Civil War, to antibiotics in World War II, to trauma and burn care during the Korean War, Vietnam War, and beyond, battles have sired significant innovations in medicine.

Plastic and reconstructive surgery, dermatology, and other fields involved in the repair, manipulation, and overall treatment of skin are among the specialties most affected by the realities of modern warfare, and surgeons in these fields are also helping to take new treatments and techniques to the bedside of both veterans and civilians. From growing and printing new organs to closing difficult wounds and using lasers to remove traumatic tattoos, what has been achieved thus far and what is yet to come is nothing short of miraculous.

"The last 13 years have made it necessary for plastic surgeons to become innovative in the way they reconstruct battlefield injuries," says Elan Singer, MD, a Manhattan-based plastic surgeon and a commissioned officer in the Navy Reserve. Singer performs monthly surgeries at the Walter Reed National Military Medical Center in Bethesda, Md.

"Due to the incredible efficiency of the global trauma care system, patient survival is high. However, surgeons are now faced with incredibly large soft-tissue defects, mostly from blast injuries. Accordingly, many of the advances in battlefield medicine as it pertains to plastic surgery [stem from] these types of injuries," he explains.

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IED strike in Baghdad, Iraq, 2007.

MODERN WARFARE MEETS PLASTIC SURGERY

"We're not shooting shells or missiles at long range," adds Eric Parlette, MD, an officer in the Navy Reserve, who is currently a dermatologist in Gainesville, Fla. "Instead, we're seeing long, drawn-out battles on the ground with soldiers being exposed for long periods of time. With the advent of improvised explosive devices (IEDs), rocket-propelled grenades, and land mines, traumatic injuries have skyrocketed."

Extraordinary advances in trauma evacuation have led to increased survival rates at a time when highly destructive IEDs and other lethal modern weaponry are causing evermore catastrophic blast and burn injuries. Around 50,000 soldiers and other military personnel have been injured in the wars in Afghanistan and Iraq—16,000 of whom most likely would not have survived in earlier wars.

"In Vietnam, a lot of these patients would not have been able to get a Medivac, and even when they were, in many cases their injuries couldn't be treated," Parlette says. "In earlier wars, soldiers with these injuries would have been expected to die."

Not so in today's conflicts, where even those who suffer traumatic brain injuries are surviving—scores of them, in fact. Considered the signature injury of the Iraq and Afghanistan wars, traumatic brain injuries were given a face in 2006, when ABC anchor Bob Woodruff sustained a

devastating brain injury while on assignment in Taji, Iraq. On the battlefield, the aforementioned advances in evacuation and trauma surgery saved him. Back home, Woodruff credited the skill of a civilian reconstructive surgeon for the successful reconstruction of his face—a process that included periodic removal of rocks from his forehead.

"When the numbers of certain injuries get this high and you have all these brains working together, you come up with ways to solve problems," Parlette explains. "At a recent medical conference, the head of trauma surgery for a major hospital commented that someone injured in the parking lot outside his hospital could have a worse chance of survival than soldiers injured in Afghanistan."

BURN NOTICE

All of these blast and burn injuries have also forced surgeons and biomedical researchers to change how they think about traumatic wounds. The end result, Singer says, is innovative techniques and technologies that add to the quiver surgeons have at their disposal. Some of these come from battlefield operating rooms, while others stem from procedures performed in a civilian setting.

One example is external tissue expansion, whereby a device is affixed to either side of the patient's wound and allowed to exert tension on the skin. This effectively expands the skin over a matter of days such that extremely large wounds can either be closed or made into much smaller, more manageable-sized wounds, Singer says.

Though external tissue expansion devices such as DermaClose and TopClosure are most often used for trauma, skin cancer resections, surgical complications with loss of skin, and other situations that leave a large wound that is difficult to close or reconstruct, the technology is also being used in aesthetic applications. For example, in cases where laser tattoo removal has suboptimal results, surgical excision is the only viable treatment modality. But if the tattoo being removed is located in an area where there is no skin laxity, such as the wrist, no skin is available to close the defect once the tattoo is excised. In these cases, external tissue expansion devices can come in handy.

External tissue expansion devices can also be useful in the treatment of complications related to aesthetic surgery, such as when skin loss results from a tummy tuck procedure. Once the necrotic tissue is excised, the defect can be treated with external tissue expansion since there is not enough skin laxity in the area to close the remaining wound primarily.

REGENERATIVE MEDICINE IN ACTION

Regenerative medicine, too, holds significant promise—namely in allowing surgeons to treat soft-tissue and bony defects. Synthetic materials have limitations, including the potential for infection and poor long-term outcomes. "For reconstructive purposes, there is no substitute for using a patient's own tissue," Singer says.

However, many of the current plastic surgery techniques involve taking tissue from one location and using it to reconstruct a defect at another location. The downside is that in addition to potential complications at the recipient site, there may be a defect and/or complications at the donor site, too. "These treatment modalities also require multiple trips to the operating room with extensive complex procedures in individuals who already have significant injuries or illness involving other body parts," Singer says. "The Holy Grail for reconstructive surgeons is using autologous tissue to treat surgical or traumatic defects without incurring donor-site morbidity."

Regenerative medicine technologies such as adipose-derived stem cells and spray-on skin (non-culture autologous cells) can promote wound healing. And "Composite tissue allograft (such as hand transfers) is also becoming a more realistic possibility in those with complete extremity amputations," Singer says.

Michael Will, MD, DDS, FACS—the current president of the American Academy of Cosmetic Surgery and a former Army Officer and consultant to the surgeon general in oral and maxillofacial surgery and trauma at Walter Reed Army Medical Center in Washington, DC—is bullish about regenerative medicine. "There has always been a constant drive for rejuvenation and regeneration utilizing emerging technologies," he says. "Finally, we have been able to isolate growth factors, stem cells, and biologic activators that can accelerate and enhance healing as well as provide the opportunity for tissue regeneration and rejuvenation."

Much regenerative medicine research is funded by the Department of Defense through the Armed Forces Institute of Regenerative Medicine (AFIRM). The first round, founded in 2008, focused on limb repair, craniofacial repair, burn repair, scarless wound repair, and compartment syndrome. More than 180 patients, including the recipient of the first double hand transplant in the US, received treatment as a result. Now, AFIRM II is looking to push the bounds of science even further.

Marine Sgt Ronald Strang was one of the patients who benefitted from AFIRM. His leg was shredded by a

Iraqi war veteran Joseph Jones underwent follicular unit extraction to restore his beard.

Joseph Jones also underwent an eyebrow transplantation after being injured by an IED blast in Iraq in 2004.

roadside bomb in 2010 while on patrol in Southern Afghanistan. The former athlete was facing a future walking with the support of a cane, but Strang ultimately became a poster child of sorts for the previously unknown field of regenerative medicine.

Strang was judged to be a very good candidate for extracellular matrix (ECM)-induced regeneration, and became one of the first participants in a clinical trial of this device funded by the Department of Defense. Strang underwent a reconstructive surgical procedure to repair muscle and tendon tissue, during which he also received an ECM that provides scaffolding for cells to grow on. Made from cow tissue and composed mostly of collagen, the ECM has been approved by the US Food and Drug Administration as an "implantable device."

J. Peter Rubin, MD, professor and chair of the Department of Plastic Surgery at the University of Pittsburgh, and a Department of Defense-funded researcher, was Strang's surgeon. "Sgt Strang is a great example of someone we were able to help with these new techniques and technologies, who otherwise would have had limited options with current treatment modalities," Rubin says. "As doctors, this is incredibly rewarding and gratifying to help our military personnel who are out there putting their lives on the line. It's an incredible privilege."

In Strang's case, Rubin, a clinical surgeon, was able to team up with Steven Badylak, DVM, PhD, MD, deputy director of the University of Pittsburgh Medical Center's McGowan Institute for Regenerative Medicine. Badylak helped show that when ECM materials are placed into an area of damaged muscle, they can repopulate natural stem cells and form contractile tissues.

Strang's case also serves as an excellent example of what Chairman of the Department of Dermatology at the Naval Medical Center San Diego, Cdr Peter Shumaker, MD, cites as an added challenge for surgeons: many of the soldiers suffering these injuries are healthy and motivated. "We've had to increase our expertise in rehabilitation to match not just the injuries but also the expectations of these injured service members," he says. "Many of them want to return to activities they were doing previously, like skiing, bicycling, mountain climbing, and other activities."

Giving Back

There are many programs that help our nation's military. A few include:

- Doctors Without Borders
  www.doctorswithoutborders.org
- Faces of Honor
  www.facesofhonor.org
- Wounded Warrior Project®
  www.woundedwarriorproject.org/give-back.aspx
- The Bob Woodruff Foundation
  www.bobwoodrufffoundation.org
- The Henry Jackson Foundation
  www.hjf.org

THE NEXT DIMENSION IN HEALING

3D printing technology for reconstructive purposes has ranged from inspiring to unexpected and fascinating. In one widely reported surgical milestone, surgeons successfully used 3D printing to reconstruct the face of a man who sustained broken cheekbones and eye sockets, as well as a fractured skull and broken jaw, in a motorcycle accident. In February 2015, in a turn of impressive creativity, veterinarians even used the technology to give a toucan a new beak.

In dermatologic surgery as well as reconstructive and plastics, 3D printing has been reported to improve preparation and therefore accuracy. "From use as a training tool to the preparation of preoperative models to medical devices used for implantation, 3D printing technology has many utilities for both surgeons and nonsurgeons," Singer says.

Will is similarly enthusiastic. "3D printing is very helpful in determining balance, projection, and proportion, and can be helpful with volumizing," he says.

Researchers out of Wake Forest Institute of Regenerative Medicine (WFIRM) in Winston-Salem, NC, recently built a 3D printer to "print" skin cells onto burn wounds—the ink being various types of skin cells. WFIRM scientists use a scanner to determine the size and depth of the wounds. The data is relayed to the printer to apply the appropriate cells over the wound. In the next phase of the study, the WFIRM team plans to investigate whether a form of stems cells found in placenta and amniotic fluid is capable of healing wounds. They hope to be able to offer a treatment based on this technology to soldiers in the next 5 years.

AIM FOR THE SCARS

Ablative fractional laser resurfacing is also seeing a paradigm shift thanks to the pioneering efforts of Shumaker and others in both the military and civilian realms. The same lasers commonly used to smooth acne-scarred or wrinkled skin are being applied to soldiers' battle scars to improve mobility. Thanks to these treatments, affected soldiers are now better able to perform everyday tasks such as holding a toothbrush or dialing the phone.

"Laser ablative fractional resurfacing of scars is one of the most exciting developments in scar treatment in decades," Shumaker says. "It produces very predictable improvements in range of motion, function, scar appearance, and texture. It can be used early in management instead of waiting for a contracture to form. It also

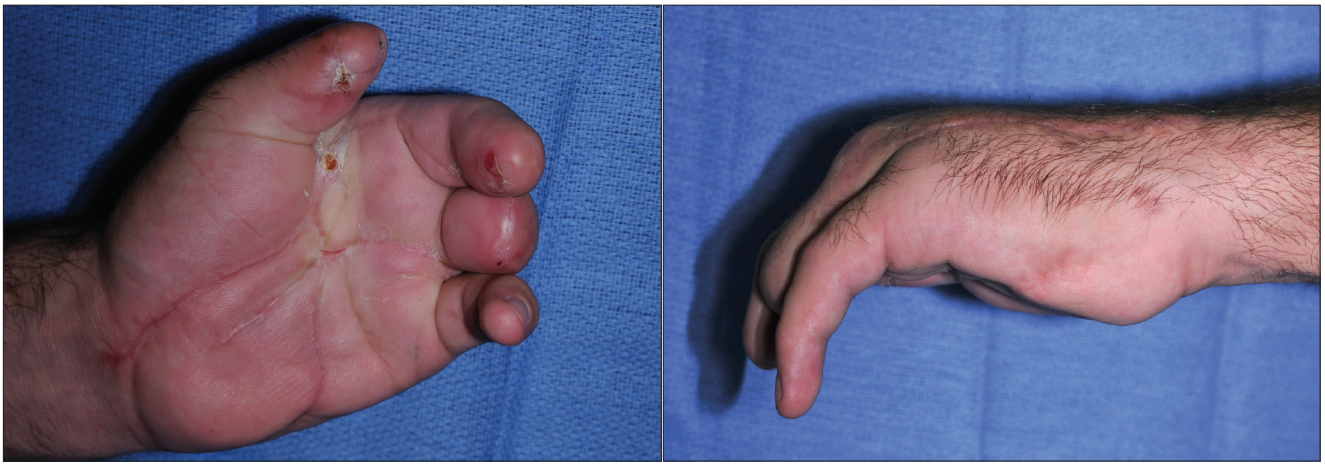

Figure 1a, 2a. Patient approximately 4 months after a blast injury to his left hand demonstrating severely restricted finger flexion despite aggressive hand therapy.

Figure 1b, 2b. Approximately 1 month after his initial outpatient ablative fractional laser treatment demonstrating rapid improvements in range of motion and interval wound healing. Enhancements tend to be cumulative and persistent with additional treatments and complementary therapies. Seemingly modest improvements can have an outsized impact on quality of life for trauma patients. All figures courtesy of Cdr Peter Shumaker and the United States Navy.

seems to normalize collagen structure and function." What's more, Shumaker says, it fills the large chasm between physical therapy and surgical revision.

Rather than just a crossover between military and civilian applications, laser resurfacing's path can instead be described as "circular," Shumaker says. In other words, fractional laser technology was pioneered in civilian institutions, repurposed to a large extent in the rehabilitation of military service members, and that application is now circling back and being applied in civilian institutions, like burn centers. As a result, millions of people worldwide with debilitating scars could ultimately benefit from techniques such as ablative fractional laser resurfacing, Shumaker says.

Another example of the bidirectional nature of the relationship between wartime innovations and general medicine occurred thanks to Faces of Honor, one of the humanitarian programs of the American Academy of Facial Plastic and Reconstructive Surgery. Faces of Honor offers pro bono medical and surgical services to veterans who suffered face and neck wounds in the conflicts in Iraq and Afghanistan.

Military veteran Joseph Jones was gravely injured in an IED blast in Iraq in 2004. Jones was left with no facial hair follicles as a result of the blast. A decade later, Jones received follicular unit extraction to restore his beard and eyebrows by Jeffrey Epstein, MD, a facial plastic surgeon in Miami.

"I have a special respect for these military people who in the line of duty to keep us safe get injured, and they deserve the very best care," Epstein says. "Faces of Honor is a wonderful program, and really helps the people who deserve it."

There are other programs, too, that help put innovative technologies and techniques in the hands of doctors in underserved or war-torn nations.

Shumaker served as lead for a multidisciplinary Navy team during an intensive multiyear medical exchange project in burn scar management with their counterparts in Vietnam under the auspices of Pacific Partnership. Shumaker, along with Parlette and other colleagues from dermatology, plastic surgery, orthopedic surgery, and rehabilitative medicine, have been able to apply techniques honed during more than a decade of conflict to treat hundreds of patients and build relationships in Southeast Asia. Programs such as Pacific Partnership, nongovernmental organizations such as Project Hope, and technology manufacturers such as Lumenis and Syneron-Candela, which loaned laser equipment to burn hospitals in Vietnam, can help bring talented doctors and cutting-edge therapeutics to areas of need.

WHAT'S TO COME

If the past and present are any indication of things to come, we can expect the military and civilian surgical arenas to continue influencing one other. Will believes that surgeons will likely be able to regenerate missing anatomic structures and rejuvenate the aging face utilizing tissue engineering methods along with stem cell differentiation and cellular growth factors.

Shumaker, too, is optimistic about the future. "It's well enough that we improve scar appearance and function, but wouldn't it be great if we could regenerate new skin and hair? My feeling is that we're getting closer." ■

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