The Management of Combat Wounds: The British Military Experience

Steven L.A. Jeffery^{1,2,*}

¹The Royal Centre for Defence Medicine, Queen Elizabeth Hospital Birmingham, Birmingham, United Kingdom.

²Department of Wound Healing, Faculty of Health, Birmingham City University, Birmingham, United Kingdom.

**Steven L.A. Jeffery, BSc, MBChB,
FRCS (Ed, Eng, Glasg), EBOPRAS,
FRCS (Plast), FHEA**

Submitted for publication April 10, 2015.
Accepted in revised form June 12, 2015.

*Correspondence: The Royal Centre for Defence Medicine, Queen Elizabeth Hospital Birmingham, Birmingham B15 2TH, United Kingdom (e-mail: sjeffery@nhs.net).

The concept of the military wound is not an easy entity to define as the wounds seen in conflict can be of many types: those caused by recognized or improvised weapon systems may have similarities to civilian wounds as well as the wounds soldiers sustain outside of battle. This article will focus on the current treatment approaches to combat wounds sustained by the deployed UK Armed Forces personnel.

Keywords: combat, wound, debridement, imaging, dressing, reconstruction

TRANSLATIONAL RELEVANCE

MEDICINE HAS ALWAYS taken great leaps forward during wars and times of conflict. Medicine has changed, and it is now much more difficult to test basic research findings in the clinical setting and also to introduce any new techniques at all into the clinical setting. This has been particularly problematic in the military, where there is great reluctance to be seen to be treating injured soldiers as guinea pigs. Nevertheless, when faced with new challenges, such as soldiers surviving with huge wounds, sometimes there is no alternative but to embrace the opportunities that new technologies bring.

CLINICAL RELEVANCE

Our experience in treating thousands of injured soldiers has produced a small team of clinicians who have become adept at anticipating and managing the inevitable complications and setbacks when dealing with such catastrophic injuries. We who have made this journey have a duty to pass on the lessons we have learned, so that the next generation of clinicians who face

these problems do not have to reinvent the wheel. I hope that this article will go in some small way toward that aim.

INTRODUCTION

As the UK military has been engaged in recent conflicts in the Middle East, the University Hospital Birmingham Foundation Trust and the Royal Centre for Defence Medicine (RCDM) in Birmingham, through which all injured British soldiers are transferred for treatment, have often been faced with challenging traumatic wounds, particularly those caused by improvised incendiary devices and gunshot wounds.

The RCDM also provides medical support to overseas operational deployments and delivers secondary healthcare for members of the military (Role 4). It is also a training center for defense personnel. All injured British military personnel from overseas are transferred back to the RCDM, part of the Queen Elizabeth Hospital Birmingham (QEHB). The QEHB is a unique center in the United Kingdom, treating both military and civilian trauma.

Changes in body armor have resulted in fewer abdominal and thoracic injuries and therefore relatively more limb injuries. These injuries are often associated with extensive soft tissue stripping and contamination. High levels of exudate are commonly present, and these wounds are particularly prone to infection both by fungi and bacteria.

MECHANISM OF INJURY

Since the evolution of our species, man has been fighting rival individuals, families, tribes, and then eventually states.

Since 2001, the majority of wounds sustained by the British serving personnel have been caused in Afghanistan and Iraq. During this period, the conduct of the conflicts has evolved. Improved medical care has led to a change in the severity of injuries now requiring reconstruction. Explosive devices in asymmetrical warfare are popular (Fig. 1). The use of such devices produces a higher proportion of extremity injuries than seen in previous conflicts fought with more conventional firearms.

The effects of a blast have been previously described and the injury patterns they cause are well

recognized. These are often traumatic amputations. Extensive fractures, heavy contamination, and soft tissue disruption are common. Improvements in medical care, such as training for all soldiers in controlling external hemorrhage, the routine use of tourniquets, new hemostatic agents, helicopter evacuation, and consultant-led surgical resuscitation, have resulted in a large number of patients surviving with severe injuries. A group of survivable unsurvivables has been identified, whose injuries would have most probably resulted in prehospital death elsewhere and who are also likely to have died in the civilian context.

WOUND MANAGEMENT

It is likely that we have been treating combat wounds since shortly after the human species evolved. These wounds continue to pose a challenge to both nursing and medical staff. In the military patient, the substantial inflammatory response creates an austere environment for complex primary reconstruction.

Wounds can be small and unpleasant or be large and life-threatening. The skin is both an immunological and a physical barrier to invasion by microbes. Any deficiency in the integrity of the skin may allow fungal or bacterial invasion.

The way that explosive devices are used now means that wounds are often heavily contaminated. In cases of suicide bombing, this situation may be further complicated by contamination with foreign human material within the wound.

The prognosis for the patient will be adversely affected by extreme contamination, massive blood

Figure 1. Extreme contamination caused by blast injury. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

Figure 2. Soapy water cleansing first. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

transfusion, suboptimal debridement before transfer, or any delay in transfer.

WOUND DEBRIDEMENT

“Debridement is one of the most important and significant discoveries in all of surgery,” Larrey, Napoleon’s surgeon.

Wound debridement is the most important first step in wound management and will significantly affect the end result for the patient. In heavily contaminated military wounds, this is often only achieved with several stages. The first debridement is performed within the constraints of damage control surgery and should be as thorough as possible without being excessive. A debridement classification as described by Granick and Chehade¹ is a useful model based on the Jackson burn wound model.² In the center of the wound is an area of dead and dying tissue surrounded by a marginal area of injured but alive tissue. This in turn is surrounded by healthy tissue. Granick and Chehade classified wounds according to the level of debridement. Incomplete debridement, where not all of the necrotic material is removed, is to be avoided if at all possible as retained necrotic material will serve as a nidus for infection and inflammation. Marginal debridement where all necrotic tissue is removed, but where injured and potentially viable tissue is retained, is an appropriate level of debridement at the first operation. The removal at this stage of potentially viable tissue is not necessary. A larger wound will be created, which will require a more complex reconstruction. Providing that there are sufficient resources available for frequent take-backs to the operating

room (OR), marginal debridement provides the maximum chance for survival of native tissues.

Before wound debridement, all wounds should be cleaned of particulate matter using soap and water (Fig. 2). A tourniquet should be applied if possible (Fig. 3). Large irregular wounds contain crevices into which contamination may be forced between tissue planes. Without tourniquet control, these areas will be filled and obscured with bleeding, making excision of dead and dirty tissue difficult. In addition, blood loss without the application of a tourniquet may be significant. A sterile disposable tourniquet is useful for proximal wounds; the surgeon can apply a sterile disposable tourniquet once the skin has been prepped and draped. With experience, the routine use of a tourniquet helps rather than hinders debridement.

The first debridement should be performed as early as possible following injury in the field hospital, once the patient is stable. When soldiers reach Role 4 (in the case of the United Kingdom: Birmingham), reassessment needs to be made of all wounds sustained. This is best performed under general anesthesia. This can usually wait until the next routine operating list unless the viability of a limb is in doubt, there is a large amount of undebrided contamination, or if there is suspicion of sepsis. This assessment should be performed by senior plastic and orthopedic surgeons, so that a plan for reconstruction can be made. Photographs must be taken.

Debridement should be performed under magnification using surgical operating loupes to help identify contaminants. Debridement should be performed systematically in layers: start at the skin and work your way in. Skin edges are best

Figure 3. Irrigation and debridement under tourniquet. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

Figure 4. All tissue planes must be inspected. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

excised using a scalpel. More mobile tissues, such as fat and muscle, are best debrided using scissors (Fig. 4). Debridement of tissue, which is difficult to pick up with forceps, such as sand, ingrained mud, and adventitial tissue, is best removed using the Versajet™ hydrosurgery system.³ This device incorporates a high-pressure jet of water, which debrides the tissues. The high-pressure water jet is tangentially placed, so the deleterious effects of standard high-pressure irrigation are avoided. The debris is continuously removed so that the surgeon can assess the extent of the soft tissue damage (Fig. 5).

At this first theater session, all wounds should be exposed, explored, and debrided. This may require the patient to be turned in theater so that wounds to the back and buttocks can be assessed.

Once debridement is complete, irrigation with at least 3l of warm saline should be performed (Fig. 6) before dressing application. High-pressure irrigation is contraindicated as it further damages the tissues and drives foreign material further in.

Wound swabs as well as tissue samples should be taken and sent for microbiological and histological examination so that the presence of fungal spores can be identified. If fungal contamination is suspected, samples should be taken of both healthy and dead muscle.

WOUND IMAGING

Currently, assessment of wounds is achieved through visual inspection and recording these findings in the clinical notes. Wounds can be measured and their dimensions can be written down.

Figure 5. Versajet debridement. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

While the English language contains many words to describe texture, form, and shape, there are limitations in using this approach to describe wound appearance and topography. The clinician will inevitably record features that appear relevant at the time of assessment. However, certain features may be incorrectly omitted from a wound description, which may have significance later.

Wounds have been represented pictorially for many hundreds of years. Surviving Roman mosaics show combat injuries. The eminent military surgeon, Charles Bell, drew and painted very clear images of his patients at Waterloo, showing injuries that are instantly recognizable and familiar to military surgeons today.

Until the advent of the digital revolution, the taking and processing of photographs were cumbersome and lengthy affairs, and the results were certainly not guaranteed. Medical photography was used by certain specialties, particularly plastic and maxillofacial surgery, but was not widespread. Wounds were seldom photographed.

Medical photography has become more widely available within hospitals, but still usually needs

Figure 6. Copious irrigation. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

the photographs to be taken by a dedicated medical photographer. Forms need to be filled in, and as it is not practical to send patients with open wounds down to the medical photography department, the medical photographer needs to be sent for; and the inevitable delay that this involves puts off anyone with a busy practice.

Digital photography now allows for many images to be taken at very low cost. A display on the back of the camera allows the viewer to see instantly whether the image is in focus and whether the subject of the photograph is adequately captured, previously a bit of a lottery with film cameras. Poor images can now be deleted and another photograph taken at no extra cost.

The reduction in cost and the increased availability of digital photography has meant that now most people own a digital camera, and indeed most people now carry around a mobile telephone capable of taking very high-resolution images. Such photographs are a useful reminder of how the wound looked, can be referred to at each dressing change, and are particularly useful when trying to convey the details of the wound to another practitioner. Medical photography is used extensively in our practice to describe the appearance and characteristics of the wound to all members of the multidisciplinary team. The trauma team at the QEHB holds regular multidisciplinary team meetings, where all members of the team discuss all aspects of the care required for our military and civilian trauma patients.⁴ Each patient is discussed in turn, through a Powerpoint presentation, including blood results, X-rays, and clinical images taken during the latest dressing change. Not all members of the team can be present at the time of the dressing change, and this would not be wise from an infection control point of view. Traditional two-dimensional (2D) photographs will suffice for most wounds, particularly simple wounds that lie in one plane.

Telemedicine now allows for images of the wounds to be sent to the Role 4 Hospital from the Field Hospital so that the receiving hospital is adequately prepared.⁵

Estimation of wound depth and volume is an important assessment of wound topography. Changes in wound volume can be an effective indicator of evolving wound status. Wound tracings can be taken, allowing serial assessment of whether the wound is in fact getting bigger or smaller. A piece of acetate can be placed on the wound and the edges traced. This technique was formalized into the Visitrak™ (Smith & Nephew, Hull, United Kingdom) device, which incorporates a digital tablet device that the wound tracing can be retraced

onto. This involves direct contact with the wound, a messy business, and such tracings are only really suitable for flat wounds.

THREE-DIMENSIONAL IMAGING

While not a new concept, the advent of recent technological advances has made the use of three-dimensional (3D) technology in medicine increasingly practicable. The latest development in this field is that of handheld 3D imaging (Fig. 7). This allows for the imaging of complex wound topography that would not be captured very well by conventional 2D images. It also allows for the calculation by the software of the wound area and volume, which can be measured serially. The ability to demonstrate to a patient that the wound is getting smaller in either size or volume may be good for the morale of the patient. On the other hand, some patients have static wounds; this can be demonstrated to them using this technology, with a view to helping them accept a change in the treatment plan.⁶

DRESSINGS

Combat wounds are challenging to dress due to their, often, large size and the amount of exudate that they produce.⁷ The introduction of negative pressure wound therapy (NPWT) has transformed the management of these wounds as it allows for total exudate capture and also total wound isolation

Figure 7. Handheld 3D camera in use.

Figure 8. Blast injury before debridement. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

(Figs. 8 and 9). These dressings are now the standard of care for combat wounds.

Many dressings include antimicrobial agents. Some dressings release the agent into the wound, while others work by trapping the wound exudate, then using the antimicrobial within the dressing to control microbial growth.

Silver has been known to have antimicrobial properties for many years and has been incorporated into many dressings. We recently published the first randomized controlled trial set in a combat zone, comparing the use of the nanocrystalline silver dressing Acticoat™ (Smith & Nephew) against plain gauze.⁸ Unfortunately, the trial did not recruit the numbers of patients that we had planned for when we powered the study due to the development of advances in NPWT dressings. Nevertheless, there was a trend toward Acticoat (Smith & Nephew) dressings having less malodor than control wounds, and it is likely that if the trial had run to 100 patients, as originally planned, that this would have reached statistical significance.

Figure 9. After debridement and application of NPWT dressing. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

NEGATIVE PRESSURE WOUND THERAPY

Subatmospheric pressure is applied to the wound bed by a filler material. This is then sealed, and exudate is drawn off by a pump into a canister. Until quite recently, the only filler available was polyurethane foam, supplied as part of the V.A.C. system (KCI, San Antonio, TX). An alternative wound filler (nonadherent gauze) is now commercially available in several NPWT devices, including Renasys (Smith & Nephew), based on the technique described as the Chariker-Jeter system.

Our preference is to use dry gauze impregnated with polyhexamethylene biguanide (Kerlix AMD; Tyco Healthcare, Gosport, United Kingdom) and placed directly onto the wound bed. We have not experienced any retained gauze using this technique. Moistening of the gauze with saline, as re-

commended by the manufacturers, is not required as the dressing soon becomes wet and to do so would reduce the chances of developing a successful seal. Drains should be placed within the gauze for deep wounds. A port system is only suitable for relatively shallow wounds.⁹ This is then sealed with a semipermeable film, with a 2- to 3-cm border around the wound onto healthy skin.¹⁰

We have found that NPWT, when used in combination with surgical assessment, exploration, and careful debridement, greatly facilitates wound management.¹¹ It also stabilizes the soft tissues, salvages compromised tissue, reduces edema, the frequency and total number of dressing changes, and facilitates further reconstructive surgery.¹²

NPWT also makes effective hand dressings when used circumferentially.¹³ In a hand with multiple composite soft tissue and bony injuries, when functional splinting is required, gauze-based NPWT allows for easily applied dressings that provide optimum conditions for wound healing and functional splinting, negating the need to apply a plaster-of-Paris splint. The ability to use variable intermittent pressure combines the advantages of intermittent therapy without the disadvantages of loss of seal or splitting effect.¹⁴

The development of NPWT, which essentially seals off the wound, has greatly reduced the odor coming from many wounds.¹⁵ Many people would be afraid of placing NPWT onto an anaerobically smelling wound, but the ability to irrigate wounds while undergoing NPWT has made this now possible.¹⁶

WOUND ODOR

Three troublesome problems caused by wounds are pain, exudate, and smell. Malodorous wounds are distressing to the patient, the relatives, and the staff. This impacts negatively on the psychosocial well being of all involved, most importantly the patient. The embarrassment that the patient with a malodorous wound experiences can lead to social isolation and withdrawal, with little or no chance for social intimacy. In the First World War, wounded soldiers were often given little bags filled with lavender to mask the smell of their wounds and allow them to sleep.¹⁷

The bad smell is caused by a cocktail of volatile short-chain fatty acids produced by interactions between aerobic and anaerobic bacteria such as *Bacteroides* or *Clostridium* species.^{18,19} Other proteolytic bacteria may produce diamines such as cadaverine and putrecine. The development of a biofilm will reduce the chances of the body re-

moving these bacteria. Some bacteria are thought to be able to be recognized by their unique smell, such as *Staphylococcus*, *Proteus*, and *Pseudomonas* species.

Signals from olfactory receptors in the nose are processed in the limbic and hypothalamic systems of the brain, considered relatively primitive, and associated with emotional responses. Strong bad odors can therefore cause physical responses such as gagging or vomiting, as well as affecting taste and appetite. Such a strong reaction to bad smell is thought to be part of our survival mechanism, warning off our ancestors against contact with potentially dangerous pathogens, particularly from rotting meat. Many injured soldiers have frequent episodes of enforced starvation associated with their anesthetics, which will further affect their nutritional status. These patients are also nutritionally challenged and the last thing that they need is a reduction in appetite as well.

The assessment of malodor is not helped by the lack of a standard measurement tool. The scale that we now use in Birmingham is adapted from the original Baker and Haig scale and incorporates the distance from the wound and the presence of the dressing.

MOISTURE SENSING

One aspect of wound healing considered essential is the control of the level of moisture in the wound bed. Moisture is an essential part of the wound healing environment, but achieving the proper moisture level in the wound currently relies on clinical judgment and dressing selection. It is a delicate balance; too wet a wound environment introduces the possibility of maceration of the skin. A wound environment that is too dry will impede healing.

The use of a moisture sensor may allow decisions about dressing changes to be made without disturbing the wound bed or removing a dressing unnecessarily, which would increase the risk of contamination. Many dressings rely on the presence of moisture to activate an antimicrobial agent (such as silver).⁹ The ability of a sensor to alert the clinician if the dressing is too dry is useful. Similarly, the ability to know that a dressing is too wet will help decisions around the timing of dressing changes as well as which dressing to choose.

In our practice, selected patients have the WoundSense™ (Ohmedics, Glasgow, United Kingdom) moisture sensor incorporated into their dressings to allow monitoring of moisture levels in wounds while leaving the dressing intact.²⁰

FUNGAL INFECTION

In our experience, fungal infection is much more common in casualties injured in Iraq or Afghanistan than in our other patients. Fungal histology and microbiology results take time to come back, and before this, the patient may demonstrate prolonged pyrexia. Some fungal species can grow up the intima of blood vessels, causing thrombosis in side branches and producing mycotic emboli. This can result in flap failure. All patients who have extensive soft tissue injuries, injured while on foot patrol within the Green Zone (arable land adjacent to water sources), should have debrided tissue sent for examination before receiving antifungal prophylaxis. Amphotericin should be the starter until sensitivities are available. These injuries may be from explosive devices or gunshot wounds, which are then heavily contaminated during evacuation by being dragged through the dirt.

TIMING OF WOUND CLOSURE

Dressing changes are uncomfortable for patients. The time they take also reduces their quality of life. Dressing changes also represent a major financial and logistical burden, particularly if they are associated with prolonged inpatient stay or require general anesthesia. Therefore, clinicians should try to achieve wound closure as soon as feasibly possible.

There are several civilian guidelines available for the management of trauma patients, such as those produced by the British Association of Plastic, Reconstructive and Aesthetic Surgeons and the British Association of Orthopaedic Surgeons. While in theory these are helpful, they may not be applicable to the management of combat injuries. For example, the aim of achieving complete soft tissue closure within 5 days of injury is usually inappropriate for the heavily contaminated and multiple injured soldiers we have become used to seeing recently.

Wounds should only undergo surgical closure when they are ready for closure. This decision about timing of wound closure is often highly subjective and solely dependent upon how the wound appears, with little objective information available to assist the surgeon with the decision. Two considerations to bear in mind are as follows; first, wounds that would actually be safe to close may have had this surgery delayed unnecessarily due to reluctance to close the wound too soon. Leaving the wound open thus risks potential further contamination and the development of infection, as well as additional OR trips (with the starvation time that

they usually bring), dressings, and inpatient stays. There is also the fear of increasing the chances of developing heterotopic ossification later on. Second, attempting surgical closure when the wounds are not actually ready for closure may mean that patients go on to experience wound problems such as infection or dehiscence.

SURGICAL RECONSTRUCTION

First, a clean wound has to be achieved through adequate debridement of both bony and soft tissues. Second, reduction and rigid fixation of associated fractures are required. Third, early soft tissue cover is required. This often takes several debridements; the number of debridements required reflects the state of the patient's wounds on arrival.

Evidence from the literature suggests that early soft tissue cover of open fractures reduces both infection and time to bony union. Reconstruction should not be performed; however, until the patient is physiologically stable, the patient should be afebrile, the nutritional status should be optimized, and all inotropic medication should be discontinued. The microbiology profile of the wound should also be understood before attempt at reconstruction.²¹ The other consideration is the availability of suitable donor sites for local or free flap reconstruction due to the extensive zone of injury.²² Reconstruction, which relies on local perforator vessels, should be used with care as the zone of trauma is often much bigger in blast injuries. The primary blast wave is likely to cause damage to the intima of blood vessels beyond the extent of the obvious injury. This occurs where perforating vessels are relatively fixed, that is, where they penetrate the deep fascia. An additional precondition of flap site selection is the potential detrimental effect of the donor defect. Commonly used muscle flaps such as rectus abdominis affect core stability; harvesting them may subsequently compromise rehabilitation.²³ The development of infection may also delay reconstruction.²⁴

The use of dermal reconstruction templates should be considered, particularly for amputation stumps.²⁵

NUTRITION

The arduous nature of operational deployment, particularly when combined with a very hot or cold climate, and difficulty in procuring fresh fruit and vegetables mean that soldiers who have been

deployed on operations for some time will inevitably lose weight. They are relatively malnourished at the time they get injured. It is therefore vital that every opportunity is taken to improve their diet on return to the Role 4 Hospital. Patients must be weighed and assessed by a dietitian on arrival. The nutritional requirements of all patients with significant injury must be supplemented with enteral feeding. Soldiers seldom complain about the passage of a fine-bore nasogastric tube if they are told that this will shorten their hospital stay. For patients who require frequent surgery, a nasojejunal feeding tube should be passed to minimize starvation times as nasojejunal feeding does not need to be discontinued before undergoing general anesthesia. This is particularly important for patients who subsequently become contaminated with organisms such as methicillin-resistant *Staphylococcus aureus* (MRSA), which will often result in them being placed last on the operation list.

PAIN

The effect of pain on the recovery of the injured military patient cannot be underestimated. Pain is also detrimental to wound healing.²⁶ Inadequate analgesia may result in a patient becoming exhausted and noncompliant.²⁷ Such patients may become primed to anticipate pain and discomfort at every subsequent intervention and this may cause significant disruption to dressing changes, cannula and catheter changes, suture removal, and subsequent rehabilitation. The ability to place nerve block catheters in the field hospital has greatly improved the pain management of patients during aeromedical evacuation to Role 4. Nerve block catheters should be left *in situ* (if still working) and should be used for subsequent operations and dressing changes.

Increased requirements for analgesia may be caused by dislodgement of the nerve block catheter or more sinisterly marred representation of the development of compartment syndrome.²⁸ Patient-controlled analgesia, if used at the field hospital, should be continued during aeromedical evacuation.

PSYCHOLOGICAL ASPECTS

Injured troops should be admitted to the same ward if at all possible. An open ward facilitates camaraderie, with soldiers effectively debriefing each other. Unfortunately, soldiers who grow cer-

TAKE-HOME MESSAGES

- Advanced resuscitation techniques, if brought forward, mean that patients with huge and complex wounds can and will survive.
- Wound debridement is a skill, which improves with practice and feedback.
- NPWT allows for exudate management and wound isolation even for the biggest wounds.
- Wound imaging is a vital communication tool.
- Nutrition and pain management are as important as the surgery.
- If the psychological aspects are ignored, the patient will do badly.

tain bacteria, such as resistant species of *Acinetobacter*, MRSA, or Panton-Valentine Leukocidin, will require isolation in a side room, where they will have less contact with their comrades and less opportunity to come to terms with their injury.

All soldiers with combat-related injuries must be reviewed by a trained psychiatric nurse from the military mental health team. This nurse will arrange for referral to a psychologist and/or follow-up by the military community mental health team as required. Injured soldiers may also be referred to counselors from specific organizations, such as the British Limbless Ex-Service Men's Association, WoundCare 4 Heroes, or the Royal National Institute of Blind People, as required. Amputees often benefit from a visit by a soldier who has recovered from a similar injury, particularly if that soldier is coping well with his or her prosthesis.

It is important that the medical and nursing staff looking after a severely injured serviceman get to know his family. Effective communication is very important and paramount as the soldier's family will understandably be very anxious about the injuries and the prognosis.

Soldiers with combat wounds often require prolonged inpatient stay. It is also likely that during the admission the patient will experience setbacks, such as infection, wound dehiscence, or delays in healing. This will be less problematic to both the soldier and his family if they are forewarned that this is likely to occur. These patients will usually require prolonged follow-up; it is important that a trusting relationship develops between the patient, the surgeon, the nursing staff, and the family.

DISCHARGE

Patients no longer need to be kept in hospital until their wounds are completely healed as long as the rehabilitation center can cope with undertaking relatively simple wound care. It is important that a prosthetist assess the patient before transfer

to the rehabilitation center to cast stumps in order that those prosthetic devices are ready when the patient arrives. The prosthetist can also help confirm to the patient that the loss of a limb or more is still compatible with an independent life.

SUMMARY

In the management of the combat injuries, a holistic approach should be taken. Many technologies, some of these new, some very old, will be required.

Advances in wound care technologies and dressings, as well as developments in prosthetic devices and rehabilitative care, have enabled more soldiers to survive and enjoy a good quality of life than in any previous conflicts.

Hippocrates recognized that war is the greatest laboratory for medical advancement. It is important that the techniques gleaned from the battlefield aid the treatment of soldiers and the advances made are

transferred to aid in treating complex civilian patients. It is also important that these lessons are recorded so that the next generation of combat surgeons do not have to learn from their own mistakes.

AUTHOR DISCLOSURE AND GHOSTWRITING

No competing financial interests exist. The content of this article was expressly written by the author listed. No ghostwriters were used to write this article.

ABOUT THE AUTHOR

Steven L.A. Jeffery, BSc, MBChB, FRCS (Ed, Eng, Glasg), EBOPRAS, FRCS (Plast), FHEA, is military consultant burns and plastic surgeon with extensive experience of the management of combat wounds from working at the UK Role 4 Hospital in Birmingham as well as multiple deployments.

REFERENCES

1. Chehade M, Granick M. *Surgical Wound Management*. New York: Informa, 2007.
2. Jackson DM. The diagnosis of the depth of burning. *Br J Surg* 1953;40:588–596.
3. Jeffery SLA. Role 4 and reconstruction. In: Brooks AJ, Clasper J, Midwinter M, Hodgetts TJ, Mahoney PF, eds. *Ryan's Ballistic Trauma: A Practical Guide*. London: Springer, 2011:657–668.
4. Jackson PC, Foster M, Fries A, Jeffery SL. Military trauma care in Birmingham: observational study of care requirements and resources utilisation. *Injury* 2014;45:44–49.
5. Jeffery S. Wound imaging: from Waterloo to tomorrow. *Br J Nurs* 2013;23:S3.
6. Savage JM, Jeffery SL. Use of 3D photography in complex-wound assessment. *J Wound Care* 2013;22:156–160.
7. Fries CA, Jeffery SL, Kay AR. Topical negative pressure and military wounds—a review of the evidence. *Injury* 2011;42:436–440.
8. Fries CA, Ayalew Y, Jeffery SL, Penn-Barwell JG, Porter K, Midwinter MJ. Prospective randomised controlled trial of nanocrystalline silver dressing versus plain gauze as the initial post-debridement management of military wounds on wound microbiology as the initial post-debridement management of military wounds on wound microbiology. *Injury* 2014;45:1111–1116.
9. Russell F, Jeffery S. Use of Renasys™ Gauze and Port to simplify negative pressure dressing techniques. *Wounds UK* 2010;6:125–130.
10. Guyver PM, Mountain AJC, Jeffery SL. Application of topical negative pressure for traumatic amputations. *Ann R Coll Surg Engl* 2013;95:226–227.
11. Birke-Sorensen H, Malmso M, Rome P, et al. Evidence-based recommendations for negative pressure wound therapy: treatment variables (pressure levels, wound filler and contact layer)—steps towards an international consensus. *J Plast Reconstr Aesthet Surg* 2011;64:S1–S16.
12. Penn-Barwell JG, Fries CA, Street L, Jeffery S. Use of topical negative pressure in British servicemen with combat wounds. *Eplasty* 2011;e35:11.
13. Taylor CJ, Chester DL, Jeffery SL. Functional splinting of upper limb injuries with gauze-based topical negative pressure wound therapy. *J Hand Surg Am* 2011;36:1848–1851.
14. Staruch R, Jeffery S. Variable topical negative pressure therapy for wound care. *Wounds UK* 2011;22:26–33.
15. Hankin E, Jeffery S. Challenges of treating modern military trauma wounds. *Wounds UK* 2010;6:47–54.
16. Jeffery SLA. Best of both worlds: combining the benefits of NPWT and instillation therapy. *J Wound Care* 2012;S1:3–10.
17. Mayhew, Emily. *Wounded: The Long Journey Home from the Great War*. London: Vintage, 2014.
18. Bowler PG, Davies BJ, Jones SA. Microbial involvement in chronic wound malodour. *J Wound Care*. 1999;216–218.
19. Miranda BH, Ali SN, Jeffery SLA, Thomas SS. Two stage study of wound microorganisms affecting burns and plastic surgery inpatients. *J Burn Care Res* 2008;29:927–932.
20. Jeffery SLA. Exudate monitoring in traumatic wounds. *Wounds UK* 2013;9:40–44.
21. Taylor C, Jeffery SLA. Management of military wounds in the modern era. *Wounds UK* 2009;5:50–58.
22. Jeffery SLA. Advanced wound therapies in the management of severe military lower limb trauma: a new perspective. *Eplasty* 2009;9:e28.
23. Evriviades D, Jeffery S, Cubison T, Lawton G, Gill M, Mortiboy D. Shaping the military wound: issues surrounding the reconstruction of injured servicemen at the Royal Centre for Defence Medicine. *Philos Trans R Soc Lond B Biol Sci* 2011;366:219–230.
24. Taylor CJ, Hettiaratchy S, Jeffery SL, Evriviades D, Kay AR. Contemporary approaches to definitive extremity reconstruction of military wounds. *J R Army Med Corps* 2009;155:302–307.
25. Foong DP, Evriviades D, Jeffery SL. Integra™ permits early durable coverage of improvised explosive device (IED) amputation stumps. *J Plast Reconstr Aesthet Surg* 2013;66:117–124.
26. Nimmo WS, Duthie DJ. Pain relief after surgery. *Anaesth Intensive Care* 1987;15:68–71.
27. Emflorgo CA. The assessment and treatment of wound pain. *J Wound Care* 1999;8:384–385.
28. Lueck RA, Ray RD. Volkmann's ischemia of the lower extremity. *Surg Clin North Am* 1972;52:145–153.

Abbreviations and Acronyms

2D = two-dimensional
 3D = three-dimensional
 MRSA = methicillin-resistant *Staphylococcus aureus*
 NPWT = negative pressure wound therapy
 OR = operating room
 QEHB = Queen Elizabeth Hospital Birmingham
 RCDM = Royal Centre for Defence Medicine