Dismounted Complex Blast Injury

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The severe Dismounted Complex Blast Injury (DCBI) is characterized by high-energy injuries to the bilateral lower extremities (usually proximal transfemoral amputations) and/or upper extremity (usually involving the non-dominant side), in addition to open pelvic injuries, genitourinary, and abdominal trauma. Initial resuscitation and multidisciplinary surgical management appear to be the keys to survival. Definitive treatment follows general principals of open wound management and includes decontamination through aggressive and frequent debridement, hemorrhage control, viable tissue preservation, and appropriate timing of wound closure. These devastating injuries are associated with paradoxically favorable survival rates, but associated injuries and higher amputation levels lead to more difficult reconstructive challenges. (Journal of Surgical Orthopaedic Advances 21(1):2–7, 2012)

Key words: DCBI, dismounted complex blast injury, damage control orthopaedics

Introduction

In 2010, under direction of the President of the United States, the number of forces in the Afghanistan Theater of Operation (ATO) increased significantly in what was referred to as the "Afghanistan Surge."

The ATO saw a relative increase in the severity of casualties in the summer of 2010 through the current conflict. The percentage of patients with amputations, open pelvic injuries, mangled extremities, and genitouninary injuries increased drastically over this time period. In 2010, twice as many triple and quadruple amputees were evacuated out of theater than all the preceding years combined (2001 to 2009) (1).

Several factors are felt to be responsible for the increase in casualty severity, which can classified into two general groups: factors relating to increased severity of injury (relatively unprotected service members on foot patrol, larger explosives) and factors relating to better survivability (hemorrhage control including far forward tourniquet use, aggressive damage control resuscitation techniques, and refined protective equipment).

When compared to the Iraq Theater of Operation (ITO), the terrain within the ATO required a shift in operational tactics. In contrast to the expansive desert within the ITO, which is well suited for vehicular traffic, the varied, largely mountainous, terrain in the ATO is not. As such, much of the patrolling in the ATO is conducted primarily on foot, outside the relative safety of armored vehicles. "Dismounted" service members are, thus, more vulnerable to attack, particularly when roadside bombs are considered.

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In addition to the far forward and individual use of tourniquets (2), the paradoxical increase in survivability of these severely injured casualties is due to an aggressive resuscitation philosophy. This topic is the focus of two subsequent articles within this issue. In summary, early use of midline abdominal incisions for proximal control of bleeding, as well as massive transfusion protocols for these types of patients, was instituted in 2010 as a Clinical Practice Guideline for the ATO (3). Ironically, patients such as these have a very high probability of survival, despite being injured thousands of miles away from the

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nearest major urban medical center. This effect is largely due to the aggressive nature of resuscitation process and the dedication of those deployed in far-forward echelons of care. By way of comparison, in the civilian sector, it is unlikely that a patient with two, three, or four traumatic amputations would survive.

Initial Management/Resuscitation

These topics will be discussed in detail within the following articles; however, the initial management of patients with DCBI must focus on hemorrhage control and aggressive resuscitation of the patient. Massive transfusion protocols, including blood component therapy, should be followed. In more austere environments with limited blood bank support, or in cases where even robust transfusion resources are likely to be exhausted, early activation of fresh whole blood donations may be necessary (4).

Control of hemorrhage ideally occurs concurrently with resuscitation and requires a multidisciplinary approach involving anesthesia providers, orthopaedic, and general surgeons. Tourniquets placed in the field are removed in the operating room once all available resources to manage large vessel bleeding become available. In the case of high lower extremity amputations, proximal control through the traumatic wound is not always possible, and a transperitoneal approach to the great vessels of the abdomen and pelvis is often necessary. This combined approach not only illustrates the complex nature of this injury pattern, but also the need for multidisciplinary involvement during the resuscitation phase of treatment (1).

Damage Control Orthopaedics

When managing patients with DCBI, one is reminded that both the energy imparted to the patient and the extent of injury is truly massive. As a result, "damage control" external fixation techniques, discussed later in this issue, is therefore considered part of the standard management. Patients must be evacuated to a higher level of care as rapidly as possible, and after initial resuscitation and hemorrhage control, expedient fracture stabilization must be performed. When applying damage control techniques, orthopaedic surgeons that find themselves in the combat or disaster settings must consider factors such as the number of patients needing treatment, available resources, stability for transport, weather conditions, and availability of medevac (5).

Amputations

The management of the amputations follows general accepted principals. However, within the context of the DCBI, a few points are worth elaboration. Limb length preservation is critical in the multiple extremity amputee and may be the deciding factor in their ambulatory potential (6). Unfortunately, in the setting of proximal transfemoral amputations with associated pelvis and peroneal injuries, revision to a hip disarticulation or hemipelvectomy may be necessary. For residual limbs that are viable, preserving limb length requires both management of the bone and management of the soft tissue. Preservation of bone length may require fracture stabilization within the amputated limb and/or joint preservation (7).

Soft tissue, however, is often the determining factor in ultimate residual limb length. Management of soft tissue often includes wound closure within the zone of injury, an appropriately tensioned myodesis, myoplasty, the use of local, atypical soft tissue flaps, and free tissue transfer. As these patients have multiple limb injuries and amputations, the common accepted donor sites for autologous tissues are becoming increasingly limited. Importantly, we limit the use of free tissue transfer involving the rectus abdominus and latissimus muscles due to the need for core strength and balance for transfers and mobility.

The primary technical consideration for management of combat-related amputations is working and closing within the zone of injury. The zone of injury for these wounds often encompasses the entire extremity. Therefore, preserving a functional limb may be at the expense of an increased risk of infection as well as the development of heterotopic ossification (8).

Another critical aspect of amputation management is the timing of wound closure. As a general practice, the wounds are kept open until deemed ready for closure (9). Wound closure is often a clinical decision based on appearance of the wound. Surveillance cultures are not routinely obtained unless the appearance of the wound suggests infection. Narrow spectrum antibiotics are typically continued from down range until wound closure (10). Antibiotic coverage is routinely tailored to the responsible organisms if the wounds become infected (11). Factors that determine timing of wound closure include if the wound is clean on inspection at debridement. Other factors may include a down-trending fever curve and decreasing white blood cell count (12). In the future, the use of cytokine panels to predict wound readiness for closure and analysis of wound effluent may be routine objective measurements for timing of wound closure (13).

Pelvis Fractures

Dismounted personnel are injured from the primary blast as well as secondary and tertiary blast effects. These mechanisms lead to extremely high-energy injuries that often result in highly unstable (Tile type C) pelvic ring injuries. Although tourniquets have been highly effective in this conflict, their use in open pelvic injuries is limited due to the inability to gain circumferential compression and occlude blood flow. As a result, massive, early hemorrhage and shock are common. Bleeding from pelvic ring injuries, however, may not be readily apparent; therefore, the unstable pelvic fracture must be recognized quickly during the primary survey through a thorough physical exam that includes the search for open injuries, external lacerations and those involving the rectum or genitourinary system. Urethral and bladder injuries are often signified by blood at the urethral meatus or inability to pass a foley catheter. An anterior posterior radiograph of the pelvis, preferably with inlet and outlet views, is also required as it is often the most expedient method available to accurately determine the extent of posterior pelvic ring gross instability: the harbinger of life-threatening hemorrhage. CT scans, particularly with multi-planar reformats, are also helpful in identifying fractures of the sacrum and lower lumbar vertebra, which are commonly associated with these high-energy injuries.

Following the initial resuscitation phase of treatment, attention should turn to the management of open wounds that communicate directly with the pelvic ring disruption. Gross contamination with shrapnel and earthen debris is commonplace, and all fascial planes and intermuscular intervals must be opened and thoroughly cleaned. In isolated cases a partial or complete hemipelvectomy may be required to gain access to contaminated intrapelvic structures. Injuries involving the rectum require diversion of the fecal stream with formal colostomy. The use of negative pressure dressings have been used effectively in managing these wounds and are popular among nursing personnel, obviating the need for frequent dressing changes which can be tremendously painful to the patient. Care must be taken to ensure that these devices are functioning properly, especially during periods where wound evaluation is difficult, i.e., during medical evacuation either by land or air. Wounds subjected to a negative pressure dressing that have lost suction can accumulate pools of fluid that serve as an optimal media for bacterial growth. This is particularly problematic in open pelvic wounds.

Once wounds are stabilized, they are generally fixed utilizing well-established techniques for pelvic ring stabilization including external fixation, plates, screws, and sacroiliac fixation. This fixation occasionally can be modified by utilization of shorter segment fixation in the case of short amputation levels as the weight of the extremity no longer is acting as a lever arm to stress the construct (Fig. 1). Once the pelvis has been stabilized, soft tissue coverage is achieved with novel flaps relying on rotational flaps. Flaps can be rotated in from the limbs or the flank. In limited cases where soft tissue coverage cannot be achieved with local flap coverage, wounds are allowed to granulate in. Alternatively, extremely large wounds unable to granulate because of exposed bone are frequently treated with a limited hemipelvectomy (discussed in a subsequent article) in order to reduce the size of the wound to facilitate coverage. This coverage is often complicated by the development of heterotopic ossification requiring subsequent removal (Fig. 2).

Upper Extremity Limb Salvage

Complex upper extremity injuries frequently occur as part of the DCBI (Figure 3) (1). While treatment of these injuries is critically important to the recovery of function, they may receive relatively little attention at forward surgical field hospitals while life-saving damage control resuscitative surgery is performed. Time and

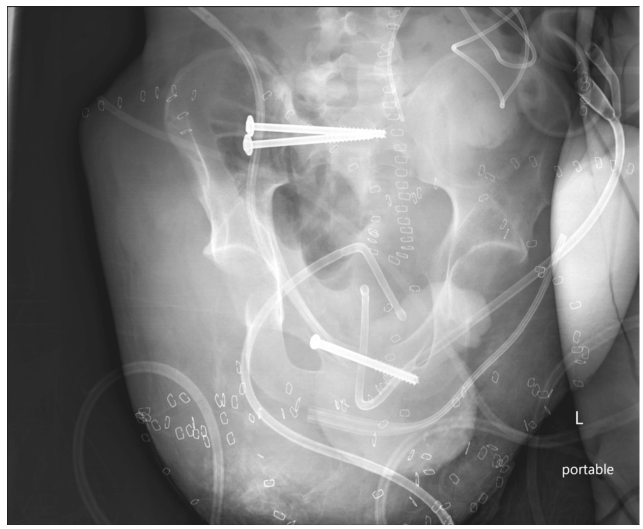

FIGURE 1 Limited pelvic fixation in bilateral hip disarticulation.

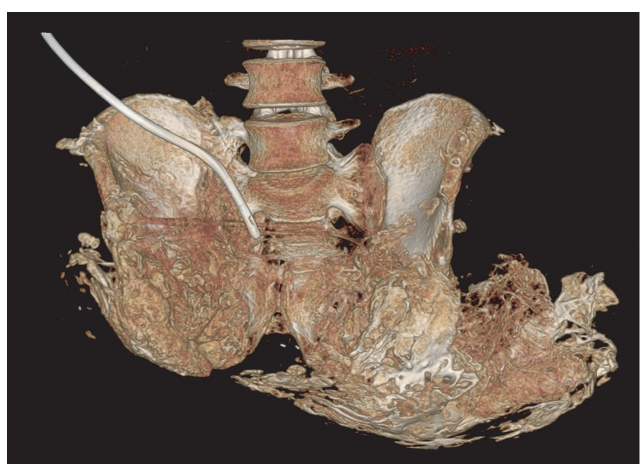

FIGURE 2 Heterotopic Ossification development in severe pelvic open fracture.

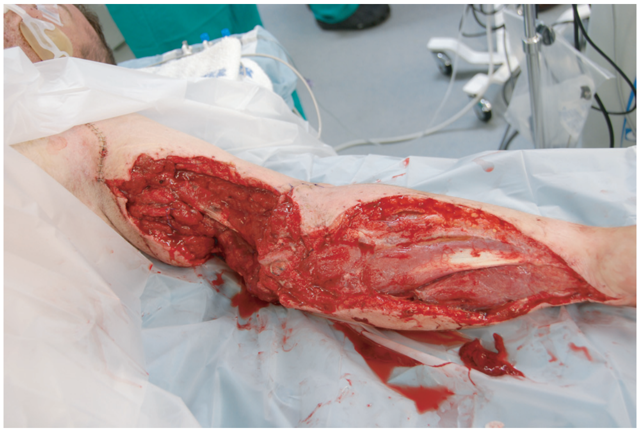

FIGURE 3 Mangled upper extremity from combat.

patient condition permitting, upper extremity wounds are grossly debrided, fasciotomies performed as indicated, rapid external fixation is applied for long bone and unstable elbow fractures, and splinting often performed for mangled hand injury. Vascular injuries in limbs are treated with vascular shunts until primary repair or vein reconstruction can be performed in the appropriate setting. Once the patient is stabilized and at a higher echelon of care, surgical management then proceeds to include staged debridement and irrigation of wounds, surgical stabilization of fractures, identification and tagging of critical structures such as injured nerves and tendons, and temporary soft tissue coverage. Temporary stabilization of fractures is typically accomplished with the use of Kirschner wires and/or external fixation. Temporary soft tissue coverage may be obtained with standard wet-to dry gauze dressings at lower echelons of care, but usually transition to negative pressure dressings at higher levels of care until definitive soft tissue coverage can be performed. Use of prophylactic and directed perioperative antibiotics has been discussed previously (14).

Tissue that is viable but may serve no functional importance should be saved for potential use to augment other tissue defects in "spare parts" fashion. Examples of this include fillet flaps, digital nerve transfers, and tendon and bone grafts from amputated digits to reconstruct other parts of the hand (15). Definitive treatment of combat hand injuries may occur when wounds have been cleared of all devitalized tissue and free of infection, typically accomplished after serial debridement procedures. Long bone fracture and elbow peri-articular injures are commonly treated with plate or intramedullary fixation as the soft tissue envelope allows, but often hand and wrist fractures are definitively treated with Kirschner wire or external fixation to limit soft tissue insult, edema, and its effects on rehabilitation (16). Soft tissue coverage is tailored to the individual needs of the wounds, and is usually accomplished with split-thickness skin grafts, full-thickness skin grafts, local fasciocutaneous and adipofascial flaps, and local pedicled flaps. Microvascular reconstruction with free tissue transfer utilizing fasciocutaneous, adipofascial and muscle flaps has been largely successful when local options are not available, with low failure rates consistent with reported rates in the literature (17). Acellular dermal matrix products such as Integra™ Bilayer Matrix wound dressing have been successfully used to allow for coverage of exposed bone and tendon with skin graft when fracture is absent or when more robust soft tissue coverage is required for future reconstructive efforts (18). Use of stem cell-mediated wound coverage products to improve wound healing rates, such as MatriStem® Wound Care Matrix, show promise, but results have not been reported to date in this patient population. The decision for delayed amputation of a perfused digit can be difficult for both surgeon and patient. All attempts must be made to salvage the thumb and allow optimal prehension. Segmental loss of bone, tendon, nerve, and skin, and options for reconstruction are all considered in the decision for digital salvage versus amputation, and currently no absolute indications exist to make this decision. Early and frequent consultation with occupational therapy specialists in a multidisciplinary fashion is critical to optimizing functional outcomes.

Major peripheral nerve injuries are commonly encountered in the upper extremity and can have devastating consequences to functional recovery. In the initial battlefield setting, severed nerve ends are identified and tagged for future repair or reconstruction. Definitive repair or reconstruction is often delayed until the soft tissue envelope is optimal. Nerve endings that may be coapted without tension are repaired primarily with suture. Use of autograft sensory nerve, such as sural nerve, remains the gold standard for reconstruction of segmental nerve defects. Decelllularized nerve allografts are increasingly being used in patients with bilateral lower extremity amputations and mangled upper extremities without optimal autograft sources. However, it is too early to report outcomes in comparison to autograft reconstruction in this patient population. For unreconstructable nerve injuries, selective nerve and/or tendon transfers are considered to improve resultant function (19). Research on use of directed stem cells, improved bioengineered nerve conduits, strategies to stabilize the nerve-muscle interface to prevent irreversible muscle atrophy, and use of decellularized and vascularized nerve grafts are all ongoing and have exciting potential (20).

Traumatic upper extremity amputations are frequently encountered in dismounted patrol IED blast injury. Very few patients elect for delayed amputation despite devastating soft tissue and nerve injuries because of significant limitations of current prosthetic options to return similar or better function than the compromised extremity. The most common amputation type is at the trans-radial level, and this level has the highest prosthetic use among all upper extremity amputees. All attempts should be made to salvage the elbow joint to preserve this level if reasonable length can be obtained, and include internal fixation of forearm fractures and use of free tissue transfer. Final closure of the amputation stump with a robust myodesis will optimize prosthetic use and function. Careful attention to identification of all distal nerve endings and use of traction neurectomy limits neuroma complications, frequently encountered in this patient population. The decision to perform a high traction neurectomy, however, must be weighed against the likelihood of subsequent patient consideration for composite tissue allotransplantation. Heterotopic ossification remains a challenge, frequently limiting motion, causing pain, and effecting prosthetic fitting. Reoperation for excision is frequent, and research efforts continue to identify its cause and produce more targeted treatments for this problem (21). The early and effective use of a multidisciplinary approach between the orthopaedic surgeon, physical medicine and rehabilitation specialists, occupational therapists, prosthetists, and wound care teams have been proven to accelerate treatment and rehabilitation of upper extremity amputees at military treatment facilities. Emerging technologies in targeted motor reinnervation to improve use of myoelectric prostheses, as well as continued improvements in immunosuppression to support composite tissue transfer, will likely change the way upper extremity amputations managed in the future (22).

Associated Injuries

The tremendous amount of energy imparted into the human body when exposed to explosive blast is directly related to proximity to the blast. Therefore, in a dismounted or unprotected situation, the vast majority of damage is directed to the lower half of the body closest to the explosion. In 2009, 86 US service members sustained major amputation, including 23 with multiple limb loss. By comparison, in 2010 there were 187 major limb loss casualties that included 72 patients who lost more than one limb (1). In addition to lower extremity amputations, injuries often involve the genitourinary system, the pelvis, the upper extremities, and to a lesser degree, the chest and head. Current body armor technology results in a lower percentage of abdominal injuries, but a higher proportion of genital injuries. While the scope of this article is to discuss the orthopaedic implications of complex blast injuries, it is important to recognize the significant social, psychological, and functional impact of associated injuries.

Urologic Injuries

In contrast to a reported baseline prevalence of 2.8% to 4.7% among combat-injured evacuations prior to 2009, urologic injuries were observed among US casualties transferred through Germany in between 13% to 19% of evacuees in the last quarter of 2010. When those who sustained major lower limb amputations were matched with those who also sustained genital injuries, the correlation approached 90% (23). While a large majority of these casualties retained at least one testicle, many required major reconstructions or complete loss.

Abdominal injuries

Recent reports on battle injuries sustained in Afghanistan document 91% survival (24). One study (1) evaluated 111 service members who died in 2010 as a result of blast injuries. Of these, 68 had multiple amputations, and 106 had severe body injuries. Death generally resulted in service members sustaining severe injuries, and nearly every case involved an associated penetrating head or torso injury. During this same period there was a corresponding increase in the number of evacuees requiring massive transfusions (i.e., greater than 10 units of blood) from 91 to 165. By way of comparison, the 2007 surge in Iraq, the highest casualty-producing year in OIF, produced 216 amputees, of whom 60 had multiple limb amputations. The correlation with survival in the face of DCBI appears most consistent in the absence of penetrating abdominal or pelvic trauma (24).

Traumatic Brain Injury

Of note, though patients with DCBI universally sustain moderate to severe traumatic brain injuries (TBI), the overall prevalence of TBI does not appear higher in the dismounted setting. Several theories include the absence of a confined space for the pressure, and dispersal of fragments. Regardless of the difference, a significant number of individuals complain of memory and visual disturbances; balance and cognition deficits that are increasingly screened as positive for mild TBI (25).

Future Direction

The successful treatment of DCBI rests on acute resuscitation of these extremely severe injuries, aggressive surgical management, and the multidisciplinary nature of care throughout all phases of treatment. Perhaps the single most important feature is the tremendous increase in resources required to care for these patients. From initial injury through the evacuation chain into one of several definitive reconstructive centers additional resources often include massive resuscitations, three or four simultaneous surgical teams and operative support. These requirements are highlighted and quantified in a subsequent article within this issue. Expertise at rehabilitative centers across the nation is growing, and the challenges encountered include obtaining suitable housing and aids for daily living, multiple prostheses, behavioral health, and reintegration into society

Conclusion

The DCBI is an emerging pattern of disease characterized by proximal bilateral lower extremity amputations, open pelvic fractures, abdominal injury, genitourinary injury and a non-dominant upper extremity amputation. Initial resuscitation and multidisciplinary surgical management appear to be the keys to survival. Definitive treatment follows general principals of open wound management and includes decontamination through aggressive and frequent debridement, hemorrhage control, viable tissue preservation, and appropriate timing of wound closure. These devastating injuries are associated with paradoxically favorable survival rates, but associated injuries and higher amputation levels lead to more difficult reconstructive challenges. One of the most inspiring characteristics of these warriors is a universal pragmatism and acceptance of their injury, each demanding a higher level of function in future life. These challenges stimulate us, as surgeons and researchers, to provide the optimal reconstructive platform and thus, enable our colleagues in rehabilitation science to help patients achieve their functional goals.

References

1. Caravalho, J., et al. Dismounted Complex Blast Injury Report of the Army Dismounted Complex Blast Injury Task Force. June 2011. http://www.armymedicine.army.mil/reports/DCBI%20Task%20Force%20Report%20(Redacted%20Final).pdf
2. Kragh, J.F., Jr, Littrel, M.L., Jones, J.A., et al. Battle Casualty Survival with Emergency Tourniquet Use to Stop Limb Bleeding. J. Emerg. Med. Aug 28 2009 [Epub ahead of print].
3. Dubose J, et al. Bilateral Internal Iliac Artery Ligation as a Damage Control Approach in Massive Retroperitoneal Bleeding after Pelvic Fracture. J. Trauma. 69(6):1507–1514, 2004.
4. Joint Theater Trauma System Clinical Practice Guideline: Management of high bilateral amputations, 2011.
5. Covey, D.C. Combat orthopaedics: A view from the trenches. J. Am. Acad. Orthop. Surg. 14:S10–S17, 2006.
6. Czerniecki, J.M. Rehabilitation in limb deficiency. Arch. Phys. Med. Rehabil. 77(3 Suppl):S3–8, 1996.
7. Gordon, W.T., O'Brien, F.P., Strauss, J.E., Andersen, R.C., Potter, B.K. Outcomes associated with the internal fixation of long-bone fractures proximal to traumatic amputations. J. Bone Joint Surg. Am. 92(13):2312–8, 2010.
8. Potter, B.K., Burns, T.C., Lacap, A.P., Granville, R.R., Gajewski, D.A. Heterotopic ossification following traumatic and combat-related amputations. Prevalence, risk factors, and preliminary results of excision. J. Bone Joint Surg. Am. 89(3):476–86, 2007.
9. Hospenthal, D.R., Murray, C.K., Andersen, R.C., et al. Guidelines for the prevention of infections associated with combat-related injuries: 2011 update: endorsed by the Infectious Diseases Society of America and the Surgical Infection Society. J Trauma. 2011.
10. Murray, C.K., Obremskey, W.T., Hsu, J.R., et al. Prevention of Combat-Related Infections Guidelines Panel. Prevention of infections associated with combat-related extremity injuries. J. Trauma. 71(2 Suppl 2):S235–57, 2011.
11. Hospenthal, D.R., Murray, C.K., Andersen, R.C., et al. Guidelines for the prevention of infections associated with combat-related injuries: 2011 update: endorsed by the Infectious Diseases Society of America and the Surgical Infection Society. J. Trauma. 71(2 Suppl 2):S210–34, 2011.
12. Hawksworth, J.S., Stojadinovic, A., Gage, F.A., et al. Inflammatory biomarkers in combat wound healing. Ann. Surg. 250(6):1002–7, 2009.
13. Hahm, G., Glaser, J.J., Elster, E.A. Biomarkers to predict wound healing: the future of complex war wound management. Plast. Reconstr. Surg. 127 Suppl 1:21S–26S, 2011.
14. McKay, P.L., Nanos, G.P. Chapter 2: "Initial Evaluation and Management of Complex Traumatic Wounds", Master's Techniques in Orthopedic Surgery- Soft Tissue Surgery, Lippincott Williams & Wilkins, 2009.
15. Brown, R.E., Wu, T.Y. Use of "spare parts" in mutilated upper extremity injuries. Hand Clin. 19(1):73–87,vi, 2003.
16. Freeland, A.E., Lineaweaver, W.C., Lindley, S.G. Fracture fixation in the mutilated hand. Hand Clin. 19(1):51–61, 2003.
17. Kumar, A.R., Grewal, N.S., Chung, T.L., Bradley, J.P. Lessons from the modern battlefield: successful upper extremity injury reconstruction in the subacute period. J. Trauma. 67(4):752–7, 2009.
18. Helgeson, M.D., Potter, B.K., Evans, K.N., Shawen, S.B. Bioartificial dermal substitute: a preliminary report on its use for the management of complex combat-related soft tissue wounds. J. Orthop Trauma. 21(6):394–9, 2007.
19. Boyd, K.U., Nimigan, A.S., Mackinnon, S.E. Nerve reconstruction in the hand and upper extremity. Clin Plast Surg. 38(4):643–60, 2011.
20. Kang, J.R., Zamorano, D.P., Gupta, R. Limb Salvage with major nerve injury: current management and future directions. J. Am. Acad. Orthop. Surg. 19:S28–S34, 2011.
21. Potter, B.K., Burns, T.C., Lacap, A.P., Granville, R.R., Gajewski, D.A. Heterotopic ossification following traumatic and combat-related amputations. Prevalence, risk factors, and preliminary results of excision. J. Bone Joint Surg. Am. 89(3):476–86, 2007.
22. Tintle, S.M., Baechler, M.F., Nanos, G.P., 3rd, Forsberg, J.A., Potter, B.K. Traumatic and Trauma-Related Amputations: Part II: Upper Extremity and Future Directions. J. Bone Joint Surg. Am. 15:92(18):2934–45, 2010.
23. Paquette, E.L. Genitourinary Trauma at a Combat Support Hospital During Operation Iraqi Freedom: The Impact of Body Armor. J. Urol. 177:2196–2199, 2007.
24. Joint Theater Trauma Registry, Institute of Surgical Research; Accessed 4 April 2011.
25. Hoge, C.W., McGurk, D., Thomas, J.L., et al. Mild Traumatic Brain Injury in U.S. Soldiers Returning from Iraq. N. Engl. J. Med. 358(5):453–63, 2008.