MILITARY AND CIVILIAN BURN INJURIES DURING ARMED CONFLICTS

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SUMMARY. Burn injury is a ubiquitous threat in the military environment, and war burns have been described for more than 5,000 years of written history. Fire was probably utilized as a weapon long before that. With the ever-increasing destructive power and efficiency of modern weapons, casualties, both fatal and non-fatal, are reaching new highs, particularly among civilians who are becoming the major wartime targets in recent wars, accounting for most of the killed and wounded. Even though medical personnel usually believe that a knowledge of weaponry has little relevance to their ability to effectively treat injuries and that it may in some way be in conflict with their status, accorded under the Geneva and Hague treaties, it is imperative that they know how weapons are used and understand their effects on the human body. The present review explores various categories of weapons of modern warfare that are unfamiliar to most medical and paramedical personnel responsible for burn treatment. The mechanisms and patterns of injury produced by each class of weapons are examined so that a better understanding of burn management in a warfare situation may be achieved.

Introduction

Wars and their hardships have plagued humanity since the dawn of time.[1] They are endemic in nature, with periods of exacerbation and remission,[2] and are shown at present at least twice a day on the morning and evening news.[3] The recorded history of mankind is a relentless succession of violent conflicts and conquests. War burns have been described for more than 5,000 years of written history, and fire was probably utilized as a weapon long before. The invention of gunpowder and sophisticated explosives turned battlefields into burning infernos and changed for the worse the odds against protective measures.[4] Wars and armed struggles will unfortunately continue to be waged as long as human ambitions for domination persist and differences between groups and nations are not mitigated by mutual understanding and tolerance and are resolved by force of arms, not by dialogue.

Trauma is the most important public health risk in wartime.[5] During any war situation, past or present, a wide range of patterns of wounding are usually seen and treated among both military personnel and civilian population.[6-8] However, as recent events show, no conflict is a fact of the past.[5] In the last century and, in particular, during the first years of this present century, each armed conflict has proved to be unique, particularly in its medical aspects, each with its own features and each teaching its own lessons.[5] War patterns are changing. Classical conflicts between opposing armies in open fields belong to the past.[9] The target is no longer the destruction of the opposing army, but rather the destabilization of the opponent's political, social, cultural, and psychological infrastructure.[2] In recent wars, non-combatant civilians are more often placed in the line of fire and are becoming major targets accounting for most of the killed and wounded.[10] Children, in particular, constitute the majority of the victims of present-day conflicts, with a trend towards a greater proportion of injuries from powerful explosive devices such as artillery shells and mines.[2]

The use of armoured vehicles since the First World War has created a subset of casualties with a different epidemiology from that of infantry soldier casualties.[9] Moreover, evolving tactics of urban warfare and terrorism using more complex, sophisticated, and devastating weaponry as well as the emergence of religious fanaticism have raised the violence of present-day conflicts to an unprecedented sinister level of cruelty and barbarism. Explosive devices directed against both civilian and military targets are frequently used in modern wars or acts of terrorism.[2] With ever-increasing destructive power and efficiency, casualties, fatal as well as non-fatal, are reaching new heights, with different wound patterns, nature, severity, and extent, reflecting the type of weaponry utilized.[10,11] The resultant injuries frequently outnumber those from gunshots, with many innocent civilians becoming victims.[12] Explosions can produce classic injury patterns from blunt and penetrating mechanisms to several organ systems, but they can also result in unique injury patterns to specific organs including lungs and the central nervous system. Understanding these crucial peculiarities is critical to managing such injuries.[12]

Burns and injuries from shrapnel fragments or small arms are the most common wounds to be expected in modern conventional conflicts.[13] Burn injury is a ubiquitous threat and its risks to military personnel during combat are well recognized.[14] Over the last hundred years, the burn threat has ranged from small shoulder-launched missiles to nuclear weapons. Materials such as napalm and white phosphorus plainly present a risk of burn, but the threat extends to encompass also personnel in vehicles attacked by anti-armour weapons, large missiles, fuel-air explosives, and detonations/conflagrations on weapons platforms such as ships.[14] While advances in protective gear, not available for protection of civilians, such as helmets and body armour combined with faster, more efficient battlefield medical care and even better appreciation of resuscitation and life-support measures are saving lives and getting heightened attention from both the military and the medical profession, these protective measures cannot keep soldiers from being injured or killed.[15] The new armoured Kevlar vests composed of a multiple-layer mesh of woven fabrics that soldiers are wearing in the present war in Iraq, for example, stop projectiles and bullet rounds, efficiently protecting the human torso, and have definitely saved countless lives. Unfortunately the surviving victims are often paying a terrible price and are left with serious mutilations and handicaps from burns and shrapnel wounds over body areas not protected by the vest.[15]

Though the firepower utilized in modern-day conflicts has increased, lethality has been decreasing gradually owing to changes in the strategies and systems of battle care.[16] In World War II, 30% of the Americans injured in combat died. In Vietnam, the proportion dropped to 24%. In the war in Iraq and Afghanistan, about 10% of those injured have died.[16,17] Though burn injuries that were fatal just a few years ago no longer are so, with rapid and proper response,[18] burns are still complicated injuries that require lengthy therapy and treatment,[15] particularly when they are complicated by other serious injuries. As the technology of weaponry advances, the number and severity of burn injuries will certainly increase.[18]

Good management of burn injuries during armed conflicts starts with a good understanding of the mechanisms of injury and the properties and characteristics of the offending agents. Various weapons may result in a higher incidence of killed in action than others that may produce a greater incidence of burns and penetrating wounds. Kamikaze attacks for example have yielded significantly more burns than incidents involving bombs, gunfire, torpedoes, mines, and multiple other weapons, whereas mine explosions were responsible for more strains, sprains, and dislocations than the other weapon types.[19] Even though medical personnel usually believe that a knowledge of weaponry has little relevance to their ability to effectively treat injuries and, in some way, may be in conflict with their status accorded under the Geneva and Hague treaties, it is imperative for them to understand the forces at work when casualties are sustained and how weapons are used and to understand their effects on the human body. This knowledge will allow the soldier medic and civil rescue worker to accurately assess the nature and extent of injuries. It also enables them to predict more accurately the number and type of casualties that may result from a combat action so that adequate medical support can be arranged and more effective treatment and evacuation decisions may be taken. The end result will certainly be a reduced death rate and morbidity; moreover, countermeasures and protective equipment can be more adequately designed.[20]

Weapons of modern conventional and asymmetric (terrorist) warfare

Changing trends in the nature of injuries during war - clearly illustrated in textbooks of military medicine - are the result of weapons development.[21] The majority of casualties in the First and Second World Wars suffered one relatively large, penetrating injury or only a few. The anti-matériel munitions that have been introduced since World War II, with the American-made bazooka, have however changed the nature of injuries caused by small particles of burning aluminium to multiple penetrating wounds and deep burns. Likewise, high-kinetic-energy munitions that penetrate armoured vehicles, buildings, and fortifications create a cloud of blown-out fragmentation debris causing similar injuries. The introduction of these new munitions added also more burns to the casualty case mix of warfare.[4]

Modern-age weapons can be categorized into explosive munitions and small arms[22] specifically designed to inflict physical harm by wounding with bullets or fragments, by damaging internal organs with blast shock waves, and by burns.[20] There are three types of wounding agents common to all weapon systems employed in conventional warfare: projectiles (bullets) that are fired from small arms; primary and secondary missiles created by explosive munitions (artillery, grenades, mortars, bombs, and hand grenades); and flame and incendiary chemicals used in incendiary munitions.[20] Improvised explosive devices (IEDs), commonly used in terrorist attacks, are yet another particular category of injurious agents with specific and complex wounding patterns.

Projectiles and small arms

Two areas of projectile-tissue injury interaction for small missiles are recognized: permanent cavity and temporary cavity. The permanent cavity is a localized area of cell necrosis proportional to the size of the projectile as it passes through the tissues. The temporary cavity on the other hand is transient lateral displacement of tissues which occurs after passage of the projectile. Elastic tissues such as skeletal muscle, blood vessels, and skin may be pushed aside after passage of the projectile, but then rebound. Inelastic tissues, on the other hand, such as bone or liver, may fracture.[22] The shock (or sonic) wave of small bullet missiles (commonly mistaken for the temporary cavity), though measurable, has not been shown to cause tissue damage.[20] With such projectiles, burn injuries, obviously, are not dominant.

Explosive munitions

The type and severity of wounds sustained due to explosive munitions are usually a complex mix of ballistic, blast, and burn injuries primarily dependent on the casualties' distance from the epicentre of the explosion.[20,22] A blast produces an instantaneous chain of events in which an explosive material is rapidly converted from a solid or liquid form into a gas, with resultant energy release under extremely high temperatures and pressures.[23,24] The generic prototype of exploding munitions is the shell. Anti-personnel exploding munitions, most commonly encountered in the form of grenades, rockets, bombs, and mines and anti-material munitions that have anti-personnel effects, including Kinetic-Energy Anti-material Warheads (e.g. Armour Piercing Fin Stabilized Discarding Sabot fired by tanks), rely on the projectile's speed and density to disable or destroy the target. Explosive Anti-material Warheads (e.g. Light Anti-tank Weapon [LAW], Anti-tank 4 Rocket [AT4]) are most commonly found in the form of a shaped charge or hollow charge warhead.[20] Modern explosive devices are designed to spread more uniform fragments in a regular pattern over a given area and cause ballistic injuries by fragments from the casing and/or the target itself.[20,22] The effects of the blast overpressure waves are exerted relatively close to the exploding munition. Injury from blast overpressure is pressure- and time-dependent and its severity increases as the pressure or its duration increases.[22] The thermal effects of exploding munitions are the result of heat and flame generated by the detonation of the explosive filler material in the munition casing and/or the result of secondary fires started on the target caused by ignited fuel, ammunition present on the target site, or hydraulic fluid.[20,22]

Casualties close to the epicentre of the explosion are likely to suffer from all three wound-causing factors and also usually from mutilating blast injury. The victims are not likely to survive. Casualties farther away from the epicentre are likely to experience a combination of blast from the explosion and penetrating trauma from primary and secondary missiles created by the explosion.[20] Victims wounded near exploding on-site munitions or when the target catches fire may have burns in addition to open wounds, which will complicate the management of soft-tissue injuries.[20,22] The further the distance from the explosion, the less likely burns will be suffered.[20]

Flame, incendiary, and phosphorus-containing munitions

Flame, incendiary, and phosphorus-containing munitions are weapons that use a combustible material source to expel people from strongholds or hidden positions and to destroy material. Although flame (aerial-delivered, such as napalm bombs, flame-throwers, rocket-launched warheads) and incendiary (aerial-delivered bombs, grenades) munitions theoretically constitute separate classes of weapons, they both use fire as the means to achieve the objectives.[20] Many anti-personnel weapons employed in modern warfare contain white phosphorus.[25] Phosphorus-containing munitions (aerial-delivered bombs, artillery shells, grenades) ignite spontaneously in air at 111.2 degrees Fahrenheit (44 degrees Centigrade) and produce flames of 1,472 degrees Fahrenheit (800 degrees Centigrade).

Phosphorus munitions will continue to burn until deprived of oxygen or totally consumed.[20] As for any other chemical burn, the depth and severity of phosphorus burns are related to both the concentration of the agent and the duration of contact with the tissues.[25] Dermal penetration with deep burns and tissue necrosis result from continued contact of the skin with phosphorus.[20] Also, fragments of this metal may be driven into the soft tissues. However, most of the cutaneous injuries resulting from phosphorus burns are due to the ignition of clothing and are treated as conventional thermal injuries.[26] Combustion of white phosphorus also results in the formation of phosphorous pentoxide, a severe pulmonary irritant, which in a closed space may reach concentrations sufficient to cause acute inflammatory changes in the tracheobronchial tree.[25]

Improvised explosive devices and asymmetric warfare - terrorism

Terrorist bombings will continue to be a difficult problem into the foreseeable future.[12,26] Given the growing threat of terrorism and the fact that the vast majority of terrorist acts involve the use of explosive devices, hospital clinicians must be familiar with the injury patterns, treatment issues, and terminology surrounding explosive incidents.[23] Terrorist bombs, also known as improvised explosive devices (IEDs), are usually custom-made, may use any number of designs or explosives, and are of two types: 1. conventional, which are filled with chemical explosives and 2. dispersive, which are filled with chemicals and/or other projectiles such as nails, steel pellets, screws, and nuts designed to disperse.[26] Temperatures from the explosive gases can reach 3000 degrees Centigrade (5432 degrees Fahrenheit) and may result in fatal third-degree burns in victims close to the detonation.[26]

On the basis of the speed of the explosion, explosives are categorized as either high-order explosives (HE) or low-order explosives (LE)[23] with different thermal effects. HE explosives involve supersonic explosions (the explosive detonates more quickly than the speed of sound) and blast overpressurized impulse waves. Examples of HE include hand grenades, TNT, military bombs, dynamite, C-4, Semtex (a plastic explosive), diesel fuel, fertilizer, nitroglycerine, and ammonium nitrate fuel oil. HEs produce higher temperatures for shorter periods of time, usually resulting in a fireball at the time of detonation. LEs, on the other hand, involve deflagration (rapid burning that gives off intense heat and sparks), not detonation. These explosions are subsonic (the explosive reaction is slower than the speed of sound) and lack the overpressurized waves of HE. Examples include napalm, pipe bombs, gunpowder, Molotov cocktails, and aircraft improvised as guided missiles, plus many petroleum-based explosives. LEs usually cause secondary fires.[23,26,27] The HE 'blast wave' (overpressurizing component) should be distinguished from 'blast wind' (forced superheated air flow). The latter may be encountered with both HEs and LEs.[23,28]

There are three typical patterns of terrorist attacks: 1. individual attacks with guns; 2. group or collective attacks using explosives under vehicles, tramp bombs, or "bomb vehicles" resulting in casualties of different severity with wounds, burns, and blast injuries; and 3. mass attacks with "bomb vehicles" in buildings or crowded public places resulting in elevated numbers of victims and producing brutal social consequences.[29] No two events are identical, and the spectrum and extent of injuries produced varies widely.[12] However, when they do occur, they have the potential to inflict multi-system life-threatening injuries on many persons simultaneously. Invariably, blast-related injuries are complex. Explosions can produce classic injury patterns from blunt and penetrating mechanisms to several organ systems, but they can also result in unique injury patterns in specific organs, including the lungs and the central nervous system, seldom seen outside combat. The injury patterns are a product of the composition and type of the bomb as also of the amount of the materials involved, the surrounding environment, the delivery method, the distance between the victim and the blast, and any intervening protective barriers or environmental hazards. Because they are relatively infrequent, they can present unique triage, diagnostic, and management challenges for the health care providers.[12,23,26,28] A bomb blast casualty may present with a primary blast injury, such as "blast lung", and may also suffer from penetrating glass shards, traumatic amputation, inhalation injury, deafness, and - in particular - burns.[23] Understanding these crucial peculiarities is critical for the management of casualties.[12]

The mechanisms of injury resulting from explosions include direct exposure to the blast wave, reflective blast waves, acceleration-deceleration forces, penetrating and non-penetrating wounds, burns and inhalation of toxic gases, and building collapse.[23] More specifically, injury patterns for low-order explosives are produced by shrapnel primary fragments (part of the weapon), secondary fragments (as a result of the explosion), blunt forces, crushing, and burns. HE, on the other hand, are generally characterized by four types of injury levels and patterns: primary, secondary, tertiary, and quaternary.[2,23,24,30-32] Primary blast injury is a direct result of the overpressurization wave's impact on the body, involving the lungs, the ears, gas-containing viscera, the brain, and the eyes, and leads to the mostly fatal "blast lung". Secondary injuries result from flying debris and bomb fragments. Tertiary injuries occur as a result of individuals being thrown by the blast wind, and quaternary blast injuries are defined as any explosion-related injury or illness not due to any of the above, such as burns (chemical or thermal) and inhalation injuries. Survivors rarely present primary injury patterns, and casualties suffer mostly from secondary, tertiary, and quaternary blast effects.[23] Flash or flame burns are encountered in 45% of the victims of explosions and bombings occurring in confined spaces, in 11% in the open, and 14% in bombings associated with structural collapse.[23,33]

Warfare burn injuries

Warfare burn injury was largely ignored. It was brought to the forefront of Army Medical Corps planning at the end of World War II. The atomic detonation at Hiroshima in 1945 instantaneously generated 59,500 burn casualties. That massive number and a comparable number of burns at Nagasaki alerted the Army to burn injury as being a major problem in future conflicts, refocusing the Army's Surgical Research Unit on the problem of burns and their management.[34,35] Materials such as napalm and white phosphorus plainly present a risk of burn, but the threat extends to encompass personnel in vehicles attacked by anti-armour weapons, large missiles, fuel-air explosives, and detonations/conflagrations on weapons platforms such as ships.[14] Sulphur mustard, a vesicant blistering agent producing chemical burns, has been used extensively in the past. The potential use of mustard gas in present-day conflicts remains a significant threat that would result in a large number of casualties with severely incapacitating partial-thickness burns characterized by considerably slower wound healing.[11,36]

Combat and non-combat burn injuries of military personnel

Military burns result from either combat or non-combat causes. Waste burning, ammunition handling, and gasoline cause most non-combat injuries, while the majority of combat injuries, which account for 63% of burn injuries among military personnel, result from explosive device detonation.[37] More specifically, war combat burns can be classified as those that are caused by incinerating materials (such as fuel-air bombs, napalms, phosphorus munitions, etc.), flash injuries due to exposure to the high temperatures of explosives, flame burns (mostly secondary to burning fuel, vehicles, buildings, or shelters that were ignited by explosives), contact burns from hot objects in the hostile battlefield environment, scalds from steam or hot fluids that were released by a direct hit or damaged machinery, chemical burns from blistering warfare agents or leakage of chemicals used or stored in the immediate environment of the injured, accidental electrical burns or burns that were caused by laser beams, and last but not least radiation burns due to exposure to nuclear weapons.[4]

Thermal injuries historically constitute approximately 5 to 20% of conventional warfare military casualties, depending largely on the tactical situation.[34,38-41] One point five per cent of all Second World War casualties were burns nevertheless, causing a tremendous load on hospitals, especially in Britain, during the early stages of the War.[4,42] The threat from burns unfortunately is unlikely to diminish.[11,14] During the Korean War burns constituted 1% of all battle casualties and 1.3% of non-battle injuries. It grew to 4.6% in Vietnam, 8.1% in the Yom Kippur War in Israel, and 14% in the Falklands War.[4,42] Large numbers of burn casualties were caused at Pearl Harbor and during the Arab/Israeli Wars. Data regarding active-duty soldiers injured in the Persian Gulf War revealed that reported burns constituted 6% of the injuries.[35] Burn injuries constituted 2.5% in Afghanistan, 7.0% in Tadjikistan, and 3.9% in Chechnya.[4,42,42] During the six-day Arab/Israeli War of 1967, 115 soldiers out of 2500 casualties suffered burn injuries. In 34 of them 15% or more of their body surface was involved.[44] It is not clear whether these statistics reflect isolated burn injuries only or include all burns with or without associated injuries. Anyway, burns are particularly common during war at sea and combat involving armoured fighting vehicles.[39] Two large studies from British World War II tank crewmen and from Israeli casualties in Lebanon showed that about one-third of living wounded casualties sustained burn injuries.[22] Other studies done on British soldiers and sailors during the Falklands War demonstrated that one-third to half of the casualties in that conflict had burns. One stick of bombs falling on a British ship resulted in 168 burn injuries.[18] The severity of the burns ranged from a mild first-degree burn to full-thickness burns requiring skin coverage.[22] Approximately 80% of the burns involved less than 20% TBSA, and were, per se, not life-threatening.[31,45]

Fortunately, serious burns are responsible for relatively few casualties in conventional warfare[20] and the majority of warfare burns among military personnel, probably unlike similar burns in the civilian population, are superficial burns to exposed skin, most often of the face, neck, forearms, and hands.[14,22] Typical features of these burn cases, however, are supplementary injuries from multiple fragment wounds, a high rate of infection, and long periods of hospitalization.[22,44] Even relatively small burns can be incapacitating, disfiguring, and painful and can strain the logistical and manpower resources of military medical units, overwhelming medical-resource allocation requirements.[20,39] Moreover, they cause serious psychological implications for both combat and medical personnel.[4,20]

Civilian burn injuries during warfare

Civilians are becoming the major targets in recent wars,[2,12,14,46] reflecting the sharp increase observed in civilian mortality and mordity.[1,47] In World War I, civilians accounted for 5 to 19% of all war-related deaths. In the World War II, civilian mortality increased to 48%. Today, civilians account for more than 80% of those killed and wounded.[1,2,48,49] Identification and classification of the numerator in civilian injury studies, however, is extremely difficult, because the definition of civilian versus military personnel in recent wars is blurred, and the classification coding is not adequate to deal with the various types of war trauma.[2,46,50] From the limited data available, specific trends can be delineated through the comparison of recent wars in terms of demographics, distribution of wounds by area of wounding, the lethality of wounds, and changes in the methods of fatal wounding.[2] In Eastern Slavonia, a comparison of gender and age distribution between civilian and non-civilian (paramilitaries, territorial defence, army) war victims revealed that more than 80% of non-civilian victims were males in the group aged 21-40 yr, whereas in the civilian population all age groups and genders were represented, including children younger than 10 yr and persons older than 90.[47] Similar demographics were found in Croatia,[50] Bosnia,[51] Lebanon,[52] and Afghanistan.[53] Whereas most casualties in earlier wars were caused by bullet wounds, recent wars have been marked by an increase in explosive wounds caused by fragmenting anti-personnel weapons such as rockets, artillery shells, mortar bombs, and mines.[2] Besides the increase in explosive wounds, recent wars have also been marked by an increase in burns and inhalation injuries. It is estimated that in modern warfare one injury in four is a burn.[4]

Peace-time burn injuries can also occur among civilians during warfare situations. They may be discussed under three main headings: domestic, industrial, and traffic. The causative agents may be open flame or flash, scald, chemical, or electrical.[6-8] Such civilian burn injuries, however, rarely simulate war injuries.[54] They are usually single, rarely associated with other serious injuries, and rarely result in mass casualties except in the event of a fire disaster.[55,56] Burn injuries combined with traumatic, chemical, or radioactive injuries are rarely encountered and often unrecognized in peace time.[57] Even during an ongoing war, the epidemiology and patterns of moderate to severe burn injuries among the civilian population may not be different from that of peace time. Moderate to severe burns (20-90% TBSA) affecting the local population treated at the Italian Red Cross Hospital in Baghdad demonstrated that the incidence of burn injuries sustained by the population admitted to the Burns Unit was particularly high for women and children, mostly occurring in the home environment, as in peace-time conditions, with a low incidence of war-related injuries.[57].

Morbidity and mortality of warfare burn injuries

Burns sustained in civilian life and those sustained under war conditions are different.[55] War-related burn injuries, even among civilians, are unlikely to be the only trauma[6-8] and are generally more extensive, deeper, more complicated, associated with inhalation injuries, and undertreated, compared with the "normal" case mix of accidental burns in our everyday life.[4,37]

Severe burns in a battlefield setting historically had a very low salvage rate. A recent American survey of military burn casualties among personnel involved in ongoing conflicts demonstrated, however, an improved mortality rate of 5% in combat and 2% in non-combat patients with equivalent percentage TBSA burned.[37] The same optimistic outcome was demonstrated in a study of the treatment of servicemen with combined burn injuries in the Chechen Republic, where the development of medical treatment systems made it possible to reduce lethality from 13.5% to 7.5% ($p < 0.05$).[58] Despite the severity of combat burns, mortality at present is low and outcomes generally good.[37] Nevertheless, the burden on military medical services in handling burn casualties is daunting, as all the physiological systems become affected.[59]

Unfortunately, the field of combined injury is relatively unfamiliar to burn surgeons.[60] On the whole, the mortality and morbidity of combined injuries is higher than that of injuries separately, and awareness of the possible injury associations is critical. As an example, cervical spine injury - uncommon in burn patients, except in those injured in explosions, high-speed vehicular accidents, and falls, or by contact with high-voltage electricity - if unrecognized may result in serious morbidity, if not mortality.[12,39] Moreover, burns are a "distracting injury". Treatment with narcotics of pain secondary to burns may make the clinical diagnosis of associated injuries such as spinal injury rather difficult.[39] It is evident that special medical care practices are required to manage armed conflict burns, whether affecting civilians or military personnel, that are different from practices usually applied to treat civilian-type burns.[54]

Burn and trauma management in warfare situations

War wounds, whether inflicted during conventional war or asymmetric warfare, as well as mass casualties, produce in general significant additional burdens and impose a heavy load on existing medical facilities and emergency, trauma, and critical care systems.[4,10,26] Within the military institution, management of battlefield casualties constitutes the climax of any military medical activity.[38] However, as armed conflicts are spreading and terrorist threats are not subsiding, and owing to new enhanced-blast munitions and some tactical considerations, military physicians, in addition to managing injuries of military personnel, are also required more and more to diagnose and treat mainly civilian primary blast injury casualties.[13] Most clinicians have considered caring for victims of explosions and bombings a remote possibility unless the provider is a member of the military or an overseas aid group. That is no longer the case.[24,26] Clinicians should be aware of the types of potential injury and of the appropriate management in these mass casualty situations so that definitive care can be provided to victims while utilizing hospital resources effectively.[26]

Although there are many similarities between civilian and military trauma care, multiple additional logistic challenges unique to the combat environment cause increased difficulty in effectively managing multiply traumatized war casualties[3,61] requiring a continuous chain of activities, starting with the first aid given by other servicemen and continuing with the measures taken by the medical corps men, the battalion (regimental) first-aid station, the medical company ('field ambulance'), etc.[38] The management of civilian casualties, whether during conventional conflicts or in asymmetric warfare, is no different, putting into effect mass disaster emergency plans and testing their efficacy.[19]

Needless to say, in peacetime it is rare to see the wide spectrum of injury encountered during armed conflicts, hence surgeons can be unaware of optimal management protocols to be followed.[62] The majority of military war injuries are inflicted on the battlefield, far away from advanced medical services, where evacuation to a rear hospital or even a basic medical echelon may be significantly delayed due to battle conditions, while medical teams work in life-threatening surroundings and under the emotional stress of the fighting zone.[4] Moreover, proper medical preparedness for mass burn casualties in military conflicts requires an active commitment to the full sharing of data on burns in the multitrauma patient.[4]

The circumstances of any given war and the available medical resources dictate the medical care delivered to war casualties.[10] The sheer magnitude of casualties often requires extensive infrastructure to support the surgeons on the battlefield and to care for the wounded.[63] In civilian practice, with optimum resources available, every burn patient receives emergency care and the seriously injured are transferred to a burn unit facility with optimum resources. In the combat setting, the tactical situation, logistical limitations, or limited availability of health care personnel may necessitate reduction in the upper limits of what is considered optimal care.[64] Medical care also depends on the importance that cultures or circumstances place on it: on the one hand, the "precious" casualty of western armies whose medical support is organized in a concept (forward medical and surgical care, ultra-rapid medical evacuation) tailored to each case, and as close as possible to the medical care of a civilian trauma patient whose models remain the North American ballistic wound managed in trauma centres; on the other, civilian victims in large numbers in poor, disorganized countries, often abandoned to their own fate or sorted by "epidemiological" triage which guarantees as efficient as possible a distribution of limited medical care. In war, advanced medical care and precarious medicine may work side by side according to two logics which do not exclude one another.[5,44] Moreover, as wars are changing in nature, military medical skills, training, and available resources must reflect these fundamental changes in preparation for future conflicts.[10]

The treatment of local burns in the field consists of bandaging, alleviation of pain, and treatment of shock by intravenous administration of fluids.[38] However, in mass casualty situations such as war, the fluid resuscitation of burn patients presents a formidable challenge. The possibility of overwhelming numbers of patients to be treated by inexperienced personnel dictates the adoption of a safe, simple and effective regimen that is computed in advance and displayed in simple tabular form.[65] Smoke inhalation, with subsequent respiratory difficulties, remains frequent major problem in the initial field management of burn victims.[38] Patients with small burns can be treated and returned to duty. Patients with a moderate burn that is all partial-thickness can be treated and then evacuated to the hospital closest to his or her home. Patients with more extensive burns associated with full-thickness skin loss can be further resuscitated and, when stable, safely evacuated.[13] The first-aid treatment of casualties with chemical burns and imbedded phosphorus particles requires immediate care of the burn wound. The offending agent must be washed from the body surface as soon as possible with copious water lavage and removal of the identifiable particles, following which the involved areas are covered with a saline-soaked dressing and kept moistened until the patient reaches a definitive treatment installation. If the transfer is going to require more than 12 h, the involved areas should be covered with a liberal application of topical antimicrobial agent to prevent microbial proliferation and the re-ignition of retained phosphorus particles.[25]

It has been mentioned that, in the best of circumstances, optimum treatment of war-related burn injuries results in salvage of approximately 50% of patients whose burns involve 60-70% of the total body surface[64] in contradistinction to a salvage rate of approximately 50% of young adults with civilian-type burn injuries whose burns involve 80% of the total body surface area (TBSA) or more.[39] With limited resources, available burn care resources should be applied to the group of patients in whom the greatest benefit will be realized, with less attention being paid to those with minor or more extensive burns.[64] In a battlefield triage scenario with resource restrictions or large numbers of casualties, expectant care should be considered for patients with burns that exceed 80%. Care can be delayed for patients with burns of 20% or less who are otherwise stable. Available care facilities and resources must be applied to those with burns in 20-70% TBSA.[39,64] With even greater restriction of health care availability, the upper limit of the maximum treatment group should be reduced by stepwise decrements of 10% until the surgical workload matches available resources.[64] Triage modifiers include significant coexisting inhalation injury and associated mechanical injury, each of which lowers the upper limit of the maximum treatment group by 10%. Conversely, burns in the hands, face, feet, and perineum in patients with lesser TBSA burns will increase the medical care necessary for such patients.[64]

Subsequently, an optimal medical-evacuation system during local armed conflicts and wars is essential. Evacuation of battle casualties is a complex operation and should be performed under medical supervision to ensure that appropriate care is given.[38] Western military surgeons have at their disposal a highly sophisticated, complex transportation system for rapid patient evacuation. All medical personnel must understand this system's advantages, limits, and potential. Undoubtedly, the judicious use of aeromedical evacuation markedly reduces the time lapse from injury to definitive care.[13] Evacuation is in two stages: initially to a first medical aid and resuscitation centre (Phase One), and then to specialized medical care services (Phase Two).[7,43,58] The decision to evacuate a patient by air to the next echelon should be made with the full knowledge of flight schedules, lag times, and the care available at each stage in the chain of evacuation. Every effort should be made to reduce the workload within the system to the essentials required for good patient care. The flight attendants should not be burdened with unnecessary dressing changes, topical medications, special diets, or other procedures that would distract them from caring for more seriously injured patients. Physicians at the originating hospital should ensure that the patient is ready to withstand the complications of the trip. Although the patient will be monitored by other physicians, it should not be assumed that they will have the opportunity to fully evaluate the patient en route. Physicians are reminded that patients with oxygenation or pulmonary-function problems at sea level may be expected to have increased difficulty at higher altitudes.[13] For routine aeromedical evacuation the patient should have stable vital signs, no active bleeding, and adequate hydration.[13] The importance of the inclusion of a surgeon in the aeromedical evacuation team and the usefulness of cling film as an initial burns dressing during evacuation were demonstrated by Operation Bali Assist following the Bali bomb explosions in 2002.[66]

In combat, the tactical situation can however prevent rapid evacuation towards definitive care, or a a casualty overload can tie up the surgical teams. All medical personnel and their supporting cadre should therefore be able to manage wounds and burns. Controlling bleeding and airways, cleaning and debriding wounds, and dressing or splinting injuries are essential knowledge as well as training for enlisted and officer personnel in all medical departments.[67] Experience of a UK reserve field surgical hospital during military operations in Iraq in March/April 2003 demonstrated the importance of the integration of surgical specialties and of consultant-led and multidisciplinary team-working in the treatment of military and civilian casualties from all sources and of all causes.[67] The close integration of general, orthopaedic, plastic-reconstructive, maxillofacial, ophthalmic, and neurological surgeons and general and intensive treatment unit anaesthetists allowed the delivery of a range of specialist treatment to a heterogeneous patient population, including children as young as 6 months and a lady in the advanced stages of pregnancy.[67] The range of casualties treated by the Defence Medical Services in the recent Gulf conflict reaffirmed the important role of plastic and reconstructive surgery within the military.[67]

Mass burn injuries, psychological health, and the treating team

Psychological problems are a frequent component of the response to burn injury. Burn victims often display symptoms that can impede recovery, causing severe long-term impairment, both physical and psychological.[68] Psychiatric problems frequently seen in burn patients are depression and post-traumatic stress disorder (PTSD), characterized by a fear reaction during the trauma and subsequent intrusions, avoidance, and hyperarousal.[68-73] The rate of PTSD among burn victims varies between 9 and 35% at 2 to 4 months after the burn injury.[68,74] Unfortunately, the extent to which psychological factors such as coping style predict the psychological outcome for burn patients is not well understood.[68,75] The true incidence of post-traumatic stress disorder after combat burn injury and how best to prevent or treat it also remain important unresolved questions.[76] Nevertheless, a variety of services must be provided at any burns centre. It is important to provide families with free lodgings near the burns care facility. Soldiers should be supported by events such as award ceremonies and visits by military leaders and dignitaries. It is generally believed that having the burns service members grouped in one location facilitates this type of support and probably has intangible benefits from a morale standpoint.[76]

Although physicians, nurses, and paramedical personnel routinely deal with crises, the rapid influx of patients with multiple burns, particularly in the context of conventional or asymmetric warfare, tests the adaptability of any medical facility as well as the physical and psychological stamina of the treating team.[77] During the crisis, the emergency team usually encounters a surreal treatment environment and has little time to understand the magnitude of the unfolding disaster. Despite frequently uncomfortably hot conditions in a crowded emergency facility or department and pungent odours of burned flesh and toxic residue, the staff usually remains focused on the basics and clinical aspects of patient trauma care.[77] It is only after the acute crisis has passed that the full-blown emotional impact on the emergency staff becomes manifest. Usually nurses repeatedly speak about the overwhelming psychological effects of seeing so many severely burned patients.[77] Nevertheless, the psychological trauma of the emergency treating team is unfortunately not really appreciated.[77]

The status of trauma ICU or burns unit staff is not very different. Doctors, nurses, and various members of the healthcare team, all of whom spend a considerable amount of their time in intense interactions with patients, are vulnerable to various visual and psychological stressors.[45] However, the majority of staff working in the stressful environment of a burns unit associated with chronic occupational stressors do not experience emotional exhaustion and do not seem to have a high incidence of burnout syndrome, which is characterized by emotional exhaustion, depersonalization, and reduced personal accomplishment.[45] Nevertheless, promotion of staff morale and emotional support to frontline clinicians and nurses are of utmost importance. Trauma ICU nurses usually find patient care to be physically demanding, particularly with time-consuming burn dressings. Patients' rooms are generally kept warm and nurses are required to wear gowns, gloves, and face masks when providing care, which makes staying in the patients' rooms rather laborious. Despite this, nurses find it difficult to leave the burns unit at the end of their shifts. Many have guilt feelings about not being available longer to assist colleagues and some prefer to keep busy rather than think about the experience.[77] Nurses may be emotionally resilient because they care for trauma patients every day, which helps to contain the emotional distress of witnessing mass suffering; however, young staff usually identify with young burn victims, and may require emotional support from colleagues. As patients start to recover, the treating team is faced also with providing them with psychological support, which is emotionally draining. Although some staff members suffer no overt psychiatric consequences, most suffer transient acute stress symptoms, including irritability, restlessness, sleep disturbance, mood lability, fatigue, and intrusive imagery. These symptoms generally resolve rapidly and do not require psychiatric intervention, but a few staff that are directly involved in caring for the burn patients do suffer an acute exacerbation of past trauma symptoms or unresolved grief.[77] All these symptoms and manifestations are naturally amplified in an armed conflict situation, which carries its inherent stressor factors.

Prevention of warfare injuries and burns

In wartime, all possible strategies need to be undertaken to minimize and prevent injuries. Both international and local efforts are necessary.[2] Perhaps the only true benefit of war is the higher standards of trauma care it forces us to develop and pass on to succeeding generations.[4] Unfortunately, the threat from war burns is unlikely to diminish; indeed, new developments in weapons seek to exploit the vulnerability of the serviceman and servicewoman to burns. Clothing can be a barrier to some types of burn, not only inherently in the properties of the material but also by trapping air between clothing layers. Conversely, ignition of the clothing may exacerbate a burn.[14] Even light-weight combat clothing can offer significant protection to skin from short-duration flash burns; the most vulnerable areas are the parts of the body that are not covered, i.e. the face and hands. In one study, 98% of tank crewmen who sustained burn injuries were wearing fireproof suits at the time. Only 12% of them sustained abdominal burns whereas 77% had facial burns, as none of them were wearing fireproof masks. Only 9% of the burned soldiers who wore fireproof gloves sustained hand burns, compared with 75% who did not wear the gloves. Wearing protective suits increased the percentage of minor burns from 21 to 51% and reduced the percentage of burns greater than 40% TBSA from 29 to 18%.[78] Multilayered combat clothing can offer significant protection for short periods from engulfment by flames, whereas lightweight tropical wear with few layers offers little protection. However, under high heat loads in the laboratory, combat clothing can ignite, even though there is little evidence that clothing ignition is a common occurrence in military burn casualties. Thermoplastic materials, however, have many benefits in civil and military clothing. There is little objective evidence that they exacerbate burns or complicate burns management. Their use in military clothing must be based on objective evidence, not hearsay.[14]

Early on in the recent Iraq war, Kevlar vests proved dramatically effective in preventing torso injuries.[15,16,79] It was later realized that in cases of blast injury these vests cause the overpressurized waves to extend upwards under the armour and inwards through axillary vents. An unprecedented burden of what orthopaedists term “mangled extremities”, with severe limb soft-tissue, bone, and often vascular injuries, have also been noticed in association with wearing the standard Kevlar cloth ballistic vest.[16] This, however, must not be construed as a reason for not using the vest; on any conceivable battlefield, the risk of being wounded by fragments far outweighs the threat of primary blast injury. Rather, the triaging physician must use this information to recognize that soldiers near an explosion may have had their lives saved by the vest but that primary blast injury to the lungs and abdomen may complicate their condition.[13]

New approaches are needed to minimize trauma to civilians. Lessons learned from Bosnia and Lebanon show that the most effective way to achieve successful surveillance and injury prevention is to enhance local skills and resources.[2] Both political advocacy and local efforts (including modifying firearms and ammunition, bullet-proof helmets for children, and anti-sniper shields) are needed. The use of incendiary weapons such as white phosphorus shells and napalm against civilian targets is banned by international treaties.[80] Article 2, protocol III, of the 1980 UN Convention on Certain Conventional Weapons states: “It is prohibited in all circumstances to make the civilian population as such, individual civilians or civilian objects, the object of attack by incendiary weapons”.[80] Moreover, as chemical warfare has been widely condemned since it was first used on a massive scale during the First World War,[81] some have claimed that the use of white phosphorus contravenes the 1993 Chemical Weapons Convention, which bans the use of any “toxic chemical” weapons which causes “death, harm or temporary incapacitation to humans or animals through their chemical action on life processes”.[80] Surprisingly, this opinion is not widely shared. A spokesman for the Organization for the Prohibition of Chemical Weapons, which enforces the Convention, stated recently that the Convention permitted the use of such weapons for “military purposes not connected with the use of chemical weapons and not dependent on the use of the toxic properties of chemicals as a method of warfare”, claiming that the burns caused by white phosphorus shells were thermal in nature rather than chemical and as such are not prohibited by the treaty.[80]

Children bear disproportionate consequences of armed conflict. The twenty-first century continues to see patterns of children enmeshed in international violence between opposing combatant forces, as victims of terrorist warfare, and, perhaps most tragically of all, as victims of civil wars. Innocent children so often are the victims of high-energy wounding from military ordinance. They sustain high-energy tissue damage and massive burns. Children have also been deliberately targeted victims in genocidal civil wars in Africa in the past decade, and hundreds of thousands have been killed and maimed in the context of close-quarter, hand-to-hand assaults of great ferocity.[82] One chronic legacy of contemporary warfare is blast injury to children from landmines. In many parts of the world, undetonated military incendiary devices such as land mines and hand grenades contaminate the sites of abandoned battlefields. Such devices cause significant numbers of civilian casualties years and even decades after local hostilities cease.[12] On the other hand, PTSD remains an undertreated legacy of children who have been trapped in the shot and shell of battle in addition to those displaced as refugees. The increase in, and plight of, child soldiers themselves has also been an urgent, unfocused, and unmet challenge. A new class of combatant comprises these children, who also become enmeshed in the triad of anarchic civil war, light-weight weaponry, and drug or alcohol addiction. The International Criminal Court has outlawed as a War Crime the conscription of children under 15 years of age. Nevertheless, there remain more than 300,000 child soldiers active and enmeshed in psychopathic violence as part of both civil and international warfare.[82] Only by vigorous and maintained advocacy of the rights and welfare of children in the context of the evolving ‘Laws of War’ can the world’s children be better protected from the scourge of future wars.[82]

Whereas most health efforts have previously concentrated on the indirect effect of wars, now innovative approaches to minimize and prevent war-related trauma must be created. Recognizing the global and thus political aetiology of most recent wars, the combination of political action along with relief efforts is advocated as the most effective means for making an impact.[2,83] The questions remain, however: Is political activism the only means of diminishing or preventing war-related trauma? Can war trauma be reduced even if war cannot be prevented? What options are available and feasible for injury prevention professionals while waiting for political advocacy to achieve an end to the conflict?[2] Regardless of these critical questions, injury interventions in wartime must deal with all the phases of the war: before, during, and after the conflict. Also, injury epidemiology in an endemic war must adopt an active process.[2]

Conclusion

Burns care is a complex, resource-intensive, multidisciplinary team process that can be provided to current care standards only in centralized burn centres.[40] Fortunately, though the wounding capacity of modern weaponry has increased exponentially since the time of the American Revolution, unprecedented salvage of the severely injured and the extensively burned is being realized.[34] Definitive care of patients with serious burns within the theatre of operations is proscribed by current military doctrine. Nevertheless, experience at deployed medical units has underscored the importance of planning for the care of civilians of all ages and of enemy prisoners-of-war with burns during and after combat operations.[40]

In an effort to determine whether new medical technologies or enhanced training might contribute to a reduction in armed-conflict-related deaths, the causes of possible death viewed as most likely to be salvageable today include, among a few other conditions, severe burns, while the areas of training most often mentioned as having a potential impact on salvageability include burns management.[84] Military medicine personnel must be aware that more time, energy, and material need to be spent on burn treatment as we enter the next millennium.[18] Moreover, experience highlights the importance of anticipating the burn care needs of both combatants and the local civilian population during war.[40] In all but the best-case scenario of medical planning for Operation Iraqi Freedom, casualty estimates exceeded the capacity of the only Department of Defense burns centre, stimulating the implementation of a system to track daily nationwide burn bed availability.[85] Medical planning for future armed conflict situations must include predictive models of the expected number of burns casualties[85] and allocate resources and facilities accordingly, despite the fact that burns management in hospitals during wartime, sadly, is almost always a problem because of the limited resources of burn/plastic surgeons and trained nurses.[38] It must include also add-on Combat Burn Life Support modules to the standard Advanced Burn Life Support course to meet the specific needs of military audiences. These modules cover the treatment of white phosphorus burns; the treatment of mustard gas exposure; the long-range aeromedical transfer of burn patients; the management of burn patients beyond the first 24 h; and the delivery of burn care in austere environments.[86] Although intended for a military audience, the course material may equally be applicable to civilian terrorist or mass casualty situations.[86]

Medicine and surgery have always been professions made up of a solid mixture of tradition and craftsmanship. Unfortunately, deep-rooted concepts evolved which could change only in the apocalyptic atmosphere of a large-scale catastrophe. Only under the overwhelming demands for medical services could the failures of an old method be demonstrated. It took crises to change and wars were always available.[41] Although burn centres were not invented during the war, it took large-scale conflicts like the Second World War to emphasize the need for a centre of excellence and the accumulation of knowledge. The "burn team" was established by Sir Archibald McIndoe to treat the Royal Air Force pilots who were burned during the Battle of Britain. Two dermatomes were "born" as a result of the need for better skin grafts, the Padgett and the Reese dermatomes, during this same period. The electric dermatome was conceived by Harry Brown while being held captive in a Japanese prisoner-of-war camp. The magnitude of his contribution was enormous.[41] If any good is to emerge from the evil which confronts us today, it will be salvaged in the form of medical progress accelerated through intensity of experience.[87] Of the 368 casualties burned in the current conflict in Iraq and transferred to the Army Burn Center, only 12 (3.3%) have died. The magnitude of the improvement in prognosis of burn casualties, and the velocity with which it has occurred, document the effectiveness of integrated clinical/laboratory research.[34] It is evident that military medical skills training and available resources must reflect fundamental changes in modern conflicts in preparation for the future.[10] It is also obvious that present-day strategies for treatment of the multiple-trauma victim with an extensive burn injury as a result of massive explosions, chemical warfare, missiles, or weapons of mass destruction will affect the treatment history of burn care in the future.[88]

RÉSUMÉ. Les lésions causées par les brûlures constituent une menace toujours présente dans l'environnement militaire, et depuis plus de 5000 ans la littérature relative contient des descriptions des brûlures de guerre. Probablement le feu a été utilisé comme arme offensive longtemps avant cela. Avec la puissance destructive et l'efficacité toujours majeure des armes modernes, le nombre des morts et des blessés touche des niveaux toujours plus élevés, particulièrement pour ce qui concerne la population civile, laquelle, dans les guerres récentes, est devenue l'objectif principal exposé au risque de la mort ou des lésions. Même si le personnel médical normalement estime que la connaissance des armements a peu d'importance pour ce qui concerne sa capacité de traiter efficacement les lésions, et que cette connaissance peut en quelque manière être en conflit avec leur rôle, accordé selon les Traités de Genève et de la Haie, il est absolument nécessaire qu'ils connaissent comme on emploie ces armes et qu'ils comprennent leurs effets sur le corps humain. Les Auteurs de cette étude considèrent les diverses catégories des armes de la guerre moderne, qui sont mal connues par la plupart du personnel médical et paramédical responsable du traitement des brûlures. Ils examinent les mécanismes et les caractéristiques des lésions causées par chaque classe des armes afin de permettre une compréhension meilleure de la gestion des brûlures dans les circonstances d'une guerre.

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