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Review of Military Casualties in Modern Conflicts—The Re-emergence of Casualties From Armored Warfare

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ABSTRACT

Introduction:

The re-emergence of armored warfare in modern conflicts has resulted in a higher number of extremity injuries, burns, and brain injuries. Despite this dramatic increase, little is reported on the type of injuries caused and their management. This review summarizes the publicly available literature and reports on the rate and type of injuries related to armored warfare, their medical outcomes, and management limitations.

Materials and Methods:

This rapid evidence review involves a systematic literature search, followed by a non-systematic literature review. The reason for choosing this approach was the inherent lack of quantitative outcome data in the literature to satisfy the Preferred Reporting Items for Systematic Reviews and Meta-Analyses checklist. The study also used content analysis to study all peer-reviewed articles, focusing on similarities and differences in the findings necessary to formulate tentative results. The electronic search included PubMed, Scopus, and Web of Science, using the following search string: "Armored; Injuries; Mechanized; Morbidity; Mortality; War; Warfare", alone or in combination.

Results:

Modern conflicts are associated with higher number of extremity injuries, burns, and brain injuries among military casualties. Several publications claim that the characteristics of armored warfare and anticipated injuries in this type of warfare might require the far forward deployment of medical support supported by a reliable casualty evacuation chain. Still the quality of the available casualty data is low.

Conclusions:

Because of the limited availability of reliable data or military trauma registries, up-to-date military casualty estimation remains a recognized knowledge gap, which needs to be addressed by armed forces worldwide. The future management of modern war casualties requires professional and well-trained staff in all levels, indicating a need for educational initiatives to provide both nurses and medics a greater proportion of medical care and management capabilities and responsibilities than in past conflicts.

INTRODUCTION

Armored warfare (AW) is, since World War (WW) I, a major component in ground warfare. Indeed, the use of tanks and heavily armored mechanized vehicles facilitated troop mobility under fire and allowed maneuver warfare with force concentration unseen before. As much as the armored vehicle protects the crew from small- to medium-caliber ballistic weaponry and shrapnel, it may become a death trap if exposed to armor-piercing anti-tank weapons.[1,2]

Thus, for battlefield medicine, the introduction of armored vehicles implied specific challenges related to anti-tank weapons. Anti-tank mines aim at penetrating the floor of armored vehicles, causing blast injuries of lower extremities and pelvis, axial skeletal and traumatic brain injuries. Rocket-propelled grenades or high-explosive anti-tank (HEAT) rounds are capable of penetrating tank armor, resulting in blast and burn injuries. Anti-tank missiles, and in combined arms warfare, anti-tank air strikes cause blast and burn injuries.[3,4] Anti-tank weapons and mines cause blast waves, which may lead to traumatic brain injury, and repetitive blast exposures may lead to shell shock, a diagnosis coined in WWI and related to posttraumatic stress disorder.[5]

The casualties afflicted by AW are difficult to evacuate by medical support personnel if medical units are not equipped with dedicated vehicles, armored and with all-terrain capabilities as the rest of the AW units. During Operation Desert Storm, for instance, armored units could move up to 150 km from the central fighting zone in just one day. These distances

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require highly mobile medical support units or Medevac helicopters to facilitate treatment and fast medical evacuation to higher echelons of medical support (role 2–3). The latter has been an important reason for mortality reduction in the conflicts of the last decades.[6,7]

The Russian surgeon Vladimir Oppel presented the uniform doctrine of treatment and evacuation system in 1916—using the principles of Pirogov.[8] The system evacuates the injured to further medical aid points, ensuring continuity of treatment at the evacuation stages with careful medical segregation according to the triage priorities. The system was developed and successfully implemented during WWII by several countries, such as the Soviet Union and the USA. Increasing attention was paid to the importance of the time interval from the occurrence of the injury to the moment of receiving qualified medical care. Shortening this period substantially reduced the mortality of the victims.[2,9–11]

During the Gulf Wars and in Afghanistan, multinational military combat medicine has established and validated the concept of tactical combat casualty care.[12] There are now validated treatment guidelines for the use of tourniquets (combat application tourniquet), hemostatic agents, needle chest decompression, and hypotensive resuscitation. The knowledge, skills, and experience gained while providing aid to the wounded during subsequent armed conflicts influenced the development of many fields of medicine, accelerated the improvement of organizational issues, such as transport and medical segregation, and became the basis for the creation of a civil model for providing aid to victims.[12]

On the battlefields of this decade, AW still plays an important role. The involved armies in the Syrian Civil War have used multiple weapons systems of AW, both tanks and anti-tank weaponry, since 2011. During the separatist insurgency in Donbas, eastern Ukraine, since 2014 and the Nagorno-Karabakh war in Azerbaijan of 2020, modern tanks and anti-tank weapon systems have had their share in the combat.[13] Despite the fact that armor and anti-tank systems evolved dramatically until now, little has been published on injuries of the mechanized AW of the recent battlefields. It is also evident that with the development of the weaponry, technology and warfare systems, all discussions about the casualties caused by AW imply the existence of a specific weaponry-related casualty evacuation system. This review aims to summarize the publicly available literature and reports on the rate and type of injuries related to AW, their medical outcomes, and management limitations.

METHOD

This study uses the rapid evidence synthesis as the basis for the review.[14] This involves a systematic literature search, followed by a non-systematic literature review. The reason for choosing this approach was the inherent lack of quantitative outcome data in the literature to satisfy the Preferred Reporting Items for Systematic Reviews and Meta-Analyses checklist.[15] The study also used content analysis to study all peer-reviewed articles, focusing on similarities and differences in the findings necessary to formulate tentative results.[14] The electronic search included PubMed, Scopus, and Web of Science to create a list of available literature in English, using the following search string: "Armored; Injuries; Mechanized; Morbidity; Mortality; War; Warfare", alone or in combination. The Swedish Defense University provided additional search regarding publication in Russian literature.

After duplicate exclusion, all articles, reviews, and related publications dated January 1, 1995 to December 31, 2020 were included. Proceedings, editorials, meeting notes, news, abstracts, and opinion papers were excluded. Authors studied all abstracts, and potential publications were studied thoroughly before inclusion.

RESULTS

Figure 1 shows the outcome of literature search in this narrative study. Of 353 identified records, 54 items were included for evidence review.

The Development of AW and Estimation of Casualties

Since the end of WWII, an urbanization of military operations has occurred due to factors, such as increase in world population and relocation of rural population to the cities.[1,16,17] The future increase (90%) in global urban population in developing countries over the next two decades indicates these nations' vulnerability to political and social unrest, terrorism, disasters, and armed conflicts, and the use of AW.[18] There are, despite continuous technological development, limitations in applying AW to the urban battlefield.[19]

Similar to previous wars, casualty estimation in modern conflicts is essential in both military and civilian populations. Nevertheless, due to difficulties in foreseeing the exact number of casualties and deaths in wars throughout recent history, only descriptive and anecdotic notes, with no simple way of estimation, were produced. However, mathematical extrapolations of casualty rates are needed to enable medical services to design operational medical support structures and casualty replacement pools.[6,16,20] Kuhn presented the first modern attempt to predicting casualty rates by studying casualties arising from WWII, the Korean War, and the Arab-Israeli wars of 1967 and 1973 by using three parameters: (1) Force size and composition by echelons, (2) Time periods considered, and (3) Overall operational scenario and its set of force missions as operations evolve. Although Kuhn's estimation was designed to meet the operational requirements of a NATO/Warsaw Pact, it still has value as a tool in today's environment of "low-cost/no cost" conflict, as long as the outcomes are reasonably evaluated.[16] Modern medical planning depend on several factors, e.g., mission type, the enemy's organization, troops' training and experience, weaponry and warfare used, terrain, time, intelligence, and concepts of operations. The result will therefore provide different figures in different battlefield situations and in larger and smaller combats (Table I).

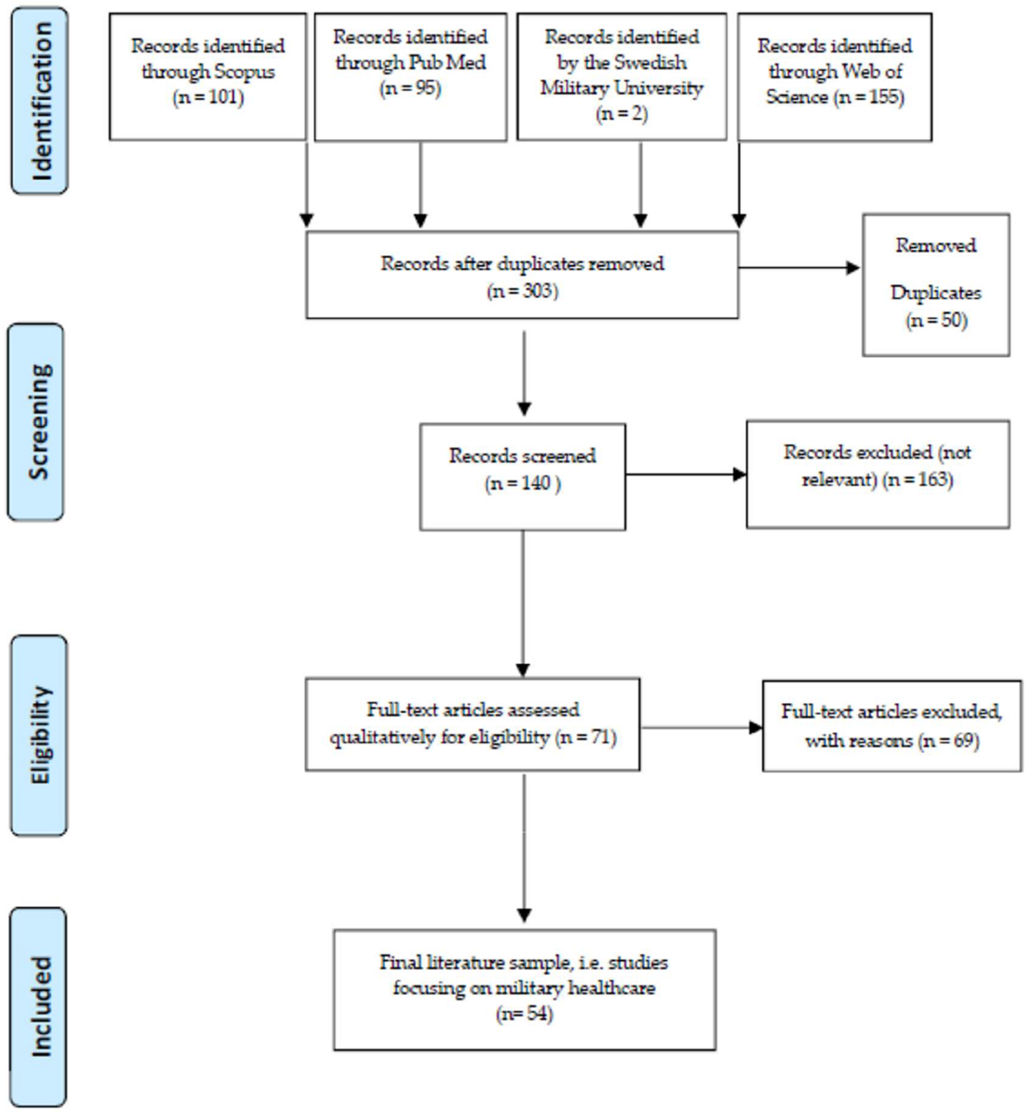

FIGURE 1. Flow diagram of literature inclusion.

TABLE I. The Number of Casualties and Deaths in Four Different Wars Involving the U.S. Army[21,22]

War	Year	Total deaths	Battle deaths	Other deaths	Non-battle deaths	Non-mortal wounds
World War II	1941–1946	405,399	291,557	113,842	–	670,846
Korean War	1950–1953	54,246	33,739	2,835	17,672	103,284
Vietnam War	1964–1975	90,220	47,434	10,786	32,000	153,303
Persian Gulf War (Desert Shield/Storm)	1990–1991	1,948	148	235	1,565	467

A study from the Vietnam War also showed that urban combat produces higher rates of wounded in action and killed in action than a non-urban operation conducted by like forces against the same enemy. Although medical resources were adequate and well trained in military medical skills, they were not prepared or organized for special challenges associated with this type of combat such as suitable ground evacuation capability (ground vs. air evacuations) direct to hospital-level care.[16]

During the 1982 15-week war in Lebanon, around 30% of the total Israeli casualties came from the infantry division and 14.1% were tank crew casualties (compared with 28% in the 1973 War). Cluster bombs were a frequent cause of injury or death (3.7%), fired either directly from aircraft or artillery or as supporting or as auxiliary weapons exploding on the battlefield. There were 11% casualties in commander groups, while the number of casualties in other units was all less than 9%. Shell, mortar, cannon, and rockets were the causes of casualties in 53%, bullets 11.6%, blast 2.3%, and the rest were a combination of one or two causes, or undefined. The infantry suffered the highest fraction of battlefield injuries in both urban and non-urban combat, 56% and 43% respectively, followed by armor division 17.1% and 34.8%, support units 21.1% and 16.6%.[16]

The AW consisting of light, medium weight and heavy tanks and light-protected armored vehicles have been used for almost 100 years and in different conflicts, and are still used in many circumstances, such as conventional conflicts, emergency insertions, and small-to-medium insurgencies, and in peacekeeping operations.[19] Previous studies from WWII have shown that the number of casualties in armored units was approximately 13.6% of the total casualty rate. An estimation of the monthly casualty showed differences between various branches of the army; however, only 55% of the battle casualties are true irrecoverable casualties.[23,24] Furthermore, the reported mechanism of combat injuries in armored divisions are in 50% ballistic, 5% blunt, 5% blast, 25% thermal, and 15% combined, which also indicate that each conflict may have its own profile of casualties and injuries.[4]

The literature also provides information about the site of injuries (Table II) and the cause of deaths in the previous armed conflicts. However, specific data dealing only with AW is limited. Leitch et al. reported that injuries caused in armored units are twice higher in non-urban conflicts than those in urban conflicts. A simple calculation based on these reports indicates that should the primary medical treatment and evacuation system function as planned, the number of military casualties in modern war would be around 13–14% in rural areas and around 6–7% in urban areas. The mortality rate would probably be around 5–10%.[4,16]

The Cause of Mortality and Morbidity in AW

Previous and recent studies have shown that blast and ballistic injuries, acceleration and deceleration injury, thermal injury, and toxic injury remain the major cause of morbidity and mortality during AW.[1,4,25–27] However, modern warfare shows even an increase in gunshot injuries and other mechanisms such as falls and assault, and an increasing number of burn injuries among military service members.[16,27] It is unclear whether this increase represents a true increase or armies realized the value in casualty registration and have improved the quality of their registration.[28]

Ballistic injury refers to the interaction of a projectile and the human body, resulting in a penetrating or blunt trauma. Blast injury is caused by rapid pressure waves created by the detonation of explosives and cause multisystem, life-threatening injuries in single or multiple victims simultaneously. Indoor explosions cause the most severe injuries and have the worst outcomes. Survivors have predominantly primary and tertiary blast injuries. Secondary blast injuries mainly occur in suicide bombings in open and/or semi-confined spaces. Life-threatening injuries involve lungs and hollow viscera.[29,30] A slowly increasing pressure wave (>0.5 s) will usually not cause damage to human bodies. Pulmonary damage occurs at around 500 kPa, and at levels of 2,500 to 3,000 kPa, 50% of exposed persons die.[1] Rupture of the tympanic membrane occurs at approximately 50-kPa overpressure. Ballistic injuries by projectile fragments or small fragments are similar to other shrapnel injuries.[1]

Acceleration and deceleration injuries are blunt injuries that occur when a vehicle is exposed to an explosion, such as a tank mine and is thrown into the air. Thermal injuries occur on unprotected skin and with an increased temperature of more than 43.3°C. Direct contact with hot metal, fluids, or HEAT jet causes more severe injuries. Inhalation can lead to severe heat damage to the upper and lower airways. Toxic injuries are most common with HEAT projectiles, when toxic fumes and smoke are released inside the vehicle, which also may lead to hypoxia.[1,27]

Cavitation, tumbling, and secondary fragments from a bullet or shrapnel may result in a multimodal injury sustained to the vital organs of mounted soldiers in armored vehicles. The impact of the bullet on tissues is characterized by a cavitation process or direct delivery of energy, and result in muscle, bone, and blood vessels injuries of extremities. All high-energy gunshots should be considered contaminated and should be treated accordingly. Stabilization of bone, soft tissue care, adequate wound coverage, and restoration of limb function are important parts of the treatment strategy. Bone loss and soft tissue coverage together with maintenance of limb alignment and joint congruency restoration in cases of severe comminution are the big challenges.[29]

In the latest U.S. Army involvement in Afghanistan and Iraq, Improvised explosive devices and gunshots were two major mechanisms of injury (40% and 9%, respectively).[30] Other reports quoting "Red Cross statistics for limited conflict" indicate 23% wounded by mines, 26% from bullets, 46% from shrapnel, 2% from burns, and 3% from miscellaneous.[16]

Specific Injuries and Medical Complications Caused by AW

The reports available from the Russian involvement in different wars show injuries to head and neck, chest, stomach, pelvis, and extremities. However, in contrast to the data from U.S. Army and NATO countries, the rate of extremity injuries has not changed. This may reflect more on the types of warfare the Russian use in their military conflicts and the protection measures they have implemented.[16] Similar anatomical locations of wounds are involved in the reports from U.S. Army

TABLE II. Shows Available Data From Some of the Recent Conflicts

	Head and neck (%)	Thorax (%)	Abdomen (%)	Pelvis (%)	Limbs (%)	Total mortality (%)	Reference study
World War I	17	4	2	–	70	21	4, 26
World War II	4	8	4	–	75	30	4, 26
Korean War	17	7	7	–	67	4–25	4, 26
Vietnam War	14–21	5–7	5–18	–	56–74	3–24	4, 15, 26
Borneo	12	12	20	–	58	2–3	4, 26, 31
North Ireland	20	15	15	–	50	5	4, 26
Falkland Islands	14–16	7–15	10–11.5	–	59–75	<1	4, 26, 32
Persian Gulf Wars	6–11	8–12	7–11	–	44–71	24	4, 26, 33
Afghanistan and Iraq	12–31	8.9–27	11–22	3.8	39–87	3.9–10	4, 26, 34–37
Chechnya	24–24.4	8.6–9	2.3–4	1.6	31–63.1	>20	4, 15, 38
Somalia	20	8	5	–	65	–	4, 25
Pakistan	19.2	8.9	–	–	71.9	12.4	37
East DRC Conflict	8	16	13	–	60	–	25

If possible, different figures from several publications are registered. Pelvis injuries might have been included in other injuries in some studies. Some studies lack separate figure for upper and lower limbs; therefore, the figures for limbs include both types of injuries. DRC: Democratic Republic of the Congo.

and NATO countries (Table II). However, these reports show that the number of injuries to head and neck and extremities, which were declining, have increased since the Persian Gulf Wars, and are today at the same level as during WWI. On the contrary, injuries to the abdomen and thorax are declining. These results may be due to an improved protection measures and a shift in the warfare from open field to urban environments.[4]

Explosive devices and gunshot wounds were the main cause of injuries and deaths in the latest conflicts. Up to 15% suffered burns. In one study, around 45% of casualties suffered from injuries in more than two regions. The percentage of patients with only one area affected by gunshots was higher than for similar patients injured by explosives (78% and 46%), leading to death due to vascular injuries, mainly from the neck region.[33,35-37,39,40]

1. Extremity Injuries and Amputation Survivors

There has been a steady increase in the number of amputations since WWI: from 2.5% in WW II, 3.1% in Korea, 5.3% in Vietnam, and 10% in Iraq–Afghanistan. This is a result of an increasing number of extremity injuries due to explosives, gunshots, fall, motor vehicle accidents, and other causes (Table II).[37,41,42] Additionally, the use of body armor reduced the number of fatal torso injuries in favor of survivable extremity injuries.[16,19,23,24] Although the management of extremity injuries has improved, the long-term outcomes are still in need of further study. The review of the literature shows that amputees are at a significant risk to developing cardiovascular diseases, obesity, joint pain, osteoarthritis, low back pain, and phantom limb pain (50–80%).[42,43]

2. Burn

As armored vehicles are contained spaces, anti-tank weapons penetrating the vehicle's armor plates will cause sudden heat exposure inside the vehicle. The improved anti-tank weapons and the increasing number of explosive injuries have resulted in a rise in burns and inhalation injuries (up to 25% in modern combat). The latter should result in immediate need for intubation, especially those combined with other injuries.[44,45] Burns associated with blast injuries can involve both civilian and military populations and demand a well-organized chain of triage and medical care actions from the scene of incident to hospital admission and intensive care treatment.[45]

3. Traumatic Brain Injuries

The main causes of severe traumatic brain injury have been penetrating injuries, followed by tangential and perforating injuries, caused by shell fragments and shrapnel, gunshot, missile projectiles, and explosives.[46] Approximately, 3–6% suffer further infection and 8–9.5% die due to their injuries. Besides immediate deaths and short-term postoperative complications such as hemorrhages and infection, more than 25% of the survivors suffer from late complications such as posttraumatic epilepsy and depression.[47] Mild traumatic brain injuries have been associated with cognitive dysfunction, shell shock, and posttraumatic stress disorder.[5,10,46,47]

The Impact of Evacuation System on the Outcomes of AW Casualties

The importance of transport time and evacuation of victims from the scene is a recognized fact and several publications

TABLE III. Results of Research Conducted by the American College of Surgeons

Conflict	Waiting time for medical assistance	Death rate from trauma
Napoleon's Wars	Around 40 h	46%
World War I	12–18 h	8.5%
World War II	6–12 h	5.8%
Korean War	2–4 h	2.4%
Vietnam War	Around 60 min	1.7%

have emphasized its significance. Shortening transport period substantially reduces the mortality of the victims.[2,10,48–50] Data in Table III indicates that the mortality of the injured is directly proportional to the time that elapses from the moment of injury to the moment of specialist treatment. Specialist medical assistance points-of-care are organized as close to the frontlines to ensure that wounded soldiers have quick access to optimal treatment.

During the Korean War, helicopters were used to evacuate the wounded, and the U.S. Army deployed specialist medical aid points, the Mobile Army Surgical Hospital, within the combat area. Contemporary military experience confirms the benefits to injured patients brought about by initial medical care in combination with quick evacuation to centers providing definitive treatment.[29,50] Currently, thanks to the efficient military medical services and a properly functioning rescue system, as many as 98% of soldiers who are not immediately killed in action are saved.[48–50] Some authors suggest that one of the main reasons for the high Russian military casualties in Chechnya was the inadequate evacuation support during AW in which both injuries to head and neck and extremities increased.[16]

DISCUSSION

General Reflections

The recent Russian operations in Georgia and Ukraine suggest a re-emergence of conventional, high-intensity land warfare in which AW will greatly be used.[51] Such a highly integrated, synchronized, and effective approach poses some unique challenges, and results in a battle with the high impact on unmounted infantry and defensive ground combat tactics. Specifically, the sophistication of the Integrated Air Defense System and tactical air defense systems reduces the possible air superiority of any army. For small- and medium-sized nations, modern armed conflicts mean a sudden onset, a quick and high-intensity battle resulting in a high number of casualties and deaths.

The medical outcomes of mechanized or AW are injuries caused by explosives and gunshot wounds, where over 50% of cases will not survive the first 24 h without proper medical care.[52] In an urban warfare, rapid evacuation of casualties by helicopter may not be safe or possible, and armored ambulances may be required for safe extraction of wounded.[16,53,54] Nevertheless, quick evacuation is necessary for definitive care of most common types of injuries, i.e., increasing number of extremity and burn injuries through immediate triage, resuscitation, and stabilization. The need for "life and limb saving" surgical intervention far forward should enhance the creation of forward surgical teams consisting of well-trained medical personnel, equipped with necessary medical resources.[55]

Uncertainty about the Casualty Figures

Estimation of the number of casualties and type of injuries are important factors influencing the outcome of the medical management of war injuries. There is, however, no certain method or instrument to use for calculating these figures, and historically the rate of injuries varies, depending on the anatomical site, from just a few to 70%, although the mortality shows a variation from 1 to 30%. Furthermore, urban warfare, re-emergence of AW, the use of new technology, such as drones, and the increasing number of civilians involved increase the uncertainty of using previous estimations and calls for new tools and methods of estimation. Additionally, due to its hybrid warfare characteristics, modern wars not only need a physical casualty estimation tool but also a tool that estimates mental health status. Such an estimation demands the collection of accurate military healthcare data and motivates the implementation of military casualty registries.[16,20–22]

Limiting Factors in Modern War Injuries

The continuous improvement of medical care on the battlefield and during evacuation, as well as the use of protective gear, has reduced the number of fatal war injuries in thorax and abdomen. Still, the number of extremity injuries, burns, and brain injury has increased. Even though these injuries may have better survivability, there are some limiting factors, which may change the outcome of their medical management.[3,23–27] In many combat-related extremity injuries, there is a need for external fixation; however, the supply of surgical instruments can be a limiting factor in both military and civilian healthcare systems. Alternative approaches and/or instruments designed for close-quarter application are needed to alleviate this issue. Furthermore, with an increasing number of amputees, the need for short-term and long-term rehabilitation, including prostheses is very high and may overwhelm the available resources. Inclusion of orthopedic surgeons in staged trauma teams should be considered.[41–43]

Burns in different grades need immediate management and wound treatment. The risk for inhalation injuries related to missile attacks and explosions is high and demands technical and instrumental preparedness for rapid intubation. This is not only a limiting factor on the field but also increases the need for intubation sets, staff with adequate skills for rapid intubation, and intensive care. Educational initiatives to secure the future ability of anesthesiologist competence are needed.[30,31,44,45]

Patients with traumatic brain injuries may have better outcomes if they can be stabilized before evacuation. However, the definitive treatment can only be given at a role 3 medical treatment facility. Preparedness for rehabilitation of successful cases and short-term and long-term follow-up to capture psychological complications are all necessary steps, which requires both resources and skilled staff.[46,47]

Evacuation Is Critical

The number of casualties is very much dependent of several factors, such as the possibility to evacuate, the terrain, the demography of the population, and on-scene capabilities to assess and treat primary injuries.[23,24,53,54] During the Beirut operation, a U.S. evacuation hospital operated 3 km south of the city. This distance necessitated adequate management of the casualties and safe evacuation to the closest surgical capacity available. In future modern wars, there is a need for collaboration between the civilian prehospital transport chain and its military partner to initiate a reliable system for evacuation of injured from the battlefield to the definitive care.[50] The U.S. success in lowering the number of war casualties in Iraq was correlated to their medical evacuation ability, although the Russians' failure in Chechnya depended largely on the failure of their evacuation system.[16]

Limitations

The majority of publications used in this review are in English, except a few translated Russian references. Consequently, some interesting data in other languages might be missing. The appropriate estimation of the casualties relies on complete data. There has been missing data regarding the number of injuries and deaths among military staff in AW, and some of the published estimations were not reliable and thus excluded from this review. Some major wars, such as the war between Iran and Iraq, were not included due to the lack of final data from Iraqi side. Additionally, information about air raids, use of Chemical, Biological, Radiological, and Nuclear, and occurrence of infectious diseases during combats was incomplete or missing.

Finally, the aim of this study was to perform a systematic review. However, the information obtained by the initial search did not allow a quantitative analysis of the results and consequently only a rapid evidence review could be performed.

CONCLUSION

This review indicates re-emergence of AW in modern conflicts with higher number of extremity injuries, burns, and brain injuries. Even small arms and light weapons contributed to a number of deaths among dismounted soldiers on the mechanized battlefield. The characteristics of urban warfare and anticipated combat injuries require the far forward deployment of medical support, stressing the importance of route planning for casualty evacuation. Due to the limited availability of reliable data or military trauma registries, up-to-date military casualty estimation remains a recognized knowledge gap, which needs to be addressed by armed forces worldwide.

The future management of modern war casualties requires professional and well-trained staff in all levels, indicating a need for educational initiatives to provide both nurses and medics a greater proportion of medical care and management capabilities and responsibilities than in past conflicts.

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