A Profile of Combat Injury

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Traumatic combat injuries differ from those encountered in the civilian setting in terms of epidemiology, mechanism of wounding, pathophysiologic trajectory after injury, and outcome. Except for a few notable exceptions, data sources for combat injuries have historically been inadequate. Although the pathophysiologic process of dying is the same (i.e., dominated by exsanguination and central nervous system injury) in both the civilian and military arenas, combat trauma has unique considerations with regard to acute resuscitation, including (1) the high energy and high lethality of wounding agents; (2) multiple causes of wounding; (3) preponderance of penetrating injury; (4) persistence of threat in tactical settings; (5) austere, resource-constrained environment; and (5) delayed access to definitive care. Recognition of these differences can help bring focus to resuscitation research for combat settings and can serve to foster greater civilian-military collaboration in both basic and transitional research.

Key Words: Civilian, Combat, Database, Exsanguination, Hemorrhage, Military.

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For the past 35 years, that is, since the Vietnam War, advances in trauma care have largely occurred in the civilian setting, with improved treatments and systems of care resulting in better outcomes. Whether such improvements are applicable to injuries sustained in combat is the source of ongoing discussion.

The characteristics of combat injuries differ from those of injuries encountered in civilian practice in terms of epidemiology, mechanism of wounding, pathophysiologic trajectory after injury, and outcome. Furthermore, the nature of combat injuries is likely to change because of changes in the ways wars will be fought; such changes may influence therapeutic tactics and techniques, and military medical planning and logistics.

The distribution of the mechanisms of combat injuries is strongly dependent on the branch of military service and how the combat is fought (Table 1).[1-4] For instance, 90% of combat injuries occurring in infantry combat have been caused by penetrating missiles, a proportion very different from that observed in naval and air combat and, indeed, in civilian trauma, in which blunt trauma predominates.

The incidence of thermal injuries is particularly high in certain military environments. For example, on board ship and among the crews of armored fighting vehicles, a figure as high as 47% was quoted for American tank crews during World War II, but this varied from the most minor to the most major burn. Of note, in these settings burns are frequently just one element of multiple-cause injuries to a combatant that might include both blast and penetrating injury.

Today, primary blast injury is relatively uncommon, but there is great concern that the development of modern explosive devices including thermobaric weapons and fuel-air explosives may make blast injury more predominant among combat injuries in the future. At present, the majority of combat injuries are penetrating, and most are caused by fragments from explosive munitions such as shells or grenades (70–80%) rather than bullets fired by military small arms.[5]

OTHER CONTRIBUTORS TO FORCE NONEFFECTIVENESS

Although combat injuries are the most visible and arresting toll of war on the human body, from a medical planning standpoint, such injuries are only one aspect of military medical care in combat. Disease and nonbattle injury can also reduce fighting force strength. Losses because of combat injuries actually constitute a minority of the total attrition in the theater of operation. Only approximately 20% of the U.S. Army noneffective rates in World War II, Korea, and Vietnam were because of combat injuries, whereas disease accounted for more than two thirds of the attrition (Table 2).[6] Combat injuries, however, have a disproportionately greater effect on the fighting power of the command because, for the most part, they occur in the combat branches (e.g., infantry, armor).

The actual number of combat injuries incurred by a given sized military unit is a highly variable quantity dependent on many factors, of which the intensity of the fighting is only one. Historical data indicate that rates of combat injury are

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Table 1 Distribution of Mechanisms of Combat Injury by Branch of Military Service[1–4]

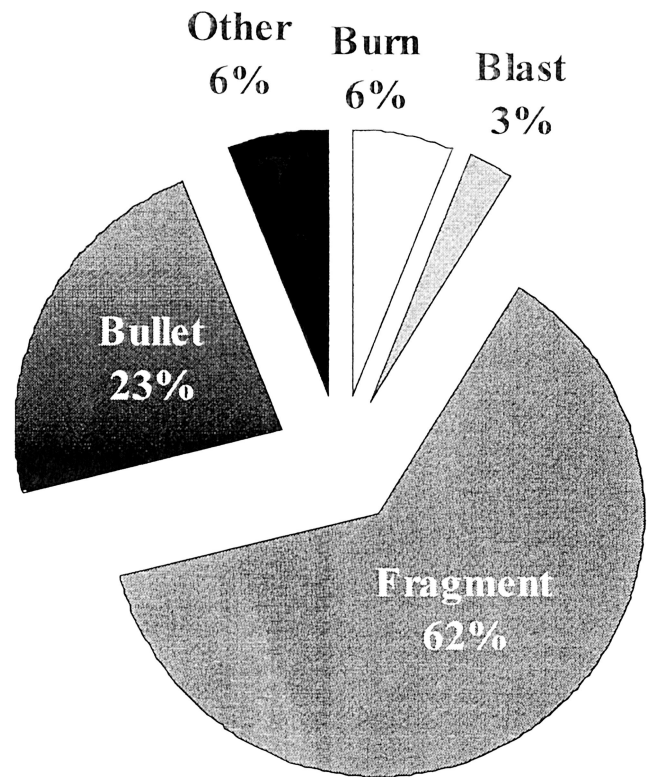|	Infantry (%)	Armor (%)	Sea (%)	Air (%)
Ballistic	90	50	25	5
Blunt	2–3	5	10	50
Blast	2–3	5	10	<5
Thermal	2–3	25	30	25
Combined	<5	15	25	10

Table 2 Contributions of Disease, Nonbattle Injury, and Wounding to Noneffective Rates of U.S. Army Personnel in World War II, the Korean War, and the Vietnam War[6]

War	U.S. Army Noneffective Rates (per 1,000/y)			Total Battle Injury (%)
	Disease	Nonbattle Injury	Battle Injury (Killed and Wounded)	
World War II	464	85	142	20.5
Korea	453	117	151	20.9
Vietnam	441	55	103	17.2

Fig. 1. *Mechanism of wounding.[1]*

inversely proportional to the size of the unit for a given level of fighting.[7] The reason for the greater attrition in smaller units is that they contain a higher percentage of combat arms personnel. Thus, in typical late 20th century combat, an entire division (often comprising thousands of personnel) might be expected to lose only 1% of its strength per day, whereas its constituent brigades, battalions, and companies (often comprising less than a few hundred personnel) may lose 3%, 10%, and 25%, respectively. Combat operations likely to be the norm in the future will be characterized by the deployment of a limited number of small combat units, thus resulting in fewer overall casualties but substantial losses among the units actually engaged.

COMBAT INJURY DATA

Data sources for combat injury statistics are multiple and often crude, with absolute numbers of killed and wounded being variably represented as census data or sample data, but usually as a normalized or indexed statistic (e.g., 20% killed) or rate (e.g., 10 killed per 1,000 at risk). Indexed statistics compiled from data from hospitals or surgical treatment facilities in which the denominator consists only of those reaching such sites are notorious for underestimating the magnitude and nature of the problem. Early lethality and delay in evacuation, the hallmarks of combat trauma, plus delayed access to definitive care, create a self-selected population. Combat mortality in hospitals under conventional battle situations has been reported as 4% or less since World War II, sometimes approaching 2% in certain circumstances (such as the Falklands), although overall mortality is 5 to 10 times greater.[1]

Wound Data and Munitions Effectiveness Team Database

Several of the more useful studies on epidemiology and outcome of injury have been performed on the Wound Data and Munitions Effectiveness Team (WDMET) database.[8] This is a database comprising meticulously collected data of 7,989 patients from 1967 through 1969 in Vietnam. Its great importance lies in that it covers the entire spectrum of combat injury from those with minor injuries to those who sustained major injuries or were killed. Because it contains a sample of Marine and Army personnel in jungle combat, it does not represent the full spectrum of combat injuries such as tank and artillery heavy combat, aerial combat, and naval warfare. It does, however, provide a lasting standard against which all future epidemiologic studies of combat injuries must be judged. Some summary analyses of this database are given below.

Mechanisms of Wounding

The mechanisms of wounding in the WDMET database are given in Figure 1.[1] Such figures are typical of modern combat, although recent data on urban combat offer some interesting shifts between fragment and bullet injuries (vida infra). Of note, most fragment injures are multiple in nature.

Site of Primary Injury

In treated casualties, by far the most frequent injuries are soft tissue injuries involving skin, fat, and skeletal muscle,
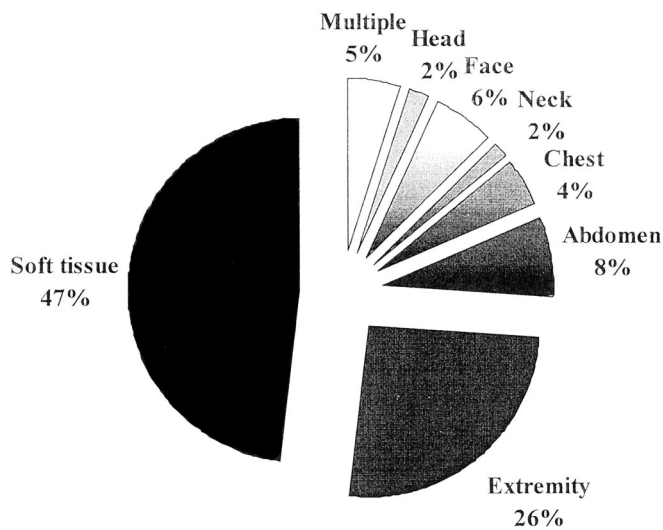
Fig. 2. *Site of primary injury[1]*

Fig. 3. *Site of fatal injury.[1]*

especially of the limb, and fractures of long bones (Fig. 2).[1] There is remarkable consistency throughout the past century (Table 3).

Site of Fatal Injury

The sites of fatal injury (Fig. 3)[1] are quite different from the patterns seen in casualty populations that include a predominance of surviving wounded (Fig. 2 and Table 3). The latter consist primarily of casualties with soft tissue and orthopedic injuries, whereas wounds of the head and torso predominate in the dead. Penetrating wounds of the head and chest have a fearsome lethality, being 78% and 72%, respectively.[1]

Death after penetrating combat injury is most commonly related to central nervous system injury or exsanguinating hemorrhage. 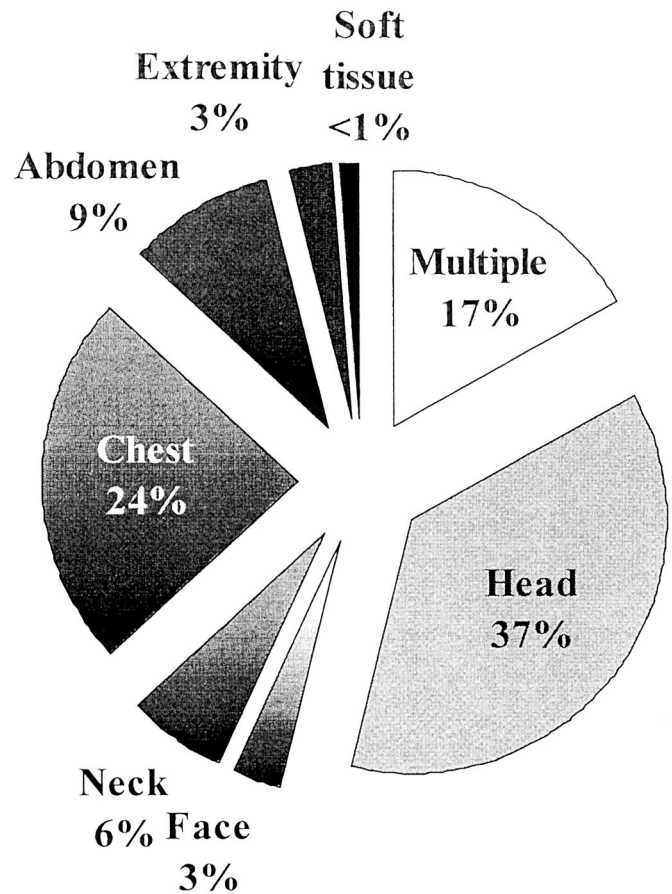Approximately 50% of those who die do so as a result of exsanguinating hemorrhage. Although approximately 80% of exsanguinating hemorrhage deaths are in the torso, where control of hemorrhage is difficult if not impossible in the tactical environment, approximately 20% of such deaths are in areas where the hemorrhage is from vessels that might be controlled by pressure, (i.e., in the neck, large soft tissue areas, and especially the limbs).[9] Increasing emphasis on the wearing of effective torso protection is likely to reduce the number of casualties who in the past would have died of wounds to the chest and abdomen. In recent conflicts, hemorrhage from limbs continues to account for about a tenth of deaths (note that this is of all deaths, not just of those dying of hemorrhage; see Table 3).

The WDMET database suggests that exsanguination from extremity wounds accounts for more than half of the potentially preventable deaths in combat,[1,9] thus the continued emphasis on hemostasis as the primary maneuver in combat casualty care and the research emphasis on agents that might provide a means of decreasing inaccessible or uncontrollable hemorrhage. Other potentially preventable deaths include simple airway obstruction and other sources of hemorrhage that are surgically remediable if such care can be provided in a timely fashion (Fig. 4).[1,10]

Table 3 Anatomic Distribution of Penetrating Wounds of the "Casualty Template"

	Head and Neck (%)	Thorax (%)	Abdomen (%)	Limbs (%)	Other (%)
World War I	17	4	2	70	7
World War II	4	8	4	75	9
Korean War	17	7	7	67	2
Vietnam War	14	7	5	74	
Borneo	12	12	20	56	
Northern Ireland	20	15	15	50	
Falkland Islands	16	15	10	59	
Gulf War (U.K.)*	6	12	11	71	(32)**
Gulf War (U.S.)	11	8	7	56	18†
Afghanistan	16	12	11	61	
Chechnya	24	9	4	63	
Somalia	20	8	5	65	2†

  * 80% caused by fragments; range of hits, 1–45; mean, 9.
 ** Buttock and back wounds, all multiple fragment injuries, as a separate figure.
   † Multiple wounds.
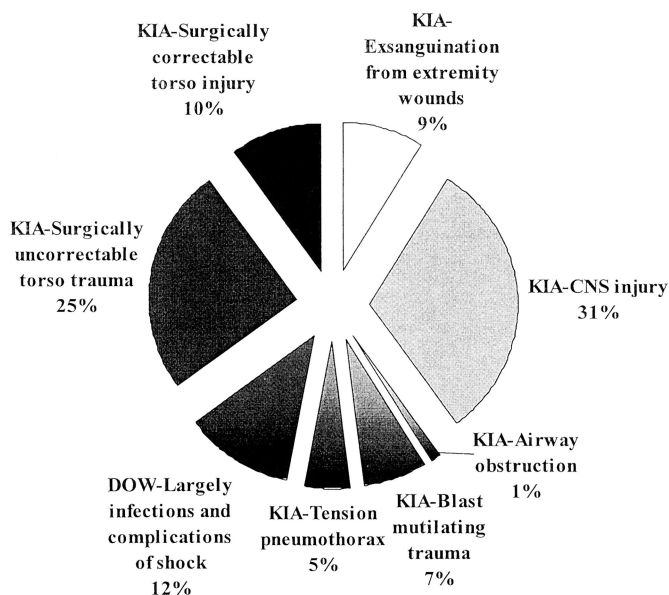
Fig. 4. *Mechanism of death in ground combat, Vietnam War.[1,10] KIA, killed in action; DOW, died of wounds.*

MORTALITY STATISTICS

The most common ways of representing mortality statistics from combat injury are to describe the data in terms of killed in action (KIA) and died of wounds (DOW). KIA is the percentage of the casualty population dying before reaching medical care at the battalion aid station or equivalent. The KIA rates of conflicts over the past 150 years have remained at approximately 20% (Fig. 5), thus testifying to the lethality of combat weapons and the constancy of human anatomy and physiology.[1] The lethality of weapon systems is well-known and varies from 1 in 3 for a military bullet, to 1 in 5 through 7 for a shell, to 1 in 20 for a preformed fragmentation device (grenade).
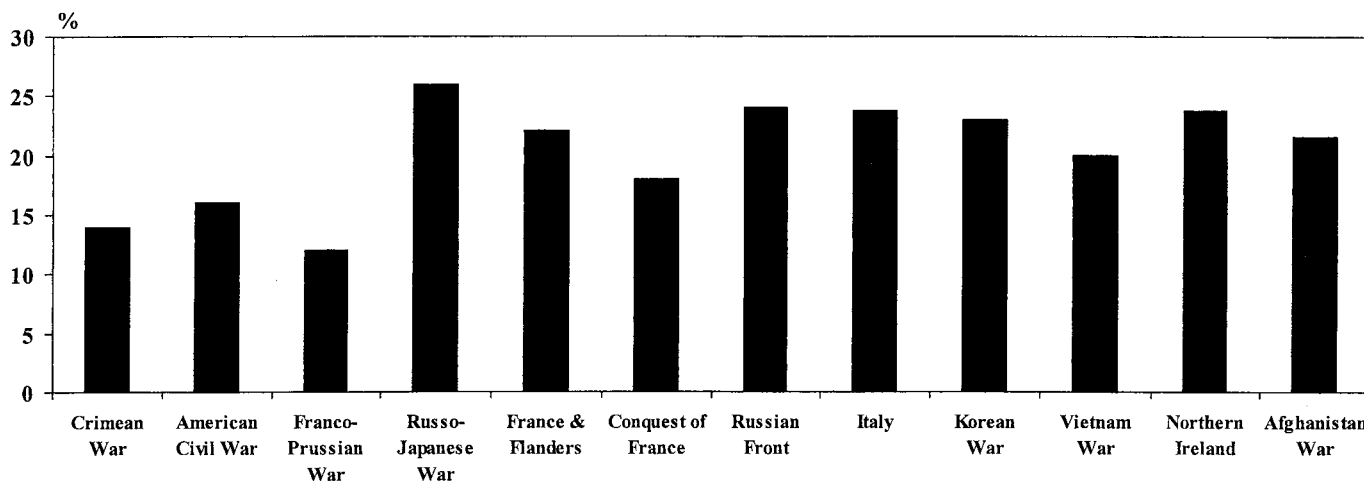
The denominator for a DOW statistic should be limited to those personnel who have been admitted to a medical treatment facility. It should not include those with minor injuries who are returned to duty or are not hospitalized. Historical data for those in the DOW category are shown in Figure 6.[1]
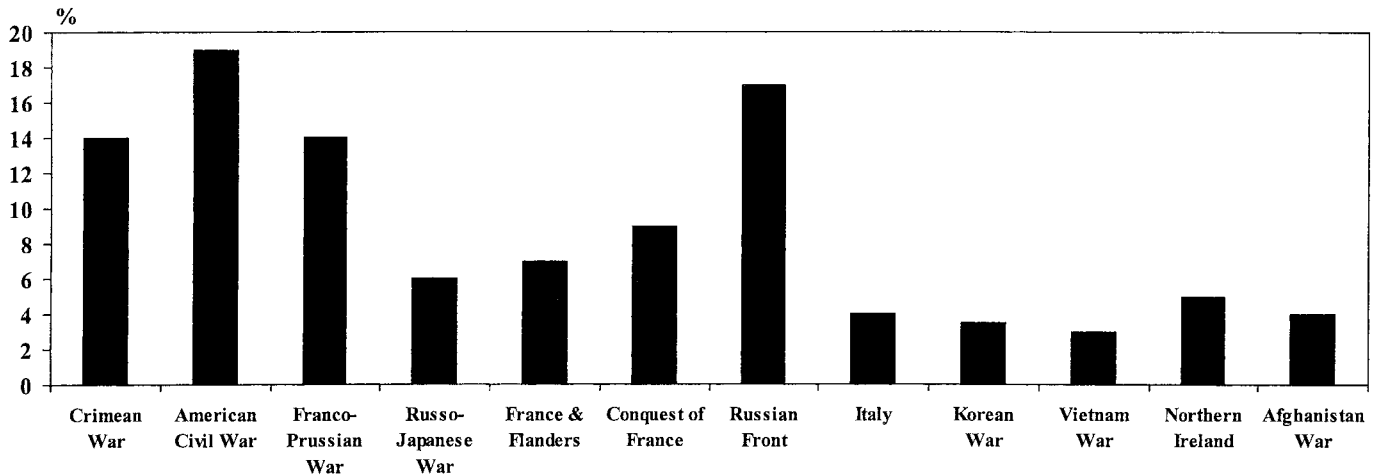
By the end of World War II, the lessons learned in the previous 30 years rapidly converged with modern anesthetic, blood transfusion, and antibiotics, and a doctrine that emphasized rapid evacuation to a surgical treatment facility for the critically wounded reduced the DOW rate to half of what it was for the U.S. Army in early World War II.

THE CHANGING NATURE OF COMBAT

Since the end of the Cold War, the concepts of modern battle have changed considerably. Although the specter of mass armies facing each other can never be ruled out, modern combat is more often described as asymmetric low density, very remote, or disbursed (e.g., Afghanistan) or nonlinear and urban (e.g., Mogadishu).

Although there is debate about the importance of urban conflict relative to other environments in increasing lethality, it certainly adds multiple dimensions of complexity. General Charles Krulac, former Commandant of the U.S. Marine Corps, who served two tours of duty in Vietnam, described the urban combat environment as a "three-block war" where ". . .we expect to be providing humanitarian assistance in one part of the city, conducting a peacekeeping operation in another and be fighting a lethal, medium intensity battle in yet a third part of the city."[11]

Asymmetric warfare refers to the discordance between the opposing forces in terms of tactics and weapons. This might refer to an urban guerilla war, where Special Forces or Marines attempt to encounter an enemy that cannot be dis-

Fig. 5. *Combat casualties: Percent killed in action, 1854–1989.[1] Crimean War, 1854–55 (British battle casualties); American Civil War, 1861–65 (Union); Franco-Prussian War, 1870–71 (German); Russo-Japanese War, 1904–05 (Japanese); France and Flanders, 1914–18 (British); Conquest of France, 1940 (German); Russian Front, 1942 (German); Italy, 1944–45 (American); Korean War, 1950–53 (American); Vietnam War, 1964–73 (U.S. Marine Corps); Northern Ireland, 1970–84 (British); Afghanistan War, 1979–89 (Russian).*

Fig. 6. *Combat casualties: Percent died of wounds after taken to treatment facility, 1854–1989.[1] Crimean War, 1854–55 (British battle casualties); American Civil War, 1861–65 (Union); Franco-Prussian War, 1870–71 (German); Russo-Japanese War, 1904–05 (Japanese); France and Flanders, 1914–18 (British); Conquest of France, 1940 (German); Russian Front, 1942 (German); Italy, 1944–45 (American); Korean War, 1950–53 (American); Vietnam War, 1964–73 (U.S. Marine Corps); Northern Ireland, 1970–84 (British); Afghanistan War, 1979–89 (Russian).*

tinguished from civilians in an urban population. To many, the epitome of asymmetric conflict is a suicide/homicide bomber in a crowd of unsuspecting civilians.

In low-intensity urban conflict, it is difficult to identify a casualty and get immediate qualified care. Thus, there is increasing reliance on self- and buddy aid for point-of-wounding care. Dispersed, low-density conflict also creates problems with access to and egress from the tactical environment. When a combat medic or equivalent can get to the casualty, interventions must be focused and effective. Even without medical gear, combatants typically carry or wear as much as 45 kg (100 lb) of equipment into combat. Thus, it becomes important that medical supplies are as compact and lightweight as possible. This consideration may well affect the clinical protocol; for example, a propensity for low-volume resuscitation may be influenced by the fact that 1,000 mL of isotonic crystalloid weighs 1 kg (2.2 lb).

Modern urban combat continues to be highly lethal. Recent data from the Surgeon General of Israel regarding Israeli Defense Force (IDF) operations in West Bank Palestinian refugee camps show 24% mortality of those injured severely enough to warrant hospitalization (personal communication to H.R. Champion from the Surgeon General of the IDF, 2002). In this setting, the most common cause of injury was from a bullet. Chest injuries accounted for 67% of moderate, severe, and lethal injuries. Almost three fourths (73%) of those with chest injuries died.

Compared with previous IDF urban combat in Lebanon, the recent IDF data (above) show an increase in the number of bullet wounds from 13% to 48% and a decrease in the number of shrapnel wounds from 74% to 17% of all injury types. Chest and abdominal wounds increased from 19% to 27% of moderate and severe injuries, and exsanguination as

the cause or a contributory cause of death increased from 41% to 56%. Evacuation times for the IDF to medical facilities compare extremely favorably with urban American Level I trauma centers: an average of 53 minutes. Although these outcomes cannot translate into other tactical settings, the IDF experience does serve to emphasize the importance of hemorrhage control in early management of combat casualties.

TIME AND COMBAT CASUALTY CARE OF HEMORRHAGE

Throughout history, an imperative of those providing combat casualty care has been to bring treatment as quickly as possible to the casualty. The Wurtz, a long, sausage-shaped cart that was deployed by Baron Percy (a contemporary of Larrey) to bring surgical instruments and dressings for 1,200 casualties onto Napoleonic battlefields, was one such initiative. In our own day, this imperative has resulted in the helicopter evacuation that characterized the latter stages of the Korean War and all of the Vietnam War.

One of the most interesting and successful clinical investigations ever carried out on combat casualties that is applicable to hemorrhage as a cause of death was that of the Board for the Study of the Severely Wounded during the last 6 months of World War II in Italy.[12] Extensive hemodynamic and biochemical measurements were made in several hundred seriously wounded combat casualties at an average time of about 6.5 hours after injury. Shock was graded into four categories using an elaborate clinical grading system. Blood pressure and heart rate were measured, and blood volume was determined using a dye dilution methodology. The results are shown in Table 4.

Table 4 Correlations among Blood Loss, Hemodynamics, and Outcome[11]

Grade of Shock	% in Each Grade	Blood Pressure, Systolic/Diastolic (mm Hg)	Heart Rate (beats/min)	Blood Loss (% of blood volume)	Lethality (%)
None	18	126/75	103	14	16
Slight	22	109/66	111	21	12
Moderate	29	95/58	113	34	25
Severe	31	49/25	116	46	66

Not surprisingly, casualties with the greatest blood loss were most likely to die, and a blood volume reduced to 50% of normal was likely to be fatal. More recent studies show similar results.[13] A study on penetrating torso injuries from the Pennsylvania Trauma Registry (patients aged 18–45) reveals the increase in risk and reduction in time to death with increasing hypotension (Table 5).[13]

Anatomic considerations indicate that approximately one tenth of all deaths are caused by hemorrhage from extremity wounds and therefore may be preventable by battlefield first aid. However, the tactical situation (i.e., enemy action) probably precludes effective first aid in one half of such casualties. Similarly, anatomic considerations suggest that perhaps 10% of those who die of exsanguinating truncal hemorrhage have wounds that are potentially correctable with surgery (i.e., iliac artery transaction) (personal communication to COL Richard Satava, MC USA, DARPA, 1997, on the basis of 100 casualty KIA who died 10 minutes or more after wounding). Because death occurs before such casualties can be evacuated to a surgical facility, salvaging such casualties will require a radically new approach to managing the otherwise fatally wounded.

Data from the Vietnam War show the importance of improved treatment of exsanguinating hemorrhage/shock, given that (1) approximately 10% of casualties admitted to a medical treatment facility were observed to be in shock,[14] (2) slightly less than 1% of admitted casualties had shock as the primary cause of death[10] (i.e., one third of the 3.4% DOW), and (3) 50% of those who were killed died from hemorrhage.

Assuming 1,000 casualties, a KIA rate of 20% (200 dead) and a DOW rate of 3.4% (27 died), one calculates that approximately 109 deaths may be attributable to exsanguinating hemorrhage/shock.[10] Because the total at risk of dying of these causes is approximately 180 casualties, exsanguinating hemorrhage/shock has a lethality of slightly less than two thirds. Clearly, more effective treatment modalities are indi-

cated, especially for those who die before admission to a medical treatment facility.

Death from hemorrhage occurs over a period of time related to the rate of blood loss. In both Somalia and Afghanistan, U.S. military personnel have bled to death in the combat zone over a period of hours, although the usual time is 5 to 10 minutes. Thus, the window of opportunity continues to be somewhat limited for individuals with uncontrolled hemorrhage whose systolic blood pressure (SBP) rapidly falls below 90 mm Hg. Paradoxically, the battlefield offers a larger target population because of the delay in evacuation compared with those in civilian settings. Those with ongoing hemorrhage of a rate that does not result in prompt exsanguination might benefit from resuscitation strategies, tactics, and techniques that aim to stretch the mythical "golden hour" to a 4- to 6-hour window before definitive care can be exercised.

Although the relationships among blood pressure, degree of shock, and volume lost are by no means certain, it is generally accepted that approximately 25% blood loss will cause a patient to go into shock with a SBP < 85 to 90 mm Hg and that blood loss of greater than approximately 60% will present an irretrievable state with SBP < 50 mm Hg, at which point cerebral perfusion and consciousness begin to dissipate. Individuals presenting with a SBP < 90 mm Hg will have diminished chance of survival over time, which will also be largely dependent on rate of bleeding, and thus hemostasis and ability to maintain vital organ perfusion pressure are critical. If the combatant starts with a circulating blood volume of 5,000 mL and a loss of 3,000 mL is lethal, with 1,000 mL producing shock, then an average blood loss of < 20 mL/min will cause an individual to exsanguinate to the point of death over a period of 2 hours. The judicious use of a volume expander that would provide 1,000 mL of expansion over a period of 1 hour might well protract the window of opportunity for an hour or more with each dose.

It is on the basis of such calculations that the recommendation was made for volume expansion with low-volume, low-dose (250 mL) hypertonic saline dextran or colloid, given over a period of 15 minutes. This anticipates that volume expansion would likely amount to some 750 to 850 mL over a period of 30 minutes.

The importance of balancing infusion volumes and rates in patients with certain estimated volumes of blood loss is of less consequence in a civilian setting, where prompt access to

Table 5 Risk of Death and Average Time to Death in Civilian Settings by Systolic Blood Pressure[12]

Systolic Blood Pressure (mm Hg)	Risk of Death	Time to Death (min)
90 +	0.042	419
76–89	0.081	188
50–75	0.458	161
< 50	0.95	18

definitive surgery is possible. However, these issues have increasing importance in tactical settings where the need to titrate care in a simple and reliable fashion over a period of hours might be critical in allowing a casualty to survive long enough to reach definitive care.

SUMMARY AND CONCLUSIONS

There are substantial differences between acute resuscitation of injured patients in the civilian and military arenas. These are the result of factors unique to combat, including (1) the high energy and high lethality of wounding agents, (2) multiple causes of wounding, (3) preponderance of penetrating injury, (4) persistence of threat in tactical settings, (4) austere resource-constrained environment, and (5) delayed access to definitive care. The physiologic consequences of these differences include the following:

● Higher mortality for shock (65%) compared with that in a civilian setting (50%).

● Higher mortality before physician-directed emergency care, such as that provided in a casualty clearing station, battalion aid station, or where forward surgical capability might be present. Death occurring before the provision of effective combat casualty care still accounts for over 90% of combat deaths.

● Patients with slower rates of hemorrhage will reach shock states and present sicker than they would normally present in a civilian setting, thus affording a target of opportunity for improved resuscitative care.

● Improved resuscitative care (i.e., carefully titrating volume expansion with blood loss) can offer substantial improvements in care for combat casualties.

Combat settings are not an environment for resuscitation research. Civilian trauma centers offer an environment for research that may benefit both the combat casualty and the civilian trauma patient. In both settings, the pathophysiologic process of dying is the same (i.e., dominated by exsanguination and central nervous system injury). Although the temporal trajectory of these processes may differ, recognition of these differences can serve to foster greater civilian-military collaboration in both basic and transitional research.

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