To Conserve Fighting Strength in Large-Scale Combat Operations

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As the U.S. Army considers near-peer threats associated with multidomain operations (MDO) and large-scale combat operations (LSCO), it must assess medical implications on overall combat effectiveness and mission success. Estimates for LSCO suggest casualty rates the likes not seen since World War II, requiring the joint force and the Military Health System to reimagine triage, combat casualty care, medical evacuation, force health protection (FHP), and prolonged casualty care to minimize the risk to force. Additionally, if the U.S. military does not gain and maintain air superiority to readily evacuate casualties from the battlefield, the inability to resuscitate, rehabilitate, and reconstitute soldiers will increase risk to mission and to strategic victory. Ultimately mission success will be driven by Army medicine's ability to clear the battlefield for commander's freedom of movement and maximizing return to duty of high-performing service members to enhance lethality.

Over the last twenty years, lethality from battle injuries (BI) has reached historic lows that are not anticipated to be achievable during LSCO. During Operations Iraqi Freedom and Enduring Freedom (OIF/OEF), 4,042 personnel were killed in action

(KIA) from hostile actions and 1,270 died of wounds (DOW) from a total of 52,143 wounded; while in nonhostile actions, there were 876 deaths from accidents, 159 from illness/injury, 51 from homicide, and 334 from self-inflicted causes.[1] In contrast, Operations Desert Storm/Shield had 382 total deaths (147 battle deaths; 235 other deaths) and 467 nonmortal wounds.[2] Conversely, the Vietnam War recorded significantly higher casualties with 58,220 total deaths (47,435 battle deaths; 10,786 other deaths) and 150,341 receiving hospital care.[3] The battles of World War II resulted in 405,399 total U.S. deaths (291,447 battle deaths; 113,842 other deaths) and 670,846 nonmortal wounds.[4] Despite the remarkable advancements in combat casualty care over the decades, the lethality of operations projected for LSCO will require a new health systems support approach to minimize both the risk to mission and risk to force.

U.S. Army medical personnel administer a transfusion to a wounded comrade who survived when his landing craft went down off the coast of Normandy, France, in the early days of the Allied landing operations in June 1944. (Photo courtesy of the U.S. Army Signal Corps)

During casualty analysis, experimentation, and adaption, services often prioritize lethality from BI while underestimating the profound impact of disease and nonbattle injury (DNBI) on lost duty days and overall lethality. However, DNBI can significantly degrade combat readiness, as evidenced in the Vietnam War from 1967 to 1970 with lost duty days of 4,458,139 for DNBI and 7,065,350 for BI and wounds (see table 1).[5] In addition, DNBI consistently outpaced BI evacuations during the wars in Iraq and Afghanistan, even during spikes in larger-scale fighting, accounting for 80–85 percent of evacuations.[6] In LSCO, the ability to rapidly return service members to duty, regardless if they sustained BI or DNBI, becomes increasingly critical especially moving from small-unit operations of Iraq/Afghanistan to division-level operations (see the figure). However, the challenge extends beyond the successful return

Table 1. Approximate Number of Man-Days Lost from Duty by Cause Among U.S. Army Personnel in Vietnam

Cause	1967	1968	1969	1970
Malaria	228,100	215,400	183,050	167,950
Acute respiratory infection	66,800	83,181	63,530	70,800
Skin diseases (including dermatophytosis)	66,400	64,832	50,790	80,140
Neuropsychiatric conditions	70,100	106,743	125,280	175,510
Viral hepatitis	80,700	116,981	86,460	85,840
Diarrheal diseases	55,500	60,132	48,980	45,100
Venereal disease (excluding CRO[1] cases)	7,500	6,840	3,130	3,700
Fever of undetermined origin	205,700	289,700	201,500	205,500
Disease total	780,800	943,809	762,720	834,540
Battle injury and wounds	1,505,200	2,522,820	1,992,580	1,044,750
Other injury	347,100	415,140	374,030	309,670

[1] CRO: Carded for record only
Preliminary estimates based on sample tabulations of individual medical records-carded for record only.

(Table from Spurgeon Neel, *Medical Support of the U.S. Army in Vietnam, 1965–1970*)

to duty and reconstitution with a unit; it involves ensuring each individual reaches and maintains their full warfighting potential and optimal performance. If they are not optimized, both the individual and the collective ability to carry out an assigned task or mission are at risk. This could manifest as reduced accuracy with a weapon system or lead to longer mission times and associated increased logistical requirements. Without peak physical and mental performance, service members may lack the necessary stamina for prolonged, high-stress environments intrinsic to LSCO, ultimately impacting mission success.

This article addresses the impact of MDO and LSCO on BI and DNBI, drawing from historical information along with lessons learned from the war in Ukraine. The goal is to maximize U.S. Army capability in LSCO by addressing the full spectrum of soldier lethality and performance challenges related to BI and DNBI. To conserve fighting strength, commanders and medical leaders must emphasize FHP and prevention. Ultimately, military medicine's ability to strive for peak performance, maximize survival rates, and ensure the highest potential functional recovery underpins the trust service members, their families, and U.S. citizens place in the military healthcare system.

Battle Injury

The standard outcome measurements of BI lethality are a combination of KIA and DOW.[7] Historical data shows a steady decline in lethality over time: from World War II (30.8 percent KIA, 3.6 percent DOW) to the Korean War (23.7 percent KIA, 3.2 percent DOW) and from the Vietnam War (19.1 percent KIA, 3.2 percent DOW) to OIF/OEF (7.1 percent KIA, 2.5 percent DOW), with substantial variability at the beginning, middle, and end of the wars.[8] The unprecedented success in BI outcomes during OIF/OEF was driven by several factors. Casualty rates were relatively low with an incredibly infrequent high concentration of casualties in time and space. Medical evacuation (MEDEVAC) by medical personnel from the point of injury versus casualty evacuation (CASEVAC) by nonmedical personnel from the point of injury was the norm for maximizing initial and en route care. In addition, the military's ability to maintain air superiority resulted in rapid MEDEVAC within a combat zone from the point of injury to surgical intervention, typically bypassing roles of care, followed by rapid evacuation to Germany and the continental United States (CONUS) through the Air Force's aeromedical evacuation system. The presence of critical care air

Observed OIF & OND Evacuations, Jan 2003-Dec 2011[28]			Estimated evacuation rate / 1,000 per year[26]	Division / Combined Joint Task Force (PAR 25,000)[27]	Brigade Combat Team (PAR 5,000)	Battalion / Squadron (PAR 1,000)	Company / Battery / Troop (PAR 100)
Clinical Category	#	% of DNBI		# of projected evacuations by clinical category in future conflict, per year			
Battle Injury[29]	8,944	---	7.07	176.6	35.3	7.1	0.7
Musculoskeletal System	8,257	16.3	6.52	163.1	32.6	6.5	0.7
Non-battle injury / Poison	7,542	14.9	5.96	149.0	29.8	6.0	0.6
Behavioral Health	5,892	11.6	4.65	116.4	23.3	4.7	0.5
Ill-defined conditions	5,065	10.0	4.00	100.0	20.0	4.0	0.4
Nervous System	2,684	5.3	2.12	53.0	10.6	2.1	0.2
Digestive System	2;592	5.1	2.05	51.2	10.2	2.0	0.2
Genitourinary System	1,794	3.5	1.42	35.4	7.1	1.4	0.1
Circulatory System	1,512	3.0	1.19	29.9	6.0	1.2	0.1
Other Conditions	1,062	2.1	0.84	21.0	4.2	0.8	0.1
Neoplastic Conditions	1,006	2.0	0.79	19.9	4.0	0.8	0.1
Skin Conditions	980	1.9	0.77	19.4	3.9	0.8	0.1
Respiratory System	882	1.7	0.70	17.4	3.5	0.7	0.1
Infectious Diseases	753	1.5	0.59	14.9	3.0	0.6	0.1
Endocrine Systems	616	1.2	0.49	12.2	2.4	0.5	0.0
Breast Conditions	502	1.0	0.40	9.9	2.0	0.4	0.0
Pregnancy	268	0.5	0.21	5.3	1.1	0.2	0.0
Congenital Conditions	161	0.3	0.13	3.2	0.6	0.1	0.0
Hemotologic Conditions	122	0.2	0.10	2.4	0.5	0.1	0.0
Total	50,634	100.0	40.00	1,000.0	200.0	40.0	4.0

Legend

- >3.0 projected events
- 1.0 -- 3.0 projected events
- 0.5 -- 1.0 projected events
- <0.5 projected events

[26] Proportional evacuation estimate is based on expected all-cause evacuation rate of 0.04 events / 1,000 personnel. See Medical Surveillance Monthly Report, Vol 17, No 2, Feb 2010.
[27] PAR = Population at risk
[28] Medical Surveillance Monthly Reports, Vol 19, No 2, Feb 2012
[29] Battle injury evacuation rate is DIRECTLY related to level of combat intensity - the estimates reflected in this chart are drawn from OIF and OND. Future conflicts may/may not share the same level of combat intensity.

(Figure from Capability Development Integration Directorate, *Prolonged Care in Support of Conventional Military Forces: Capabilities Based Assessment* [U.S. Army Health Readiness Center of Excellence, 14 April 2017])

Figure. Summary of Battle Injury, Disease, and Nonbattle Injury Determination from Operation Iraqi Freedom and Operation New Dawn with Correlation to Personnel at Risk During LSCO

Fellow soldiers help a wounded Ukrainian defender at a first-aid station on 22 November 2022 in the city of Bakhmut in the Donetsk region. (Photo by Serhii Nuzhnenko, Radio Free Europe/Radio Liberty via war.ukraine.ua)

transport teams enabled the movement of the critically injured patients with exceptional clinical outcomes. These successes were bolstered by enhanced body armor and other insights gained through the Joint Trauma Analysis and Prevention of Injury in Combat.[9] The delivery of high-level medical care within seconds of injury including tourniquet use, lifesaving interventions like blood product support, and surgery within one hour of injury were all key medical interventions that positively impacted survival.[10] In addition, clinical practice underwent rigorous refinement through the Joint Trauma System by its Department of Defense Trauma Registry.[11] Despite a 44 percent decrease in BI mortality over OIF/OEF, the U.S. military healthcare system did not reach the goal of 0 percent preventable deaths from BI.

The war in Ukraine highlights key challenges MDO will impose on BI management in LSCO, which is further complicated by the ubiquitous presence of drones. Considering casualties at all roles of care in Ukraine, BI accounts for 35.7 percent of casualties, disease for 56.2 percent, and nonbattle injuries for 8.1 percent. Focusing on Role 1-2 care, DNBI accounts for 30 percent while BI makes up a full 70 percent.[12] Of note, these statistics reflect personnel losses who cannot return to duty on the day of their initial visit. Initially, military medical leaders in Ukraine implemented tactical combat casualty care standards that were initially established during OIF/OEF and adapted them to their operational environment.[13] Over time, however, the significant increase of casualties in local fighting exceeded 1,200 per day when coupled with the use of drones, extended evacuation times, insufficient blood product availability, and the targeting of medical assets that resulted in worse outcomes than observed in Iraq and Afghanistan.[14] A primary challenge to survivability is evacuation delays by CASEVAC and not MEDEVAC. Whereas evacuations in Iraq and Afghanistan typically occurred within one hour, evacuations times in Ukraine take an average of eight to twelve hours before reaching surgical intervention.

This delay to definitive care severely impacts survival rates. Limited blood product availability across the battlefield and prolonged tourniquet application (three to six hours) not only causes limb death necessitating an amputation but also results in elevated potassium levels and reperfusion injury from fluid shifts leading to shock.[15] A 2023 survey of the top three causes of death in Ukraine differs from OIF/OEF but parallels the etiologies observed in the Vietnam War: head injury, hemorrhage, and shock likely from infection, high potassium levels, and reperfusion syndrome.[16] Of note in the Vietnam War, if one survived the first twenty-four hours after injury, the top two causes of death were shock and pulmonary embolism.[17]

The war in Ukraine also highlights the importance of military medical intelligence. As an example, the movement of blood by the Russian military along with their medical infrastructure at the onset of the war was a major indicator of definitive combat operations versus an exercise, enabling the prediction of a window of time. As blood moved forward and there was an increase in blood collection drives, the likely window of onset of combat operations could be pinpointed based on the storage duration of packed red blood cells (forty-two days).[18]

Global health engagements are one strategy to close the knowledge gap, but it still requires analyzing and distributing that knowledge to be predictive and prescriptive. Army medicine has determined three major challenges to casualty care essential for supporting operational priorities: clearing the battlefield to enable commander's freedom of movement, maximizing return-to-duty rates, and overcoming congested logistics. One critical shift during LSCO will be the reliance on CASEVAC, the use of nonstandard casualty movement without dedicated medical personnel, versus traditional MEDEVAC for the movement of most casualties.[19] This will delay enhanced medical care at the point of injury and during en route care. The "golden hour" standard for reaching specialized care will be replaced by a triage-focused approach.[20] Additionally, the inability to rapidly move casualties to CONUS, in combination with the inability to rapidly move in theater, will require prolonged care at echelon. Although planners often approach problem sets as a math and physics problem, casualty management is dictated by the realities of anatomy and physiology.

The role of the frontline medic and nonmedical provider is paramount to the survival of a casualty in the initial moments following a battlefield injury. The nonmedical provider plays a crucial role in self and buddy aid, a practice with significant success during OIF/OEF. In Ukraine, tactical combat casualty care methods are employed; however, due to delayed evacuation, medics must now assess and manage interventions applied during care under fire and tactical field care to enhance survivability. This shift requires medics to have a deeper understanding of anatomy and physiology to deliver prolonged casualty care, including the administration of blood products and the execution of tourniquet takedown procedures. The challenges of contested logistics and prolonged evacuation times further highlights the need for frontline medics to make lifesaving decisions based on the operational environment.

Unique problems identified during the war in Ukraine also include the management of civilian trauma and patients with chronic medical conditions in an overlapping military and civilian healthcare system. Ukraine has moved civilian patients to other European countries to maximize service member care in Ukraine.[21] Agreements for care across Europe were required because of the volume of civilian and military casualties, especially those military casualties who were not going to return to combat quickly. This will be an issue not only for U.S. casualties overseas but will also be an issue with U.S. civilian facilities given the limited inpatient, ICU, and rehabilitative care available in U.S. military treatment facilities. Of note, most civilian hospitals including the VA function at 95 percent plus capacity without surplus rooms or staff. Very little data about detainee care is available from Ukraine, which underscores the requirements and challenges the United States will have with prisoner-of-war care. Coalition nations must plan clear medical rules of engagement to synchronize service member, civilian, and prisoner-of-war healthcare resourcing during conflict.

Another challenge the United States and allies will face became increasingly evident as Ukraine received medical supplies worldwide in support of their forces and civilian population. Currently, U.S. service members are unable to use non-Food and Drug Administration (FDA)-approved medication and

Table 2. Predicted Mortality in a Hypothetical Population of 1,000 Untreated Combat Casualties

Location	0–1 Hour	1–6 Hours	6–24 Hours	1–7 Days
Head	70	11	15	27
Face	6	2	1	24
Neck	9	2	1	3
Thorax	48	11	8	33
Abdomen	28	17	16	31
Upper extremity	4	4	3	29
Lower extremity	15	12	10	67
Multiple	15	7	3	5
Total	195	66	57	219
Cumulative total		261	318	537

(Table adapted from Ronald F. Bellamy, "The Causes of Death in Conventional Land Warfare: Implications for Combat Casualty Care Research," *Military Medicine* 149, no. 2 [February 1984]: 55–62, https://doi.org/10.1093/milmed/149.2.55)

non-FDA-cleared devices without legislative change. The validation of safe medication and devices will result in challenges using host-nation medical supplies, which becomes even more problematic considering the European Union's centralized approval of medications and devices when compared to the lack of a similar approval system across other regions of the world. Also, currently much Class VIII is sourced from potential adversaries, with a limited supply chain and widespread use of just-in-time inventory management.[22]

A unique challenge arising is the use of whole blood/walking blood bank products, which was initially illegal in Ukraine at the onset of the war, most likely due to their high hepatitis and HIV rates.[23] This required a policy change to enable the use of this lifesaving measure. Similar challenges exist across Europe and other global regions.

The necessity for terms of reference for key medical capabilities also became apparent as a combat medic in the U.S. Army has certain knowledge, skills, and behaviors, while a "medic" in Poland is equivalent to a U.S. Army physician assistant, and an emergency medicine-trained physician in France accompanies ambulances during emergency care. The role of medical mobility further complicates healthcare delivery in MDO as surgery, postsurgical care, and ICU-level care is not conducive to rapid movement. This becomes even more problematic if there is purposeful targeting of medical assets, necessitating enhanced protection, distributed formations, and novel positioning of medical assets including civilian buildings of opportunity and underground locations. While noncombatant evacuation operations of non-Ukraine civilian personnel did not overwhelm surrounding countries, there was a significant demand for medical training of Ukrainian personnel outside of the country to train the trainers within.

Historical data underscores the critical relationship between mortality and the time elapsed from injury to definitive treatment. During World War I, mortality rates increased from approximately 10 percent within the first three hours postinjury to approximately 35 percent in the next three hours, and then reaching 75 percent after eight hours.[24] This was validated during the Vietnam War with greater context to causes of death by the injury site and increased granularity of time with the highest predicted mortality of 0–1 hour for head, 1–6 hours for abdomen, 6–24 hours for abdomen, and 1–7 days for extremity (see table 2).[25] Death at 0–1 hours was due to hemorrhage followed by central nervous system trauma and finally shock.

As casualties survive the first few critical hours after injury, survival rates increasingly depend on access to advanced, intensive care-level support. In Ukraine, the presence of hyperkalemia (an elevated potassium level) and reperfusion syndrome (tissue damage caused by returning the flow of blood to previously blood-deprived parts of a body) harkens back to the challenges faced in

World War II. In that war, acute kidney injury (AKI) affected 18 percent of the severely injured patients, a stark contrast to the Korean War, where the AKI incidence dropped to 0.5 percent with the introduction of battlefield dialysis.[26] By the Vietnam War, only 0.17 percent of all casualties developed AKI. Dialysis was a standard capability in field hospitals until around 2014, when it was eliminated from the modified table of organization and equipment. The institutional training of Army dialysis technicians ceased around 2022 due to a reduced demand caused by rapid patient movement to initial surgical care with advanced ICU care followed by rapid movement to the CONUS.

Another major concern in Ukraine is the report that nearly 100 percent of casualties develop an infection with multidrug resistant (MDR) bacteria in which there are no available antimicrobials to treat the infections.[27] As noted during OIF/OEF, the presence of MDR bacteria complicates treatment, especially after the first five days of injury, leading to extended hospitalizations, more ICU days, increased surgical interventions, and poorer outcomes.[28] This portends a bigger concern than typically discussed, as U.S. casualties will likely be returning to CONUS civilian facilities to absorb the expected number of patients due to lack of sufficient bed capacity in military treatment facilities (MTF). This was not an issue during OIF/OEF but will become an additional threat to the homeland healthcare system as returning service members could expose civilian hospitals and patients to MDR bacterial infections from the battlefield.

Once casualties survive their initial BI, as shown in Ukraine, the role of rehabilitation can become increasingly complicated because of the numbers of amputations and lack of inpatient and rehabilitative care facilities within the country. The U.S. military could experience similar challenges of limited assets within theater and the challenges of evacuating patients to CONUS. To maximize return to duty, enhanced forward-care capabilities are essential—an approach not fully developed during OIF/OEF. The 60-to-120-day evacuation window to CONUS in the Europe and Pacific theater of operations during World War II show a potential way to maximize return to duty. Patients spent an average length of 80, 70, and 65 days after BI during World War II, the Korean War, and the Vietnam War, respectively.[29] Of the 194,716 wounded in Vietnam, 61,269 (31 percent) were treated and returned to duty.[30] Of those admitted to MTFs, the distribution for return to duty was 42.1 percent in Republic of Vietnam, 7.6 percent in the U.S. Indo-Pacific Command, and 33.4 percent in the CONUS.[31] To replicate this approach to casualty care in a future LSCO environment would require maximizing rehabilitation in theater. Establishing Role 4 rehabilitation facilities equipped with physical therapists, occupational therapists, physical medicine and rehabilitation physicians, rheumatologists, and specialized technicians will be essential to enable in-theater recovery and return to duty.

The impact on risk to mission can be seen by comparing orthopedic injury data from Operations Desert Storm/Shield (ODS/S) and OIF/OEF. During ODS/S, the military healthcare system deployed limited rehabilitative resources. In a retrospective review of orthopedic injuries from ODS/S, authors Michael Travis and Michael Cosio noted that 45 percent of injuries evacuated from theater were orthopedic in nature and 45 percent of those with orthopedic injuries were able to return to duty without further treatment.[32] In LSCO, the MEDEVAC of soldiers who can be returned to duty represent a substantial risk to the mission. During OIF/OEF, Military Health System (MHS) leaders deployed additional rehabilitative experts such as physical therapists. In a retrospective review, Travis and Cosio found that physical therapy accounted for 45 percent of the workload in a combat support hospital's outpatient mission and that 96.1 percent of soldiers were returned to duty with either no restrictions or a temporary limited restriction easily accommodated by commanders in a deployed environment.[33] Additionally, an orthopedic surgeon who reviewed the cases estimated that 17.7 percent of these soldiers would have been evacuated to Germany or CONUS had the physical therapist capability not been available.[34]

Once patients are evacuated CONUS in LSCO, their care will likely be more reflective of events in World War II, the Korean War, and the Vietnam War. Then, service members received treatment across the civilian healthcare system and VA facilities. An adequate comprehensive organizational structure like warrior transition units or soldier recovery units—used over the past fifteen years during OIF/OEF—will be challenging to support the number of casualties returning CONUS during LSCO. A shift in the approach that leverages civilian capabilities will likely be required. Current efforts by U.S. Northern Command seek to address these challenges through the National Disaster Medical System-Integrated CONUS Medical Operations Plan, but much work remains to ensure preparedness for future demands.[35] One consideration could be to include centers for military and civilian experts to layer in MTFs, VA facilities, and civilian large level 3 trauma and rehabilitation centers with graduate medical education and strong research centers to maximize the synergistic rehabilitative systems. Such examples include the University of Texas Health Sciences San Antonio/Fort Sam Houston, Texas; Colorado University/Fort Carson, Colorado; University of North Carolina/Fort Bragg, North Carolina; and Vanderbilt University/Fort Campbell, Kentucky.

Overall, models need to be refined for prolonged care in theater, along with unique requirements of rehabilitation in theater. The global demand on strategic platforms and inadequate staffing available for patient air movement will require policy updates to incorporate rehabilitation in theater to support optimization of return to duty as far forward as possible. Further investigation into sea evacuation and other multimodal evacuation approaches offers opportunities to drive the experimentation required to develop relevant doctrine, organizational structure, training, materiel solutions, leader development, personnel with unique expertise, facilities, and policies (DOTMLPF-P) (see table 3).

Disease

Disease complications like diarrhea and respiratory tract infections from infectious diseases (including tropical diseases), skin disorders, and behavioral health issues have historically been significant burdens across wars. However, the prevalence of diseases has decreased over time from 91 percent in World War II to 69 percent in the Vietnam War (see tables 4 and 5).[36] This decline likely reflects improved FHP infection prevention measures and shifting endemic tropical disease regions worldwide through eradication and vector control programs. During more recent conflicts, disease rates have continued to drop. The disease rate of 0.307/1,000 U.S. Army soldiers in ODS/S decreased to 0.166/1,000 for OIF and 0.227/1,000 for OEF.[37] The top five conditions resulting in hospital admission in OIF/OEF were respiratory symptoms, kidney stones, cellulitis/abscess, appendicitis, and generalized symptoms (alteration of consciousness).[38] DNBI was responsible for approximately 50 percent of MEDEVACs, with leading causes being behavioral health conditions (~10 percent), ill-defined conditions (~9 percent), digestive (~6 percent), genitourinary (5 percent), and nervous system (~3.5 percent).[39] The lack of substantial infectious diseases including tropical disease in Iraq and Afghanistan is reflective of the low tropical disease threats within these regions. In contrast, rates of infectious diseases are expected to be significant in a conflict in Southeast Asia, Asia, Africa, or South/Central America. However, implementing and acting on disease surveillance during wartime remains difficult. Of note, disease data from Ukraine is limited, especially regarding behavioral health issues.

It is a challenge to provide detailed information from Ukraine on the impact of DNBI as Ukraine only reports a limited number of diseases that help provide insight into key infections.[40] However they do track key infections that would impact blood safety and walking blood like HIV, which is noted to have the second highest rate of HIV in Europe, only behind Russia.[41] There needs to be an establishment of a joint casualty system for BI and DNBI that must include a strong medical intelligence arm that can fully inform the threat and impact of infectious diseases. For example, an overall lack of emphasis on DNBI across the enterprise likely reflects the low rate of disease during OIF/OEF. Furthermore, a lack of understanding of the impact on the performance and lost duty days associated with a specific disease means that modeling the impact on personnel and missions to fully address DOTMLPF-P implications remain challenging.

Infectious disease. Historically, particularly up to World War I, death on the battlefield was predominantly caused by diseases such as smallpox, cholera, malaria, and typhus.[42] The ushering in of critical advancements during and after the war—including in sanitation, nutrition, germ theory, antimicrobial agents, vector control, prophylaxis, tracking, treatment, and personal protective measures like insect repellent and nets—resulted in a transition of dying from disease to dying from combat-related wounds. The death ratios from infection to trauma was 1.1:1 during World War

Table 3. Proposed DOTMLPF-P Recommendations to Address LSCO Impact on Battle Injury, Disease, and Nonbattle Injury

Doctrine	Organization	Training	Materiel
Updates to Army key doctrine and programs of instructions —Army health services —Tactical combat casualty care (TCCC) + triage —Hospitalization —CASEVAC Update to biothreat and medical intelligence proponency Global health engagement and security cooperation updates addressing medical intelligence and agreements for in theater management especially for prolong care, evacuation, rehabilitative care, and civilian care	Convalescent hospital for rehabilitation with Holistic Health and Fitness (H2F) Forward deployed H2F Intelligence analytics and informatics with AI for predictive and prescriptive outcomes Theater-level medical intelligence section for predictive and prescriptive outputs Joint Trauma System expands to joint casualty system to incorporate disease and nonbattle injury (DNBI) and modernizes to link with electronic deployable medical record with data analytics for predictive and prescriptive outputs Rapidly deployable special medical augmentation response teams (SMART)—vascular, infection prevention/control/tropical medicine, renal disease, medical informatics, research, CBRN, and virtual care Updated force health protection in LSCO environments Multimodal evacuation formations—ground, air, maritime, train, and river	Updated initial and sustainment training —Triage —CASEVAC —TCCC —Combat life saver —LSCO + multidomain operations Virtual, augmented and mixed reality (AR/VR/MR) training Medical Simulation Training Center–Next Generation (MSTC–NG) for point of injury, Role 1 and 2 care Models for battle injuries (BI) and DNBI incorporated into exercises that address evacuated personnel, mortuary affairs, and sustainment operations that also include lost duty days and impact on human performance Behavioral health training including moral injury Mobile training teams for U.S. military personnel and coalition partners across BI and DNBI	Novel therapy and infection prevention and control for multidrug-resistant bacteria AI process to be predictive and prescriptive of DNBI Methods to be predictive and prescriptive with moral injury, PTSD, and stress reaction Wearable technology with decision support tool for BI and DBNI Medical common operational picture that is predictive and prescriptive for commanders to enable risk-based disease assessment and impact on human performance Prophylaxis and prevention for DNBI Novel platforms that allow for surgery, postsurgical care, ward care, and ICUs to be mobile and protected
Leadership/Education	**Personnel**	**Facilities**	**Policy**
Mitigation strategies for DNBI especially commander emphasis and adherence on force health protection and behavioral health support iCOVER exposure CASEVAC and triage exposure CBRN impact exposure Moral injury exposure Cold weather exposure Updated AI and data analytics capabilities with established applicable data systems	Military medical intelligence experts Data analytics and informatics experts for DNBI H2F experts in operational rehabilitation and prevention Changing civilian graduate medical education will change personnel knowledge and skills impacting future capabilities necessitating a reassessment of doctrine, organization, and training (i.e., more specialized experts without generalized knowledge and skills)	Novel infection prevention and control infrastructure for multidrug resistant bacteria U.S. centers of collaboration-civilian, military, VA centers of operational, clinical, teaching, and research excellence MSTC–NG AR/VR/MR environments U.S. medical industrial base development and expansion	60–120-day evacuation policy National Disaster Medical System–Integrated CONUS Medical Operations Plan for United States receiving of casualties Modernized Solider Readiness Program for movement from fort to port with congested logistic challenges reliant on civilian industrial base to include clear tracking system and redundancy Approval of non-FDA approved medication or cleared devices for use on U.S. military personnel Agreements with host nations for care of U.S. military casualties Noncombatant evacuation operations agreements Standardized terms of references across coalition and partners Updated doctrine and program of infrastructure processes for rapid development and implementation

(Table by authors)

Table 4. Selected Causes of Admission to Hospital and Quarters Among Active-Duty U.S. Army Personnel in Vietnam

Cause	1965	1966	1967	1968	1969	1970
Wounded in action	61.6	74.8	84.1	120.4	87.6	52.9
Injury (except wounded in action)	67.2	75.7	69.1	70.0	63.9	59.9
Malaria	48.5	39.0	30.7	24.7	20.8	22.1
Acute respiratory infections	47.1	32.5	33.4	34.0	31.0	38.8
Skin diseases (includes dermatophytosis)	33.1	28.4	28.3	23.2	18.9	32.9
Neuropsychiatric conditions	11.7	12.3	10.5	13.3	15.8	25.1
Viral hepatitis	5.7	4.0	7.0	8.6	6.4	7.2
Venereal disease (includes CRO)	277.4	281.5	240.5	195.8	199.5	222.9
Venereal disease (excludes CRO)	3.6	3.8	2.6	2.2	1.0	1.4
Fever of undetermined origin	42.8	57.2	56.2	56.7	57.7	72.3

CRO: Carded for record only
Rate expressed as number of admissions per annum per 1,000 average strength.

(Table from Spurgeon Neel, *Medical Support of the U.S. Army in Vietnam, 1965–1970*)

Table 5. Hospital Admissions for All Causes, U.S. Army During World War II, the Korean War, and the Vietnam War

War	Year	All Causes	Nonbattle Injury	Battle Injury and Wounds	Disease	Disease as Percent of All Causes
World War II						
China-Burma-India	1942–1945	1,037	85	8	944	91
Southwest Pacific	1942–1945	1,067	147	30	890	83
Korean War	1950–1952	1,005	165	229	611	67
Vietnam War	1965–1969	505	69	85.6	351	69.2

Average rate expressed as number of admissions per annum per 1,000 average strength.

(Table from Spurgeon Neel, *Medical Support of the U.S. Army in Vietnam, 1965–1970*)

II; and the ratio was 0.2:1 in the Korean War, Vietnam War, and OIF/OEF.[43]

Although DNBI has a limited impact on death on the battlefield today, its impact on lost duty days remains significant. During the Vietnam War, up to 80 percent of lost duty days were attributed to infectious diseases (see table 1), and they also contributed to high rates of hospital admissions (see tables 4 and 5). However, some of the infectious diseases in the Vietnam War are less relevant today.

As an example, viral hepatitis is less of an issue due to availability of a vaccine with a 90 plus percent protection against hepatitis B. Although no hepatitis C vaccine exists, there is effective curative therapy available. Of note, both infections are spread through blood transfusions, which highlights the potential impact of the walking blood bank (and the sources of blood for the walking blood bank) on battlefields of the future. HIV did not exist in the Vietnam War, but Russia and China are experiencing increasing rates, which also impact walking blood banks. Also of note, the Philippines saw a 411 percent increase in daily incidence from 2012 to 2023. Drug-resistant tuberculosis rates are increasing in Russia, North Korea, the Philippines, and other countries across Asia.[44] Although improved malaria control with prophylaxis agents and personal protective measure will likely improve those numbers in future wars, personal protective measure adherence rates have historically been challenging despite command emphasis. Other

Soldiers carry a wounded comrade through a swampy area in Vietnam circa 1969. (Photo courtesy of the National Archives)

vector-borne diseases like dengue, which is increasing in Southeast Asia, can cause large outbreaks; others can be associated with prolonged syndromes that limit activity.[45] For example, Chikungunya—spread by the Aedes mosquito and present across South and Central America, Africa, southern Europe, and Asia—has an attack rate of approximately 30–50 percent with symptoms including fever that lasts seven to ten days and a 4–78 percent attack rate of arthritis of major joints that can impact performance and persist for three months or longer.[46] Although an FDA-approved vaccine is available, it is not currently part of deployment vaccine regimens. The potential for large outbreaks of infectious diseases persists. The 1918–1919 influenza pandemic, with fifty million worldwide deaths, was strongly linked with U.S. military training facilities and the worldwide transmission was augmented by military movements.

The challenges with diarrhea and respiratory tract infections substantially impacted lost duty days during OEF/OIF.[47] In a survey of 4,348 personnel deployed in OIF, 76 percent reported at least one diarrhea episode during their deployment and more than 50 percent reported multiple episodes. Diarrhea decreased job performance in 45 percent of personnel for a median of three days; 62 percent sought medical care at least once.[48] Disease burden included 31 percent who required intravenous rehydration. Of those cases, 17 percent were confined to a bed for a median of two days and the lost duty days was an estimated 3.7 days per 100 person-months.[49] Of particular concern is that nearly 10 percent of affected individual reported persistent diarrhea greater than fourteen days and 3 percent more than thirty days.[50] Norovirus, which causes severe vomiting and diarrhea, nearly closed a hospital in Basra, Iraq, at the beginning of the war and did close the airfields in Camp Arifjan, Kuwait.[51] On the one hand, tropical diseases in Iraq and Afghanistan had minimal impact in contrast to World War II where malaria was a major concern. On the other hand, leishmaniasis impacted both Afghanistan and Iraq for approximately two to three years, highlighting the impact diagnostic, treatment, personal protective measures, and environmental changes in living structure and field sanitation can have when fully implemented.[52]

An increased understanding of the impact of specific infectious diseases on service member performance is needed. As wars progress, the collapse or deterioration of local, regional, and national systems designed to mitigate disease through sanitation, vector control, and personal interactions often lead to resurgence of endemic diseases or the introduction of new ones brought in by foreign military forces. To address this effectively, critical information about disease prevalence and impact must be incorporated into medical requirements models to better assess their effect on operational outcomes and commanders' decisions. In addition, there will be a need to adapt FHP policies, processes, and formation to meet the challenges of LSCO such as constant observation, drones, and long-range fires. Additionally, the Army must transition to predictive and prescriptive AI to enable operations. We can potentially add a simple concept that data should not be simply a way of telling a story and a presentation of facts for which a leader can draw their own conclusions for future efforts. Leveraging data for both predictive and prescriptive outcomes present leaders opportunities to direct action based on forward-looking analysis. An increased effort is needed to prevent, diagnose, and treat key pathogens as near to the point of need as possible to minimize lost duty days, enhance performance, and maximize return to duty.

Behavioral health. Behavioral health (BH) has significantly impacted warfighters throughout history, especially with posttraumatic stress disorders (PTSD) and acute stress responses. During the Vietnam War, BH-related lost duty days increased dramatically from 70,100 lost duty days in 1967 to 175,510 in 1970 (see table 1).[53] This equated to a rate increase from 11.7 per 1,000 soldiers in 1965 to 25.1 in 1970.[54] During OIF/OEF, BH diagnoses were the most common cause of evacuation for care, though rates varied over time; 334 deaths were attributed to self-inflicted causes.[55] Similarly, there were more deaths from self-inflicted causes (33) than KIA and DOW together (23) in Operation Inherent Resolve.[56] In the ongoing war in Ukraine, BH conditions have been associated with combat ineffectiveness in up to 50–60 percent of some regular Ukrainian armed forces units.[57] As a result, Ukraine has requested assistance from Walter Reed Army Institute of Research and Uniformed Services University to provide short-course training for their military personnel to mitigate the harmful psychological impacts of modern war. Reports of rotating time on the front and the rear at 1:3-week ratios are reminiscent of the trench warfare during World War I.[58] A major concern with LSCO, especially with the role of triage and prolonged care, is the impact of moral injury on medical professions and first responders triaging large numbers of patients to expectant outcomes.[59] This challenge has not been well characterized in previous wars. The ubiquitous presence of drones on the modern battlefield creates a unique trigger for stress and trauma, unlike experience in previous conflicts. This requires further characterization and development of mitigation strategies.

An assessment of 7,023 psychiatric aeromedical evacuations from Iraq and Afghanistan revealed risk factors for evacuation from the battlefield included younger, female, white, divorced or widowed, and less-educated personnel, along with junior enlisted service members serving in combat arms military occupational specialties.[60] The primary BH diagnoses among evacuees include depressive disorders (25 percent), adjustment disorders (18 percent), PTSD (9 percent), bipolar disorders (6 percent), anxiety disorders (6 percent), and suicidal ideation and associated behaviors (3 percent).[61] Notably, peak psychiatric evacuations coincided with significant combat operational events, highlighting a clear connection between operational intensity and BH outcomes. Given the potential magnitude of these BH symptoms in a LSCO environment, having enough highly trained behavioral health specialists to effectively detect, manage, and treat these conditions will be a significant challenge. Just as triage and tourniquet utilization significantly improved survival on the battlefield, broad dissemination of psychological first aid and techniques to mitigate acute stress reaction will be critical to conserve fighting strength.

A holistic approach to battlefield BH will be essential for addressing the challenges associated with LSCO. The development of methods to expand the ability to detect and manage BH issues, especially given the magnitude of the potentially impacted personnel and the shortage of BH specialists across the battlefield, should be prioritized in resourcing decisions. All personnel must be trained to recognize and address immediate BH concerns, which impact readiness and ultimately survival on the battlefield. A short course for combat medics to enhance their ability to screen and address

BH issues (BH-GEAR) has been developed, including buddy aid and psychological first aid.[62] These approaches need to be standardized and integrated across the force during initial entry training and refreshed regularly throughout a service member's career. iCOVER, a validated method from Israeli and U.S. militaries for mitigating the impact of acute stress reaction, provides a structures six-step approach to identify a team member who is having an acute stress reaction, connect to bring them to the present moment (eye contact, touch, hearing), offer commitment to reduce sense of isolation, verify facts with simple questions to get the thinking brain back in gear, establish order of events to reorient the individual, and request action to reengage in purposeful action.[63]

Overall, the ability to be predict and effectively address BH challenges at both the individual and collective/unit level will remain a significant battlefield challenge, especially when aiming to optimize service members' full potential and performance. In competition with peer and near-peer competitors with technologic parity on the battlefield, mental agility and cognitive flexibility become more critical to maintain an operational advantage. Increased efforts to monitor stress and fatigue, potentially through wearable technology, must be developed to alter commanders and medical professionals when service members are losing mental acuity, cognitive flexibility, emotional regulation, resilience, and grit; signaling the risk to the service member (e.g., acute stress reaction) or to the unit through impaired performance or decision-making. Predictive insights into risks for sleep deprivation, PTSD, acute stress response, and suicidal ideation can empower commanders and healthcare professionals with actionable data. Once identified, these insights must be integrated into doctrine, training, leader development, and policies to systematically support service members and maximize their performance under the stress of a LSCO environment.

Nonbattle Injury

Nonbattle injuries (NBI) markedly impacted lost duty days during the Vietnam War with up to 415,140 loss days in 1968 and elevated hospital rates across World War II, the Korean War and the Vietnam War (see tables 1, 4, and 5).[64] During OIF/OEF, NBI was the leading cause of evacuation at approximately 32 percent.[65] The leading NBI causes were sports and physical training (~23 percent), falls and near falls (~24 percent), motor vehicle (~10 percent), crushing and blunt trauma (~10 percent), and lifting/pushing/pulling (~6 percent).[66] In a study of a Stryker brigade combat team involving 593 volunteers, 45 percent sustained an injury, resulting in 5,049 days of limited duty, an average of 8.5 days per injury.[67] The most common injury sites were lower back (17.4 percent), knee (12.7 percent), and shoulder (10.0 percent) with 65 percent occurring while working.[68] The most common causes were lifting and carrying (9.8 percent), dismounted patrolling (9.6 percent), and physical training (8.0 percent).[69] Risk factors for NBI include older age, higher enlisted rank, female sex, months deployed, time spent standing, longer strength training sessions, heavy ruck load, and heavier or more frequent lifting tasks. Admission rates for NBI per 1,000 soldiers during ODS/S were 0.110, dropping to 0.071 in OIF, and rising again to 0.122 in OEF.[70] The most common NBI admissions were concussion (5.7 percent), facial bone fracture (4.4 percent), ankle fracture (3.9 percent), other injury (3.9 percent), and fracture of the tibia and fibula (3.8 percent).[71] Because limited NBI injury data has been collected from the war in Ukraine, its impact remains underrepresented in current casualty models, thereby limiting the ability to adequately inform commanders regarding expected return-to-duty rates in LSCO.

The capability to rehabilitate in theater for NBI would be similar to requirements for BI casualties. The presence of far-forward providers including a physical therapist and other members of the Army's Holistic Health and Fitness (H2F) team could facilitate rapid rehabilitation and help sustain performance while also implementing preventive strategies to reduce the causes of NBI. This is particularly important given the common causes of NBI during OIF/OEF would likely not change in LSCO. Having these resources embedded in the unit's footprint would allow soldier easier access to providers who can help keep them focused on the mission. Additionally, a Role 4 facility for BI would also enable surgical correction and rehabilitation of some NBI to further maximize return to duty. Overall, maximizing return to duty improves soldier and unit lethality and combat power.

A better understanding of the NBI impact on the battlefield will allow for the development of models

to better equip commanders to make an operational decision based on service members' performance and potential. In addition, preventive strategies that can be implemented far forward to enhance service member lethality.

Soldiers from Company C, 4th Battalion, 9th Infantry Regiment, 4th Stryker Brigade Combat Team, 2nd Infantry Division, transport a trauma victim to a medical helicopter on 30 September 2007 in Tarmiyah, Iraq. Al-Qaida members triggered an explosion earlier in the day that wounded many Iraqi civilians. U.S. Army medics assisted local hospital personnel in administering aid to the victims before calling in a MEDEVAC. (Photo by Petty Officer 2nd Class Summer Anderson, Defense Imagery Management Operations Center)

Summary

LSCO will markedly change casualty care, placing a priority on clearing the battlefield to enable commander's freedom of movement. Maximizing return-to-duty rates will maximize lethality. To do so, the MHS must increase the emphasis on prevention, diagnosis, treatment, and rehabilitation of DNBI and BI casualty care, aligning more closely with prior conflicts like World War II, the Korean War, and the Vietnam War. Insights from Ukraine can offer a glimpse into to this future operational environment, highlighting the need for advancements in BI care, especially with CASEVAC, triage, and prolonged care.

Addressing these challenges will require new doctrine, organizational structure, training, and policies. Key BI considerations include reevaluating the role of dialysis on the battlefield, the management of MDR bacterial wound infections that will threaten the homeland, and the postsurgical rehabilitation in theater. In addition to BI, models must be refined to further assess the impact of DNBI on lost duty days and operational performance. Emphasis on infectious diseases must prioritize pathogens prevalent in the future operational environment, particularly in regions with a high tropical disease threat risk like the U.S. Indo-Pacific Command. A lack of medical intelligence throughout the Department of Defense remains a critical knowledge gap to include disease prevalence, attack rates, and lost duty days along with impact on human performance.

Behavioral health prevention and treatment options, including fatigue management and resiliency building, are especially vital as challenges faced in garrison will be exacerbated in combat. H2F activities addressing NBIs could be adapted to the operational environment with rehabilitation facilities in theater, reducing evacuation of those who could potentially return to the battlefield.

The Defense Health Agency's role as a combat support agency presents an ideal opportunity to centralize key aspects to conserve fighting strength across the joint force. Cultural and operational service differences across the all-domain LSCO of the future remain key.

These challenges and the developed solutions must be integrated into battle labs, combat training centers, experiments, and exercises. Consideration should be given to dedicated training exercises or extension of current exercises to focus on medical and sustainment functions, including mortuary affairs, protection, and personnel for reconstitution modeling. These models must enable predictive and prescriptive data analytics and enable an improved medical common operating picture of the battlefield utilizing AI. Across DOTMLPF-P, key updates to warfighting formations are required to enable rehabilitation in theater, material solutions for far-forward diagnostics, and prevention and treatment platforms. Evacuation policies should be amended to maximize appropriate care in theater to maximize return to duty; doctrine needs to align with the LSCO operations of the future; and training point of injury must account for prolonged care, triage on the MDO-LSCO battlefield, and the role of CASEVAC in contested environments.

The combat medic and the entire MHS are vital to a soldier's will to fight harder, further, and longer. The soldier on the battlefield and the American people know that medical personnel will run to the sound of need surrounded by the sound of gunfire. This trust is foundational to soldier performance on the battlefield. Military medicine will optimize their chance for survival and maximum potential for functional recovery. We MUST be our best on the soldier's WORST day. ■

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US ISSN 0026-4148