

Putting Medical Boots on the Ground: Lessons from the War in Ukraine and Applications for Future Conflict with Near-Peer Adversaries

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In the past 20 years of the Global War on Terror, the US has seen substantial improvements in its system of medical delivery in combat. However, throughout that conflict, enemy forces did not have parity with the weaponry, capability, or personnel of the US and allied forces. War against countries like China and Russia, who are considered near-peer adversaries in terms of capabilities, will challenge battlefield medical care in many different ways. This article reviews the experience of a medical team, Global Surgical and Medical Support Group, that has been providing assistance, training, medical support, and surgical support to Ukraine since the Russian invasion began in February 2022. The team has extensive experience in medicine, surgery, austere environments, conflict zones, and building partner nation capacities. This article compares and contrasts the healthcare systems of this war against the systems used during the Global War on Terror. The lessons learned here could help the US anticipate challenges and successfully plan for the provision of medical care in a future conflict against an adversary with capabilities close to its own. (J Am Coll Surg 2023;237:364–373. © 2023 The Author(s). Published by Wolters Kluwer Health, Inc. on behalf of the American College of Surgeons. This is an open-access article distributed under the terms of the [Creative Commons Attribution-Non Commercial-No Derivatives License 4.0 \[CCBY-NC-ND\]](https://creativecommons.org/licenses/by-nc-nd/4.0/), where it is permissible to download and share the work provided it is properly cited. The work cannot be changed in any way or used commercially without permission from the journal.)

On February 24, 2022, Russia invaded Ukraine in what it called a “special military operation.” The Global Surgical and Medical Support Group (GSMSG), a nongovernment

organization that provides medical care and training in conflict zones, mobilized the first US surgical team into Ukraine, arriving there on March 5, 2022. For the past 12

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Abbreviations and Acronyms	
ACS	= American College of Surgeons
GSMMSG	= Global Surgical and Medical Support Group
GWOT	= Global War on Terror
IED	= improvised explosive device
MEDEVAC	= medical evacuation
NPA	= near-peer adversary
TBI	= traumatic brain injury
UKRSOF	= Ukrainian Special Operations Forces

months, GSMMSG has worked alongside Ukrainian forces and healthcare providers (see Appendix).

The conflict in Ukraine represents a unique opportunity for the US to prepare for future potential conflicts with near-peer adversaries (NPAs)—adversarial nations with equivalent military force. Despite poor performance in smaller battles and significant losses, Russian forces remain in Ukraine, and the war continues. Russia generally has been considered an NPA to the US, because it has a military with similar capabilities. The current threat from NPAs, such as China or Russia, is at its highest level since the Cold War Era.¹ For more than 20 years during the Global War on Terror (GWOT) in Iraq and Afghanistan, US military forces and their medical corps were engaged in a conflict against insurgent or terrorist organizations who used unconventional strategies and tactics because of their vastly unequal combat capabilities. Their capability to mount offensive and defensive strategies against US forces was limited. For instance, during the GWOT, the air, ground, and sea dominance of the US assured relative freedom of movement for medical evacuation. The war in Ukraine, however, is a much different operating environment

(Table 1). Russia has equivalent or superior combat forces to Ukraine, which limits Ukrainian mobility and evacuation.² There are several other challenges that have been recognized, and the current conflict in Ukraine thus offers the opportunity to develop tactics, training, and a healthcare system in preparation for future conflict with an NPA.

THE GLOBAL MEDICAL AND SURGICAL SUPPORT GROUP

GSMMSG is a nongovernment organization with extensive experience providing surgical and medical care in combat environments and austere settings around the world. GSMMSG’s teams of healthcare providers have experience in low resourced environments and on the battlefield. They have also responded to natural disasters like Hurricane Michael in 2018 and the COVID-19 pandemic in New York City in 2020. GSMMSG also has personnel with extensive military experience, including a significant number of veterans from the US Special Operations community (Table 2).

GSMMSG initially mobilized a 10-person team with combat surgery capability that entered Ukraine 9 days after Russia invaded. Their mission was to provide training in combat casualty care for any interested and capable Ukrainian citizen, provide combat trauma care training and surgical support for the civilian Ukrainian medical system, and provide combat care training for the Ukrainian military personnel and military physicians. GSMMSG rotated additional teams of surgeons with expertise in trauma, surgical critical care, burn, plastics, orthopaedics, vascular, and neurosurgery. With the cooperation of the Ukrainian Ministry of Defense and Ministry of Health, GSMMSG also formed a partnership with the physicians of the Ukrainian Armed

Table 1. Comparison of the Global War on Terror vs Near-Peer Adversary Warfare

Variable	Global War on Terror	Near-peer adversary
Threat scope	Limited in duration, scale of attack, and weaponry used	Sustained offensive action with much broader array of weapons, in larger volume, for longer duration and further distance
Ability to quickly achieve battlespace dominance	Very fast, usually within minutes to hours	Unlikely able to achieve battlespace dominance
Effect of distance on safety of evacuation and rendering care	The further from point of injury, the safer the patient and ability to render care	No significant increase in safety until patient is entirely evacuated from the theater of operations
Use of appropriate blood transfusion for damage-control resuscitation	Well established	Unable to be achieved due to operational security considerations and disruption by opposition forces
Command and control of medical infrastructure	Well established	Unable to be achieved due to operational security considerations and disruption by opposition forces
Data collection capability for process improvement and other use	Joint Trauma Registry is well established	No central data collection currently exists for the war in Russia; a Joint Trauma Registry could easily be implemented

Table 2. Composition of Global Surgical and Medical Support Group Team

GSMSG team member professional	% of total roster (n = 2,200)
Medic or licensed practical nurse*	31
Nurse	17
Nurse practitioner	8
Physician assistant	9
Emergency medicine physician	5
Anesthesiologist	6
Critical care physician	3
Other nonsurgical physician	1
General surgeon	5
Orthopaedic surgeon	4
Vascular surgeon	1
Trauma surgeon (general surgery)	9
Neurosurgeon	1
Other specialty surgeon	2
Total civilian	24
Total military	76

*This includes veteran US Army combat medics, US Army special forces medics, US Navy corpsmen, US Navy special warfare medics, US Air Force pararescue, US Marine Corps special amphibious reconnaissance corpsman.
GSMSG, Global Surgical and Medical Support Group.

Forces, Ukrainian Special Operations Forces (UKRSOF), and Ukrainian Special Surgical Groups, who have provided damage control surgery as close as 0.5 km from active combat with Russian forces. Since arriving in Ukraine, GSMSG team members have trained more than 20,000 Ukrainian civilians and military service members. They have also provided surgical support to more than 300 patients, some located as close as 10 km from the frontline (Tables 3, 4).

THE GLOBAL WAR ON TERROR VS CONFLICT WITH A NEAR-PEER ADVERSARY

Global War on Terror: the threat

During the GWOT, US and allied forces' injuries were generally from small-caliber firearms, improvised explosive

devices (IEDs), and indirect fire from short-range mortars and rockets.³ There were an estimated 7,076 US deaths and 53,337 US wounded during the course of those 20 years.⁴ Explosive mechanisms of injury made up the largest portion of combat wounds in the GWOT, accounting for approximately 79% of battlefield injuries. During nearly any attack by insurgent forces, US forces quickly achieved battlespace dominance and were able to evacuate casualties under the umbrella of superior ground fire or close air support.⁵ In general, the threats during the GWOT were limited in duration and scope.⁶⁻⁸ It is also well-documented that quality medical care could be rendered quickly and safely on or near the battlefield. Because of air-evacuation capabilities, patients could be brought quickly to treatment facilities. The further medical assets were removed from the conflict, the safer they were, even if they were still in the combat theater of operations.⁹ Finally, damage control resuscitation had been modified to include early use of fresh whole blood and improved protocols, which reduced the overall amount of blood product needed to save lives.¹⁰⁻¹²

Near-peer adversary threat: greater lethality

IEDs caused significant casualties in the GWOT.¹³ They could injure multiple personnel at once and even disable vehicles. Compared with insurgent/terrorist forces, NPAs have much heavier and longer-range weaponry, with a resultant increase in morbidity and mortality among combat casualties. Although it is possible to arrange IEDs to provide successive blasts to increase their lethality, these configurations were infrequently employed in the GWOT. In Ukraine, Russian forces have used modern portable antitank guided missiles with advanced dual shaped charge or thermobaric warheads or thermobaric rocket artillery barrage fire. These thermobaric weapons cause blunt and penetrating wounds as well as massive thermal injuries.¹⁴ A recent incident using this weapon claimed 12 immediate fatalities from victims who were within 20 meters of the impact point. A casualty 60 meters away from the point

Table 3. Global Surgical and Medical Support Group Educational Activities in Ukraine, March 2022 to December 2022

Educational activity	Learners
Didactic lectures on combat trauma care, traumatic brain injury, torso trauma, orthopaedic trauma, vascular trauma, etc.	Ukrainian surgery/emergency medicine residents and faculty, Ukrainian surgery/emergency medicine/internal medicine/primary care/anesthesia providers
Tactical combat casualty care training	Ukrainian police departments, Ukrainian military, Ukrainian military medical providers and first responders
Stop the Bleed training	Ukrainian police officers, Ukrainian military medical providers and first responders
Infection control, sterile instrument processing, and intraoperative sterile procedures	Operating room and sterile processing personnel

Table 4. Global Surgical and Medical Support Group Surgical Case Consultations in Ukraine, March 2022 to December 2022

Specialty	Case example
Trauma	Thoracic trauma, hollow viscus injury, enterocutaneous fistula, complex skin and soft tissue wound, amputation, postoperative infection
Vascular	Limb salvage, arteriovenous fistula, pseudoaneurysm
Orthopaedics	Complex extremity fracture
Plastics	Wound debridement and flap coverage

of impact suffered 80% total body surface area burns that proved lethal within 72 hours despite medical evacuation and resuscitation attempts.

Russian use of incendiary munitions causes significant deep burn injuries, organophosphate poisoning, and other toxic effects from the vapors associated with the burning substances.¹⁵ Care of burn casualties imposes a significant logistical and medical burden because of the complexity of care and the extensive resuscitation required. This underscores the need to plan for significant thermal/burn injuries in future combat.

Modern antitank guided missiles that have been used widely by Russia have a nearly +75% fatality rate when employed against personnel or lightly armored vehicles, because they are intended for use against tanks or bunkers. US military personnel encountered these weapons infrequently during the GWOT.¹⁶ They appear to be a much more frequent occurrence in this NPA conflict.¹⁷ The injuries sustained have been devastating, and survival rates are significantly lower than those from nondirectional blast injuries such as artillery and mortars.¹³ Additionally, Russian forces in this conflict have been firing nearly 60,000 artillery rounds a day. This represents a volume of fire that US forces have not seen since World War II.

In Ukraine, Russian forces often used area denial munitions, such as antitank and antipersonnel mines. These munitions are built using standardized, consistent construction completed on a much larger scale. As such, they are more available, operationally reliable, effective, and deployable. IEDs used in the GWOT were, by definition, improvised and thus had questionable reliability. They often comprised an array of available explosive devices and were used with much less density of devices in a given area when compared with broad NPA employment.

Safety of medical assets on the battlefield

The ability to quickly evacuate patients and the safety of responding medical teams are compromised because of better NPA weaponry. The ability of the Russian forces

to strike accurately well beyond the front line with long-range weapons such as cruise missiles or drones means that the threat to injured personnel only subsides once a patient is far removed from the conflict theater (Fig. 1). In Ukraine, hospitals and medical facilities were targeted and hit as far west as Zhytomyr, which is approximately 400 km west of the Russian border¹⁸ (Fig. 2). Additionally, Russian missile strikes have occurred within 25 km of the Polish border with Ukraine, meaning that Russian weapons could strike medical centers in any Ukrainian city.¹⁹ In comparison, in the GWOT, the insurgent arsenal had a reach of approximately 20 km. When applied to possible future conflicts with NPAs, it is likely that the enemy's arsenal would be able to reach hundreds of kilometers from the front line. For example, the Chinese CJ-10 cruise missile is capable of carrying a 1,000-lb warhead more than 1,500 km.²⁰ If an operation is to be performed in a forward environment, patients will need to be treated while under the threat of attack in hardened and protected facilities until the patients are removed entirely from the theater of operations.

Transfusion at the front line in Ukraine

Surgeons on the GSMSG teams helped incorporate whole blood use into the conflict in Ukraine in April 2022. The number of patients who arrive at a UKRSOF forward surgical team alive and already in hemorrhagic shock is estimated at 25%. An additional 15% to 20% of alive and injured soldiers arriving at the first point of medical care needed a blood transfusion. Ukrainian surgeons sometimes operating as close as 0.5 km from the front line are the first to receive casualties from the battlefield. UKRSOF surgeons cite that difficulties with long-term storage pose the biggest obstacle to maintaining stores of any available blood products. Running power generators for refrigerating stored blood products at the forward surgical sites for extended periods of time could compromise security. In addition to limiting the ability to store whole blood or blood products, the lack of electrical power often prohibits thawing available frozen blood products with fluid warmers. Supply lines to the forward surgical teams routinely come under Russian attack, impairing the ability to replenish supplies of blood products for transfusion. There are additional strategies for generating readily available whole blood for transfusion, such as the Ranger O Low Titer/Walking Blood Bank, which require a large, stable donor pool.^{21,22} However, the current rate of casualties, relocation of units, or reorganization of units given the operational tempo in Ukraine precludes the ability to execute these strategies. Implementation would require broader organizational evolution of the Ukrainian military.

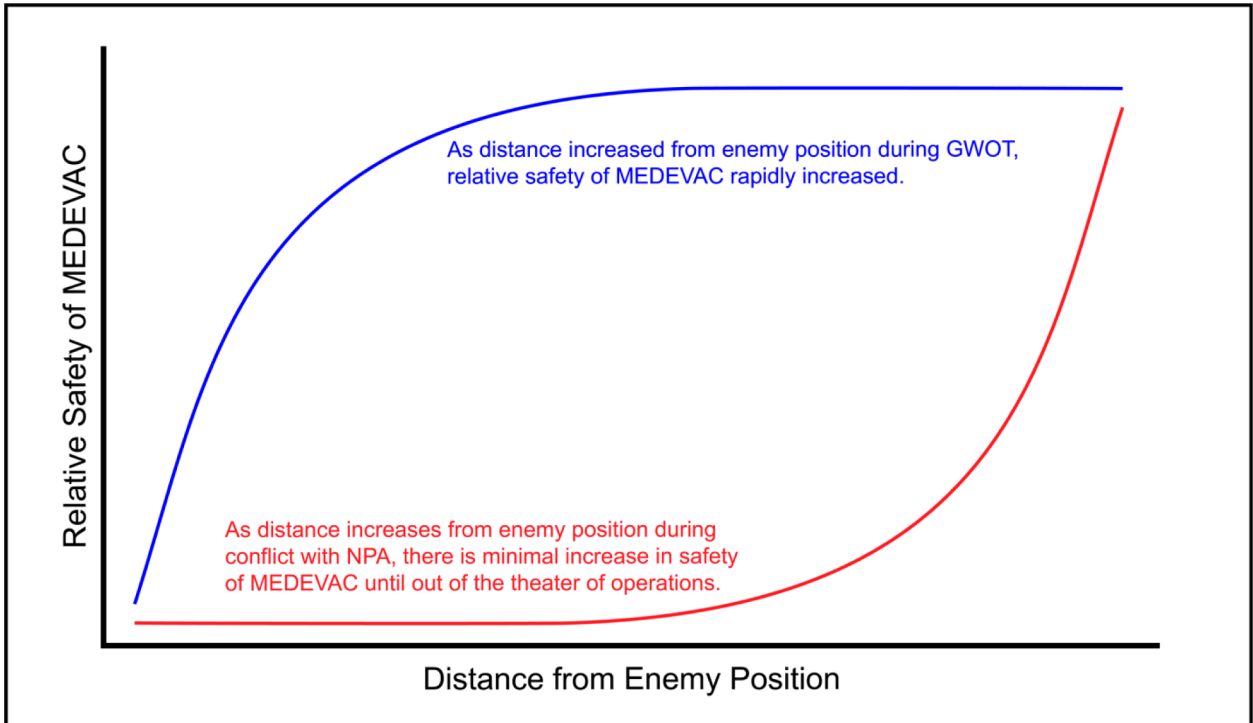


Figure 1. Linear effect of distance. This figure highlights the relationship of relative safety of MEDEVAC units as distance from the enemy position changes. The blue line shows the relationship in the GWOT, which highlights the rapid increase in safety with a small amount of distance from the enemy position. The red line shows the relationship in NPA conflict, which highlights that a large amount of distance from the enemy position is needed to achieve significant safety. GWOT, Global War on Terror; MEDEVAC, medical evacuation; NPA, near-peer adversary.



Figure 2. Map of Ukraine. Russian forces have struck hospitals and medical facilities in Zhytomyr, about 400 km west of the Russian-Ukrainian border. Russian missile strikes have also occurred within 25 km of the Polish-Ukrainian border, which means nearly any location within Ukraine is within Russia's reach. Image modified from Google Earth.

Greater number of injuries

The Ukrainian conflict has seen the use of purpose-built munitions on an industrial scale and sustained rocket and artillery barrages by Russia. This increase in firepower has translated to an increased injury burden. Statistics shared by Ukrainian physicians demonstrate that more than 70% of all Ukrainian combat casualties are due to artillery and rocket barrages from Russian forces, which has resulted in significant polytrauma to multiple organ systems. By comparison, in most recent non-NPA conflicts, soldiers who sustained injuries to the thoracic and abdominal cavities could survive if concomitant injuries to extremities and the rest of the body were limited.²³ In Ukraine, Russia's weapons have led to more devastating injuries to a larger number of soldiers in any given attack. In a retrospective analysis of 100 patients treated by Ukrainian military surgeons operating within 5 km of the front line, the average Injury Severity Scores exceeded 36 in victims of such barrage artillery and rocket attacks. Common mechanisms of injury include multiple high-velocity penetrating injuries, barotrauma, and blunt injuries from being thrown during the explosion, and traumatic brain injuries. A single IED or even a chain of IEDs in the GWOT affected fewer patients, in general, and caused less severe injury (to others besides the person who directly triggered the IEDs) than an NPA rocket or artillery barrage, which produce dozens of explosions across a much larger area, leading to simultaneous, multicasualty situations. It is estimated that 5% to 10% of Ukrainian soldiers deployed to the theater of operations will be either wounded or killed in action. During the GWOT, there had been approximately 7,000 deaths and 32,000 wounded in a total of 2 to 3 million deployed US personnel, for a casualty incidence of 1.3% to 2%.²⁴ Thus, mortality rates in this and future NPA conflicts may be 5 times greater than in the GWOT (although Ukrainian mortality rates are raw estimates based on publicly available information at this time and not adjusted for injury severity, mechanism, etc.). Overall, medical evacuation planning, prolonged field care, and other interventions planned by treating medical personnel will need to anticipate massive polytrauma, significantly more patients at a time, and the resources required for a single patient will be significantly greater.

The UKRSOF surgeons reported receiving several patients simultaneously with multiple potentially lethal injuries. Patients often require multiple emergent damage control interventions before clinicians can begin to care for the next patient. During a 3-week period with sustained incoming artillery barrage fire, a single Ukrainian surgeon treated more than 200 patients, of whom 36

underwent laparotomies and 20 underwent thoracotomies. Penetrating abdominal and thoracic wounds occurred lateral to body armor plates in approximately 60% of cases and inferior to body armor in 30% of cases. An estimated 10% either had material penetrate their body armor plates or they were not wearing body armor. Traumatic penetrating injuries to the skull were nearly universally fatal and were managed expectantly.

The incidence of penetrating thoracic trauma is significantly higher in this conflict with an NPA than in the GWOT. Most soldiers in the current war in Ukraine have front and rear panel armor as well as a helmet. With incoming artillery rounds in a trench, soldiers generally face forward and cover their heads. However, this leaves the lateral aspects of the body vulnerable to injury. Use of standard center mass front and rear plate armor that protects the vital organs within "the box" may not be sufficient to save lives when ballistic material is coming from a lateral trajectory. Although available US body armor systems do offer more thorough lateral and abdominal protection with side armor plates and ballistic material that can protect lateral trajectory projectiles, such equipment is extremely heavy and cumbersome.

Barotrauma and traumatic brain injury

Blast injuries also have barotrauma effects and can cause blunt trauma if the explosion results in the victim being thrown or large objects being launched at the victim. Consequently, traumatic brain injuries (TBIs) will likely be greater in conflicts against an NPA. During the GWOT, there was a significant incidence of TBIs sustained from single IED detonations. The concussive effects of these blasts have been well documented. Between 9% and 28% of service members experienced a TBI during the GWOT.²⁵ In a rare modern instance of US forces encountering NPA-level weaponry, the US Al-Asad base in Iraq was struck by Iranian ballistic missiles on January 8, 2020, and 109 US soldiers suffered TBIs.²⁶ In the Ukraine conflict, concussion injuries and related complaints were noted in nearly all instances of patient encounters with opposition rocket or artillery fire, although oftentimes they were overshadowed by other wounds or injuries. We also know that if patients sustain successive concussions or TBIs, the long-lasting effects are significantly more devastating.²⁷ In a combat situation against an NPA, it is likely that TBIs will be far more prevalent than what was experienced in the GWOT. Reinforcing and burying defensive positions so that personnel are not as exposed to the blast effects may help mitigate these injuries; however, medical planning should continue to be directed at prophylactic, protective, and treatment measures to combat TBIs.

Medical evacuation

During the GWOT, battlespace dominance by US forces was usually quickly established, and threats were generally cleared before medical evacuation could occur, with the exception of rare isolated instances.^{28,29} Per discussions with Ukrainian Ministry of Defense counterparts, as of this writing, there is minimal ability for the Ukrainian Air Force to fly any type of sustained air operations against Russian forces, which includes airborne medical evacuation (MEDEVAC) from frontline positions or areas adjacent within the envelope of Russian anti-aircraft fire.³⁰ MEDEVAC by ground forces also routinely comes under attack by Russian forces. The US should assume that advanced, accurate, and very long-range weapon systems will be readily available to future NPAs. As such, the safety of being further away from combat will require that evacuation capabilities, whether by air, ground, or sea, may need to move hundreds of kilometers from the front line before the casualty and the MEDEVAC platform itself is actually safe from NPA fire.

This also means forward medical teams will need the capability of providing prolonged field care, more damage control resuscitation, and even multiple damage control surgeries on a larger number of patients before they can be moved away from the frontline area. UKRSOF surgeons stationed adjacent to the front line of combat often could only move patients from the point of injury to locations as close as 500 m into hardened locations where a surgical team can operate and hold the patient for an extended period of time. This was occasionally done under ongoing Russian artillery and rocket fire. Future US service members who are injured in combat may consequently not reach definitive care until days later, and medical personnel providing care will definitely be in harm's way.

Current US Department of Defense protocols and clinical practice guidelines prepare for smaller forward surgical teams to be able to operate on 2 to 4 surgical patients and hold 3 to 8 patients for 16 to 72 hours without resupply.³¹ Additionally, they should be able to pack their equipment within 1 hour to relocate. It is estimated that, based on UKRSOF experience in combat with Russia, such teams should be prepared to perform 10 damage control operations in 48 hours and hold up to 15 critically ill patients for the same amount of time without resupply. This is about the size of an intensive care unit in a medium-sized US hospital. Expanding a forward team's capabilities would make it less mobile and more difficult to relocate. This poses an obvious paradox between the need for greater forward medical capabilities and the ability to relocate rapidly to new safer locations as needed and to maintain pace with a constantly moving front line.

Despite clearly violating international laws from the Geneva Convention, Russian forces are specifically targeting ambulances and healthcare facilities. According to the Ukraine Crisis Media Center, approximately 1,100 healthcare facilities have either been damaged or destroyed since the beginning of the conflict.³² Forward medical facilities, like a combat support hospital, therefore, may need to be positioned entirely underground. That may mean significant investments in rapid tunneling and earth-moving type of equipment are needed, none of which currently exists in a capability that can be deployed rapidly to a battlefield. The current practice of surrounding the structures with concrete walls and earth barriers will still leave them vulnerable to vertical attack. Rapid advances in point defense systems from the existing Counter-Rocket, Artillery, Mortar (C-RAM) or the Israeli Iron Dome, will also be a necessary component of protecting critical military medical infrastructure. If waterborne evacuation is considered, future US forces need to recognize that ships at sea offer very easy targets for future NPAs. A potential solution is to establish "lily pad" medical installations on any adjacent land masses, as the US Pacific forces did in World War II, constructing airfields on the Marshall and Mariana Islands en route to Japan.³³

MEDEVAC operations are also more likely to be challenged by a lack of communication during conflict with an NPA. In past wars, US personnel were able to communicate with MEDEVAC units to coordinate movement of injured personnel.³⁴ The practices of opposition forces jamming the electronic spectrum used by US forces to communicate will impair these processes during future NPA conflicts. In Ukraine, responding medical personnel and receiving medical installations frequently have no advance notice as to the nature or extent of the injuries of the incoming patients from the front line for fear of Russians intercepting the communications and then attacking the location of the casualty collection point. One way for future US medical teams to prepare for loss of communication will be to emphasize no-notice scenarios in training and simulation. In the civilian arena, no-notice or limited-notice scenarios may occur when patients are transported by police officers or private vehicle.³⁵⁻³⁷ All clinicians can benefit from practicing these situations. There is reason to believe that these wartime communication obstacles would also extend to controlling and commanding medical supply chains over the entire area of operations. Through decades of conflict and previous experience in total war, such as World War II, and regional conflicts, such as Vietnam, that placed massive stress on US military medical systems, the US has developed systems to properly and uniformly allocate medical assets and supplies to

areas of greatest need. In the face of future NPA conflicts, the allied command-and-control hierarchy may be cut off either for operational security reasons or due to NPA disruption. This also must be addressed in a conflict against an NPA, even though it is not an entirely new concern.

Surgical cadre

Each year, nearly 1,000 surgeons who graduate from residency training will practice general surgery in some capacity.³⁸ There are currently 25,000 active general surgeons in the US, approximately 4,130 of whom are trauma surgeons.^{39,40} This could serve as a sufficient pool of potentially qualified individuals who can provide competent trauma surgery services in a war with mass mobilization. Yet, even with this many qualified surgeons, it is difficult for the US military to maintain a ready pool of surgeons who are well versed in damage control surgery and able to deploy to a frontline combat area at a moment's notice. Surgical specialists, including thoracic surgeons, neurosurgeons, orthopaedic surgeons, oral and maxillofacial surgeons, otolaryngologists, urologists, vascular surgeons, etc., are needed to provide comprehensive wartime care. Unfortunately, for a country like Ukraine—or any country facing opposition like Russia—it is practically impossible that they will have enough qualified surgeons on hand. It is difficult to determine the exact number of Ukrainian surgeons. Data collected by the Lancet Commission on Global Surgery in 2014 reported 87 surgeons in Ukraine per 100,000 but did not delineate this number further by specialty or active status.^{41,42} Because of the shortage, any practicing surgeon in Ukraine, regardless of training or scope of practice, may be brought combat casualty patients to manage to the best of their ability. The American College of Surgeons (ACS) created programs such as the Military Clinical Readiness Curriculum “M-Course” to teach the basics of damage control surgery, damage control resuscitation, and emergency wartime operation to help fill this gap. The ACS also collaborated with GSMSG to provide expert surgeons from the US to Ukraine to work alongside host nation surgeons and to provide education and training in combat trauma-specific topics like burn surgery, plastic surgery, and even biological and chemical warfare. GSMSG's primary goal in working with any host nation is to rapidly transfer relevant skills and knowledge to the partner-force surgeons and medical professionals. As of December 2022, GSMSG has held training sessions for more than 650 Ukrainian attending and resident physicians and participated in hands-on training in more than 300 operating room cases with Ukrainian surgeons since the start of the war.

In all, several areas of the US combat medical system need to change in response to the threat of an NPA. It should be noted that in Ukraine there is currently no trauma registry similar to the one used by the US Department of Defense for its wars in Iraq and Afghanistan. The data presented here are based on personal experience of GSMSG team members and firsthand reports. Establishing an effective registry with robust and reliable data capture is needed to provide proper planning and reaction to combat against an NPA as well as retrospective analysis. Properly staffed nongovernment organizations like GSMSG can be an important asset in such conflicts because they can provide valuable training, combat care, and experience for host nations without escalating the conflict by directly involving foreign governments or militaries. Additionally, they can be a source of valuable information after the official involvement of the US Department of Defense to help it prepare for conflict.

In summary, listed here are the lessons learned from the experiences of GSMSG and partner physicians from the Ukrainian Special Operations Forces from 1 year of war against Russia in Ukraine. Considerations for future medical care in combat operations against NPAs are highlighted.

1. Injury in NPA conflict
 - a. Current US military body armor will likely be insufficient against NPA arsenals with ballistic components that can hit laterally, above, or below standard issue armor plates from multiple angles due to the larger number of accurately impacting munitions.
 - b. Concussive injury and TBI will be far more prevalent when facing NPA arsenals that can accurately deliver large volumes of more devastating fire.
 - c. NPA arsenals will be capable of causing significant multisystem trauma to far greater numbers of US personnel.
2. Providing care for injured in NPA conflict
 - a. Medical facilities are not safe areas to provide care, even if they are hundreds of kilometers from the line of ground fighting.
 - b. The resources needed to adequately provide life-saving care will be far greater than what the US has allocated for in the past.
 - c. Air, ground, and sea-based medical evacuation will be practically impossible due to very long range and accurate fire capabilities of NPA arsenals; forward surgical teams should be established in hardened structures, possibly underground, capable of withstanding direct attack by NPA munitions.

3. Preparation and training of US medical teams for NPA conflict
 - a. Forward medical/surgical capabilities by US personnel will need to be able to handle more casualties simultaneously.
 - b. Prolonged field care should be a routine part of the medical training curriculum, because evacuation may be delayed or impossible in an NPA conflict.
 - c. In a future NPA conflict, communications may be limited or nonexistent due to jamming by the NPA or for operational security reasons, preventing advanced notice of casualty arrivals, a scenario that should be practiced regularly (no-notice casualty loads with extensive high-fidelity, situation-based training).
4. System-level preparation of the US military medical system and structure for future NPA conflict
 - a. Given electronic jamming by NPA adversaries, robust and redundant command and control of medical assets should be able to be delegated further into the field.
 - b. Cadres of qualified and capable surgeons need to be developed so that they are ready, able, and willing to deploy to forward locations in a future NPA conflict.
 - c. Surgeons with expertise in damage control surgery and resuscitation are limited, but this gap may be filled through specialty training, either in person by groups like GSMSG or remotely through programs like the M-Course provided by the ACS.
 - d. NPAs may ignore international laws against attacking medical resources, medical evacuation platforms, and infrastructure.
 - e. A database like the US Joint Trauma Registry needs to be implemented for process improvement in the war against Russia, but the US could implement its already established data collection protocol in a future NPA conflict.

APPENDIX

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REFERENCES

1. Vergun D. Near-peer threats at highest point since Cold War. DOD News March 10, 2020.
2. Boston S, Massicot D. *The Russian Way of Warfare: A Primer*. Santa Monica, CA: RAND Corporation; 2017.
3. Nessen SC, Lounsbury DE, Hetz SP. *War Surgery in Afghanistan and Iraq: A Series of Cases, 2003–2007*. Textbooks of Military Medicine. Falls Church, VA: US Department of the Army; 2008.
4. Casualty Report 11212022. US Department of Defense ; 2022.
5. White JM, Stannard A, Burkhardt GE, et al. *The epidemiology of vascular injury in the wars in Iraq and Afghanistan*. *Ann Surg* 2011;253:1184–1189.
6. Bolton M. *From minefields to minespace: an archeology of the changing architecture of autonomous killing in US Army field manuals on landmines, booby traps and IEDs*. *Polit Geogr* 2015;46:41–53.
7. Walton GR. *Overcoming the Odds: How the US Army Can Achieve Indirect Fire Superiority*. Fort Leavenworth, KS: U.S. Army Command and General Staff College; 2018.
8. Jelic Z, Zagoricki A, Hameed A, Shukla A. Fragmentation and lethality analysis tool for natural and controlled fragmentation, and pre fragmented warheads, presented at the 27th International Symposium on Ballistics, Feiburg, Germany, 2013.
9. Department of the Army. Casualty evacuation. ATP 4-02.13. 2021.
10. Chandler MH, Roberts M, Sawyer M, Myers G. *The US military experience with fresh whole blood during the conflicts in Iraq and Afghanistan*. *Semin Cardiothorac Vasc Anesth* 2012;16:153–159.
11. Schrage JJ, Branson RD, Johannigman JA. *Lessons from the tip of the spear: medical advancements from Iraq and Afghanistan*. *Respir Care* 2012;57:1305–1313.
12. Spinella PC, Perkins JG, Grathwohl KW, et al. *Warm fresh whole blood is independently associated with improved survival for patients with combat-related traumatic injuries*. *J Trauma* 2009;66(4 Suppl):S69–S76.
13. Overton I. *A decade of global IED harm reviewed*. Available at: <https://aoav.org.uk/2020/a-decade-of-global-ied-harm-reviewed/>. Accessed November 26, 2022.
14. Tegler E. *Russia's TOS-1 heavy flamethrower lobbs brutal thermobaric rockets at close range*. *Forbes* March 2, 2022.
15. Hambling D. *'White Phosphorus' claimed to be used in Ukraine may really be Russian napalm weapon*. *Forbes* March 25, 2022.

16. Rayment S. MoD kept failure of best tank quiet. *The Telegraph* May 13, 2007.
17. Horton A. Soleimani's legacy: the gruesome, advanced IEDs that haunted U.S. troops in Iraq. *The Washington Post* January 3, 2020.
18. Silva CD. Russia warns Kyiv residents to leave, convoy nears capital. *NBC News*. February 28, 2022.
19. Cullison A, Forrest B. Russian missiles strike Ukrainian military training base near Polish border. *The Wall Street Journal*. 2022.
20. DF-10 CJ-10 DH-10 cruise missile surface-to-surface technical data sheet specifications. Available at: https://www.armyrecognition.com/china_chinese_army_missile_systems_vehicles/df-10_cj-10_dh-10_cruise_missile_surface-to-surface_technical_data_sheet_specifications_pictures_video_12301163.html. Accessed March 1, 2023.
21. Gaspary MJ, Kyle AI, Lawson SM, et al. Obstacles to an effective low-titer O walking blood bank: a deployed unit's experience. *Mil Med* 2021;186:e137–e142.
22. Fisher AD, Miles EA, Cap AP, et al. Tactical damage control resuscitation. *Mil Med* 2015;180:869–875.
23. Eastridge BJ, Mabry RL, Seguin P, et al. Death on the battlefield (2001-2011): implications for the future of combat casualty care. *J Trauma Acute Care Surg* 2012;73(6 Suppl 5):S431–S437.
24. Crawford NC, Lutz C. Human cost of post-9/11 wars: direct war deaths in major war zones. Providence, RI: Brown University Watson Institute of International & Public Affairs; 2019.
25. Reger MA, Brenner LA, du Pont A. Traumatic brain injury and veteran mortality after the war in Afghanistan. *JAMA Netw Open* 2022;5:e2148158.
26. Ali I, Stewart P. More than 100 U.S. troops diagnosed with brain injuries from Iran attack. *Reuters*. 2020.
27. Committee on Sports-Related Concussions in Youth, Board on Children Youth and Families, Institute of Medicine, National Research Council. Consequences of repetitive head impacts and multiple concussions. In: Graham R, Rivara F, Ford M, Spicer C, eds. *Sports-Related Concussions in Youth: Improving the Science, Changing the Culture*. Washington, DC: National Academies Press (US); 2014.
28. Adams S. Medical care in the wars of the future. *Legion Magazine* March 10, 2022.
29. McDonnell PJ. Medical choppers not immune to Iraq perils. *Los Angeles Times* January 26, 2004.
30. Fazal TM. Ukraine's military medicine is a critical advantage. *Foreign Pol* October 31, 2022.
31. Baker JB, Northern DM, Frament C, et al. Austere resuscitative and surgical care in support of forward military operations—joint trauma system position paper. *Mil Med* 2021;186:12–17.
32. Ukraine Crisis Media Center. Russians damaged 1,100 medical facilities in Ukraine. Kyiv, Ukraine. Available at: <https://uacrisis.org/en/rosiyany-poshkodyly-v-ukrayini-1100-medzакladiv>. Accessed March 9, 2023.
33. Spennemann D. Building the Navy's bases: Majuro Naval Base. Available at: https://marshall.csu.edu.au/Marshalls/html/WWII/Majuro_Base.html. Accessed March 1, 2023.
34. Nettesheim N, Powell D, Vasios W, et al. Telemedical support for military medicine. *Mil Med* 2018;183:e462–e470.
35. Demetriades D, Chan L, Cornwell E, et al. Paramedic vs private transportation of trauma patients: effect on outcome. *Arch Surg* 1996;131:133–138.
36. Cornwell EE 3rd, Belzberg H, Hennigan K, et al. Emergency medical services (EMS) vs non-EMS transport of critically injured patients: a prospective evaluation. *Arch Surg* 2000;135:315–319.
37. Winter E, Hynes AM, Shultz K, et al. Association of police transport with survival among patients with penetrating trauma in Philadelphia, Pennsylvania. *JAMA Netw Open* 2021;4:e2034868e20348–e2034868e268-e.
38. Ellison EC, Pawlik TM, Way DP, et al. Ten-year reassessment of the shortage of general surgeons: Increases in graduation numbers of general surgery residents are insufficient to meet the future demand for general surgeons. *Surgery* 2018;164:726–732.
39. Elkbuli A, Sutherland M, Sanchez C, et al. The shortage of trauma surgeons in the US. *Am Surg* 2022;88:280–288.
40. Association of American Medical Colleges (AAMC). Number of people per active physician by specialty, 2021. Washington, DC. Available at: <https://www.aamc.org/data-reports/workforce/interactive-data/number-people-active-physician-specialty-2021>. Accessed March 14, 2023.
41. Holmer H, Lantz A, Kunjumen T, et al. Global distribution of surgeons, anaesthesiologists, and obstetricians. *Lancet Glob Health* 2015;3(Suppl 2):S9–11.
42. Specialist surgical workforce (per 100,000 population) - Ukraine. *The World Bank*. Available at: <https://data.worldbank.org/indicator/SH.MED.SAOP.P5?locations=UA>. Accessed March 1, 2023.

Invited Commentary

Total War: A Succinct Surgical Overview and Why Civilian Surgeons Should Care

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In 2018, US Army General Michael Lundy succinctly noted, “In addition to violent extremist organizations with global reach, the current and future strategic environment is defined by a revanchist Russia, an expanding China, a rogue North Korea, and a calculating Iran.”¹ With the unprovoked Russian attack on Ukraine in February 2022 and rising tensions in the South China Sea, the specter of a potential total war against our near-peer adversaries looms ever larger. This special article in the current issue of the *Journal of the American College of Surgeons* provides an exceptional first-hand account of combat operations in Ukraine and enumerates the surgical implications of large-scale conflicts between modern