Members of a joint force austere surgical team offload gear 29 November 2017 following a mission in Afghanistan. Consisting in this case of five members, the team carries all of the required equipment to provide one operating table and two resuscitation bays by hand, minimizing its footprint on the aircraft. (Photo by Staff Sgt. Douglas Ellis, U.S. Air Force)

Death Ignores the Golden Hour

The Argument for Mobile, Farther-Forward Surgery

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The employment of emergency surgical assets has defined military medical planning since 2001. Although the footprint of medical resources has significantly contracted in recent years, the geography of ongoing operations has not. As a result, at-risk soldiers find themselves reliant on more tenuous limbs of medical support, far removed from the meticulously orchestrated medical evacuation (medevac) rings once deemed an operational imperative. The first hour after the occurrence of a traumatic injury is considered the most critical for emergency stabilization of a casualty. This "Golden Hour" concept establishes a serviceable standard for the distribution of fixed medical resources supporting areas of operation. However, the Golden Hour paradigm is insufficient for large-scale combat operations (LSCO), specifically when planning medical support for those offensive operations associated with the highest risk to force or those conducted in movement-restricted environments where timely medevac is not guaranteed. In order to provide ground force commanders with options for risk reduction consistent with best medical practice, medical planning will need to recalibrate from the prevailing Golden Hour paradigm to a more deliberate mission support model. Planners must consider operational importance, asymmetric distribution of risk to force, and available surgical assets' capacity to influence preventable combat mortality and improve the efficiency of the casualty care system.

Only Half of Casualties with Potentially Survivable Lethal Injuries Will Survive the Golden Hour

A 2012 analysis of combat casualties from the first decade of post-9/11 conflict serves as a valuable foundation for planning medical support for offensive operations. The study analyzed nearly 4,600 combat fatalities in Iraq and Afghanistan through June 2011 and found that 87.3 percent of deaths occurred prior to hospital arrival. Of those deaths, approximately one in four was deemed potentially survivable from a strictly medical perspective, which means prehospital care and evacuation influenced up to one thousand combat-related deaths by 2011.[1] This study makes clear that to meaningfully impact combat casualty survival, attention and resources must focus on improving prehospital care and shortening time from injury to surgery.

In 2009, former Secretary of Defense Robert M. Gates established the Golden Hour standard for theaters of conflict that distributed coalition surgical and medevac assets to ensure an injured soldier could arrive at a medical treatment facility within sixty minutes of being injured, calling the standard both a "matter of morale" and a "moral obligation." This policy has been credited with saving as many as 359 lives between 2009 and 2013 by increasing the number of soldiers for whom surgical hemorrhage control could be achieved prior to dying from severe blood loss.[2]

A 2014 study of more than a decade of early trauma deaths in a statewide civilian trauma system determined that the classically described Golden Hour would result in access to life-saving surgery for only about half of those who need it; to afford access to surgery for 95 percent of patients with potentially lethal injuries, the time from injury to surgery would need to be reduced to twenty-three minutes. This interval was reduced even further, to nineteen minutes, for patients sustaining a penetrating mechanism of injury, as is more commonly seen in combat.[3]

The Gates policy was successful because it substantially improved upon the previously established two-hour standard, and it continues to serve as a reasonable standard for establishing medical support for stability operations where numerous operations of similar risk are geographically dispersed. The Golden Hour standard, however, is inadequate for planning decisive operations, where the risk to a specific unit is heightened but temporally limited and geographically confined. Such operations demand the commitment of sufficient resources for a higher standard of risk mitigation than the Golden Hour paradigm, and it is specifically the finite limitation of heightened risk in time and space that makes such a higher standard tactically and logistically feasible.

Similarly, medical support planning for LSCO requires revision of the prevailing area-support model. While logistically more challenging, proper positioning of far-forward surgical assets is imperative in peer-to-near-peer conflict. In LSCO, the availability of large medical elements is restricted by exposure to enemy fires and hybrid threats. Casualty evacuation, meanwhile, is subject to ground-centric movement schemes stemming from a contested air domain. Although casualty volume is expected to exceed treatment, hospitalization, and patient movement capacities, by executing expert casualty triage and stabilizing

interventions, far-forward surgical assets will negate the effects of evacuation hinderances.[4]

Hemorrhage remains the greatest killer on the battlefield. In 2018, the Committee on Tactical Combat Casualty Care incorporated the concepts of advanced resuscitative care (ARC) to address prehospital hemorrhagic death and support dynamics.[5] Intended to minimize unnecessary death on the battlefield, ARC employs the principles of on-target blood transfusion, early control of hemorrhage not amenable to external compression or tourniquets (known as noncompressible torso hemorrhage), and far-forward access to damage control surgery. Because the demands of ARC extend beyond what an operational unit can issue and a ground-force medic can carry, the concept created new expectations for medical operational support planning that targets the largest source of preventable combat death.

On-Target Blood Transfusion

A 2018 review of more than forty-five hundred casualties found that patients who received a required blood transfusion on the battlefield were more likely to reach the hospital alive compared to those who did not receive a needed transfusion.[6] This followed a 2017 study of more than five hundred combat casualties that found casualties who received a blood transfusion before arriving at a field hospital were 3.6 times more likely to survive the first twenty-four hours after injury and twice as likely to survive for at least thirty days.[7]

Planning recommendations. An optimal medical plan would enable the initiation of blood transfusion in close proximity to the place and time of injury, in the prehospital setting, without delaying the rapid evacuation of the casualty to a surgical capability. Maintaining a supply of transfusable blood products on target should be considered a medical logistics priority. In most cases, this supply chain can be coupled to the medical evacuation chain. Ground medics receive resupply from medevac personnel, who in turn are resupplied by the receiving medical unit. This exchange, however, requires adequate planning and coordination with supporting medical units and treatment facilities to obtain and position the necessary blood products.

Early Control of Hemorrhage

Hemorrhage accounts for 91 percent of potentially survivable prehospital battlefield deaths. Of those deaths, 13.5 percent are due to extremity hemorrhage. To address this, the military standardized the issue, familiarization, and training of combat tourniquets throughout the force, reducing the death rate from extremity hemorrhage by 85 percent, from an average of 23.3 deaths per year to 3.5 deaths per year.[8]

Newer technology emerging in both civilian and military practice may facilitate presurgical hemorrhage control in the remaining 79 percent of potentially survivable prehospital deaths caused by noncompressible torso hemorrhage. Resuscitative endovascular balloon occlusion of the aorta (REBOA) refers to both the equipment and the technique of inserting a balloon-tipped catheter through an artery in the groin and inflating the balloon in the aorta to arrest the flow of blood to the site of the injury. Such occlusion can arrest hemorrhage from abdominal, pelvic, or junctional blood vessels, buying time to achieve definitive surgical control before the patient bleeds to death. The earlier-referenced 2012 analysis

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of combat fatalities suggests that up to 62 percent of potentially survivable combat injuries that resulted in death could have benefited from REBOA.[9]

The caveat to this technology, however, is that there are potentially significant life-threatening metabolic consequences associated with the cessation of blood flow to abdominal organs and extremity musculature. Current recommendations suggest complete aortic occlusion in the distal chest can be sustained for up to forty minutes and in the pelvis for up to sixty minutes. Experience with combat casualties has demonstrated successful outcomes associated with aortic occlusion ranging from seven to thirty-four minutes.[10] However, animal studies performed at military medical research centers have shown that the metabolic consequences of greater than sixty minutes of complete aortic occlusion are lethal.[11] REBOA must, therefore, be employed only as a component of a more comprehensive system of evacuation, resuscitation, and timely, definitive control of traumatic hemorrhage.

Planning recommendations. Though experience with the therapeutic benefit of REBOA continues to accumulate in civilian and military applications, its use in the prehospital setting remains experimental. The theoretical value of prehospital REBOA is in its potential to extend the amount of time before a casualty bleeds to death from noncompressible torso hemorrhage. REBOA should not be considered as a primary method of risk mitigation but rather as an adjunct when it is not possible to position a surgical element to achieve a time from injury to surgery of less than twenty minutes.

The procedure requires a minimum of eight to ten minutes to perform, even in the most competent hands.[12] Plans incorporating REBOA into operational medical support should aim to have the initiation of the procedure within fifteen minutes of injury in order to have a theoretical chance to benefit up to 95 percent of eligible casualties. It must be determined whether it is more feasible to move the casualty to the provider, the provider to the casualty, or some aggregation of both to achieve colocation as quickly as possible.

The downstream logistical demands of REBOA are extensive. For one, REBOA can reduce the volume of ongoing blood loss, but for any survival benefit to be realized, the blood already lost will need to be replaced as soon as possible. Therefore, blood transfusion on-target and during evacuation are essential, and massive transfusion volumes should be expected in the majority of REBOA patients. Additionally, because the metabolic consequences of aortic occlusion begin to accumulate at the moment of inflation, it is essential that casualties reach a surgical unit within thirty minutes of REBOA placement. Otherwise, any decrease in prehospital deaths from hemorrhage will be negated by in-hospital deaths from subsequent organ failure.

Prehospital REBOA should not be considered when adequate blood product resuscitation and expedient transfer time to surgery of less than thirty minutes from aortic occlusion cannot be achieved. REBOA casualties with resultant multisystem organ failure in austere environments would consume extensive resources, significantly undermining the support of ongoing operations, with no demonstrated benefit in survival.

Far-Forward Damage Control Surgery

In 1982, surgeons identified a cohort of patients that sustained life-threatening injuries and died a short time after surgery despite the successful repair of their injuries. These patients, they observed, were dying of the accumulation of the metabolic consequences of injury and their subsequent treatment, a mutually reinforcing lethal triad of low blood pressure, hypothermia, and impaired blood clotting.[13] It would take almost thirty years for the identification and widespread adoption of damage control principles that prevent, interdict, and reverse these metabolic insults, improving the chance of survival for some of the most grievously injured patients.

The goal of damage control surgery is to achieve adequate control of hemorrhage and gastrointestinal spillage in no more than sixty to ninety minutes. These limited objectives allow far-forward surgical teams to use less operative equipment and perform several operations in relatively rapid succession. According to a 2018 study of nearly thirteen years of combat casualties, undergoing surgical stabilization at a Role 2 facility decreased the likelihood of a casualty dying by one-third compared to initial surgical stabilization at a Role 3, independent of transport time or injury severity.[14] This finding indicates that damage control surgery is more effective when interventions are restrained; breadth of expertise and depth of surgical supply do

Sailors from the Navy Expeditionary Medical Unit care for a simulated casualty 1 August 2019 during a mass casualty exercise at Erbil Air Base, Iraq. (Photo by Spc. Kahlil Dash, U.S. Army)

not necessarily translate into better casualty outcomes in the first hours following injury.[15] The availability of REBOA further complements damage control surgery by allowing medical teams with experience in advanced resuscitative strategies to temporarily control noncompressible torso hemorrhage in select combat casualties while a colocated surgeon completes another time-limited damage control procedure, enhancing the depth of a far-forward surgical element.[16]

Planning recommendation—constitution of far-forward surgical elements. Originally, the forward surgical team (FST) was designed to serve the far-forward surgical need, in close proximity to the combat. Doctrinally, the FST mission provides forward surgical capability for brigade combat teams and echelons above brigade, possess organic ground mobility assets and should be mission capable shortly after the FST's arrival at a predetermined position.[17] However, the FST has more commonly been deployed in an area-support posture, often split in a nondoctrinal fashion into two ten-person teams supporting battalion- or smaller-size operational areas. Presently, split FSTs can be found at forward operating bases with a company to company-minus maneuver element and are rarely repositioned or utilized for direct mission support.

Each branch of service has identified a need for small, more mobile surgical teams to fill the gap in medical support left by the evolution of the FST mission. In the present environment of small-unit, limited-combat operations, planning should consider the size of the at-risk population, casualty estimates, the duration of the operation, and the demands of the operational unit to determine the optimal size and type of supporting surgical element. In LSCO, the tasks of far-forward surgical assets will not change, but considerations governing their deployment will. Planning will need to calibrate a mission's operational importance and unmitigated risk. Surgical assets execute early stabilizing interventions and conduct expert far-forward triage. This expertise interdicts preventable combat mortality and allows casualties to be reclassified as lower evacuation priorities,

Table. Doctrinally Established Forward Surgical Teams across the Services and Their Compositions

Surgical team	Branch	Operating room tables	Total personnel	Surgeon	Anesthetist	Emergency medicine/ intensive care unit physician	Orthopedic surgeon	Physician assistant/ independent duty corpsman	Critical care nurse	Emergency medicine nurse	Practical nurse	Medic/corpsman	Surgical technician	Respiratory therapist	Administrator	Communications
Forward Resuscitative Surgical Team (FRST)*	U.S. Army	2	20	2	2	2	2		2	2	2	1	2		1	
Golden Hour Offset Surgical Team (GHOST)*	U.S. Army	2	10	2	2					2		2	2			
Expeditionary Resuscitative Surgical System (ERSS)	U.S. Navy	1	9	1	1	1		1		1	1	1	2			
Expeditionary Resuscitative Surgical Team (ERST)	U.S. Army	1	8	1	1	2	1		1	1			1			
Damage Control Surgical Team (DCST)	U.S. Navy	1	7	1	1	1		1	1	1			1			
Ground Surgical Team (GST)	U.S. Air Force	1	6	1	1	1			1				1		1	
Special Operations Surgical Team (SOST)	U.S. Air Force	1	6	1	1	1			1				1	1		
Surgical Resuscitation Team (SRT)	Joint forces	1	5	1	1	1	**1	1				**1				1

(Table by authors. *Designates a team that can be split into two equally capable teams, each with half of the operating room capacity and personnel of the full team. **Designates doctrinally established supplementary personnel/capability)

enhancing the efficiency of a restricted medevac system. The table lists characteristics of the existing austere surgical teams across the services. In small-unit operations, larger teams generally provide more depth and hold capacity, enabling them to remain on station and mission capable for more extended operations in support of larger mission forces. Smaller teams are more mobile and less logistically demanding but run a greater risk of culmination if adequate resupply and onward casualty evacuation are not reliably executed. In movement-restricted combat operations, however, any collection of casualties is at once both a tactical liability and an operational moral imperative. Far-forward hold capacity becomes less of a consideration when the alternative is higher rates of potentially preventable combat death. In most cases, an established far-forward surgical element can be customized to accommodate the mission demands and logistical constraints of a given operation.

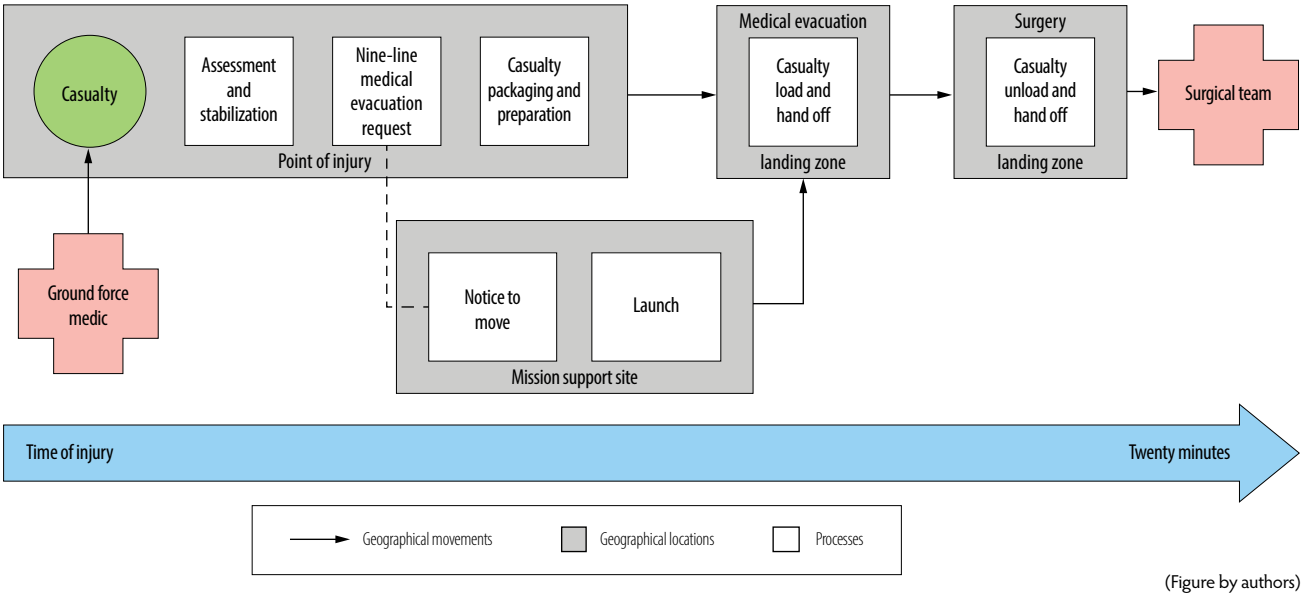
Planning recommendation—location of far-forward surgical elements. In both current small-unit and future LSCO, risk mitigation and prevention of combat mortality depends on proper positioning of far-forward surgical assets within an area of operations characterized by constantly evolving operational risk and priorities.

The optimal location of surgical team employment should be as close to the potential casualty producing

site as tactically feasible, targeting an interval from injury to surgery of no more than twenty minutes. Figure 1 illustrates the tasks and movements required from the point of injury to arrival at a surgical unit. Shortening the distance between locations will shorten the time required for the movement for a given transportation platform. Alternatively, faster evacuation platforms would also increase the likelihood of arriving at the surgical element within the goal of twenty minutes from time of injury. Training, rehearsals, planning, positioning, and resourcing should all be optimized to achieve maximum efficiency with each of these processes and movements.

preserves designated medevac platforms for continued point-of-injury evacuation by leveraging other theater assets for onward evacuation of the stabilized casualty.

Reducing the distance between the point of injury and surgical capability affords numerous medical advantages. Shorter distances typically shorten evacuation times and allow access to surgical hemorrhage control for patients who otherwise would have died before arriving at a fixed facility. Hypotension, hypothermia, and hypocoagulability are easier to prevent than they are to reverse, and reversal of these conditions is easier earlier in their course. Earlier access to blood transfusion and earlier access to surgery enable

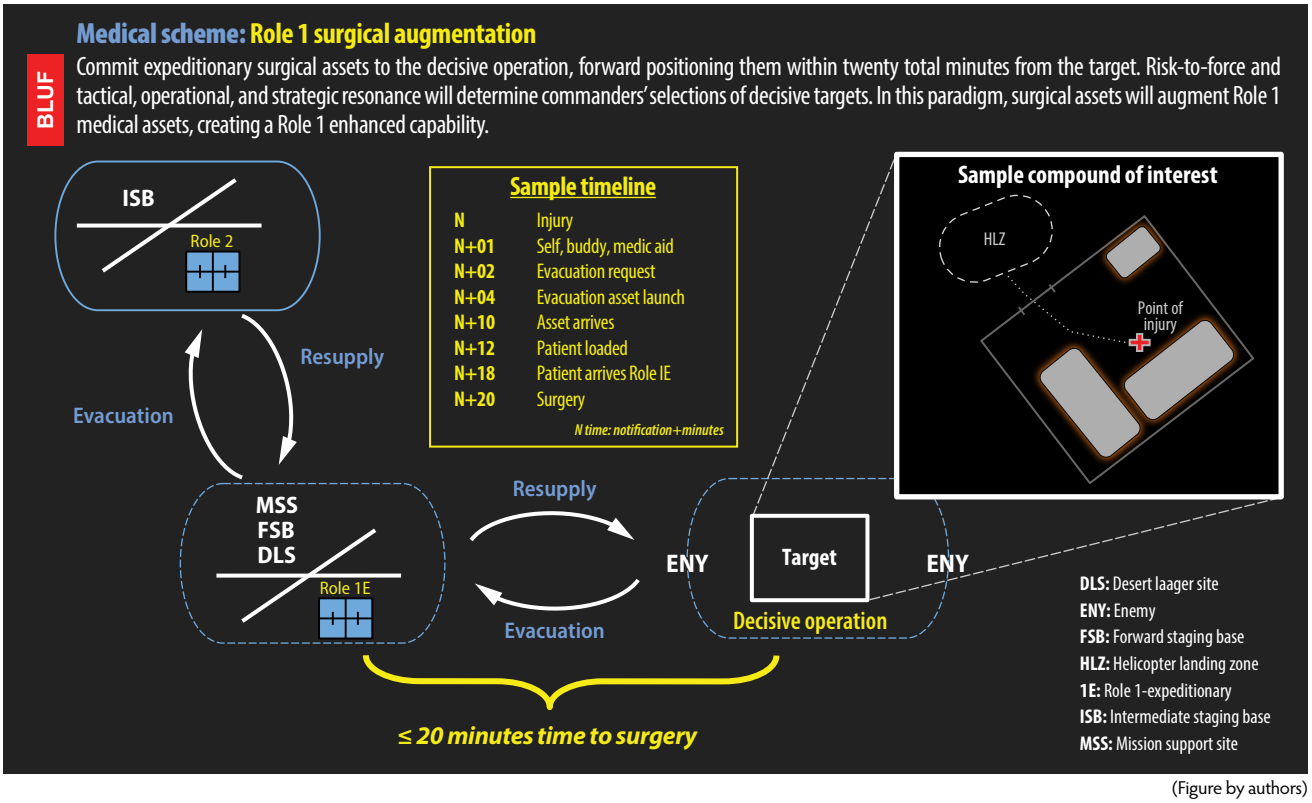


(Figure by authors)

Figure 1. Tasks and Movements Demanded by Casualty Care and the Medical Evacuation Process between Time of Injury and Arrival at Surgery

There are two doctrinal frameworks to relate the battlefield employment of far-forward surgery. The first framework embeds the surgical team with the doctrinal Role 1. Such positioning would minimize the time from injury to surgery, provide the surgical elements with shelter and security, and add additional depth for simultaneous casualties while maintaining control of evacuation at the unit level. The second framework places the surgical team at a far-forward ambulance exchange point. Staging at an ambulance exchange point enables rapid casualty stabilization and surgeons to perform procedures on patients arriving in better condition with greater physiologic reserve and resilience, improving the chance of a positive outcome while consuming less resources.

Additionally, far-forward surgical units substantially impact medical operations through their ability to enhance casualty triage. Expert casualty prioritization improves resource utilization in small-scale operations by limiting evacuations unlikely to influence patient outcomes and thereby allowing assets to continue support of ongoing operations. In LSCO, expert triage



(Figure by authors)

Figure 2. A Template for Surgical Asset Employment in Deliberate Offensive Operations

combined with far-forward surgical stabilization enhances the efficiency of medical evacuation efforts in a movement-restricted environment. Combat support hospitals are characterized by breadth of available specialty care and depth of patient hold capacities, but their logistical demand limits their employment to a fixed area-support posture essential to decompression of forward medical assets but limited in its ability to interdict preventable combat mortality.

Adequate shelter should be considered an operational imperative for far-forward surgical elements. Environmental conditions should be considered when evaluating options for shelter. Hypothermia is a life-threatening consequence of combat injury, and sufficient concealment should be afforded to enable the use of light without compromising security. Potential shelters could include established outposts, tents, cleared buildings, and large mobility platforms such as CH-47, CV-22, or C-130 aircraft.

Planning recommendation—Roles 2 and 3 support of far-forward surgical elements. A far-forward surgical element will always be constrained in the volume and duration of its capacity to hold casualties and its depth of expendable class VIII (medical supplies). By definition, damage control surgery terminates with an expedient, temporary closure of opened body cavities. It is rare for patients to require a second surgery in the first six hours following the index surgery. Definitive surgical repair of injuries and permanent closure ideally occurs six to twelve hours after the initial procedure, providing a window of time for safe evacuation. Postoperative casualties remain critically ill and will require critical care medical personnel to continue blood product resuscitation, ventilator support, and close monitoring of sedation and pain control. Tactical critical care evacuation teams and certain medevac teams possess such capability; however, their limited availability may require using surgical unit personnel for transport, though the core of the surgical team, the surgeon and anesthetist, should remain on station to provide continuous surgical support for ongoing tactical operations.

The resupply of a forward surgical element can be facilitated with prestaged packages of high-use items delivered through the logistical chain of the supported unit or through incoming medical evacuation platforms. At the conclusion of the operation, forward surgical teams will require access to a fixed logistical hub to reset and refit. This may require a Role 2 or 3 military treatment facility for sterilization of surgical equipment and temperature-controlled storage of blood products.

Conclusion: Death Ignores the Golden Hour

It has long been doctrine to amass forces at a battle's decisive point, though this principle has not been consistently applied to medical support planning. Surgical capability, like all other critical capabilities, should be positioned to best support the decisive point of an operation. The Golden Hour paradigm that serves as the foundation of medical planning for area support operations has successfully reduced combat-related mortality to the lowest levels seen in modern warfare, but data indicates that reducing the number of preventable combat deaths requires the adoption of a new standard for operational medical support, focusing on the prehospital environment and shortening the interval from injury to lifesaving, damage control surgery.

“It has long been doctrine to amass forces at a battle's decisive point, though this principle has not been consistently applied to medical support planning.”

Theory in Practice

Figure 2 (on page 46) depicts a proven template of a surgical asset employment scenario during offensive operations. The assault force establishes a primary base of operations at an intermediate staging base, a platform used to project concentrated combat power into the battlespace. From there, multiple concurrent operations can establish forward staging bases, affording proximity and rapid operational reach to target. Commanders will mass forces at these forward nodes across all warfighting functions, posturing assets to best support their priorities. Surgical assets are repositioned for each operation in line with the planning priorities discussed, ensuring the operational risk mitigation afforded by a far-forward surgical capability remains within reach of decisive points.

This model has been tested and proven effective in operations of varying scales using both rotary-wing and ground evacuation assets. In 2017, during the Battle of Mosul and again during the seizure and clearance of Raqqa, U.S. surgical assets were placed far forward on a linear battlefield and were repeatedly repositioned to remain immediately behind the forward line of troops as this line advanced. Mobile, far-forward surgical elements have also been deliberately employed at a variety of temporary staging locations in support of the full spectrum of special operations in Iraq, Syria, and Afghanistan.

Employment of far-forward surgical teams should focus on the principles of expert triage, advanced resuscitative care and far-forward damage-control surgery, maintaining the ability to provide on-target blood transfusion, early hemostasis, and a time from injury to surgery of less than twenty minutes. Implementing this standard will reduce preventable combat mortality, providing commanders with tested, data-driven options to mitigate risk for the full spectrum of military operations.

In LSCO, it will be incumbent upon medical, evacuation, and logistics elements to position surgical assets further forward and in greater isolation than in recent theaters. Doing so maximizes medical effect proximate to the point of injury. Limitations on the positioning of larger medical elements will inhibit their ability to effect preventable combat mortality, and movement restriction in a contested environment will hinder the medical evacuation system on which an area support model relies. The battlefield medical system must modernize to maximize the further-forward surgery paradigm despite the inherent logistical challenges. Status quo, like the Golden Hour, is no longer acceptable. ■

Notes

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