Special Amphibious Reconnaissance Corpsmen assigned to November Company, 3rd Raider Battalion, provide tactical combat casualty care training to Soldiers of 1st Battalion, 102nd Cavalry Regiment, during routine deployment to Somalia, August 24, 2019 (U.S. Navy/Patrick W. Mullen III)

The "Survival Chain"

Medical Support to Military Operations on the Future Battlefield

By Jennifer M. Gurney, Jeremy C. Pamplin, Mason H. Remondelli, Stacy A. Shackelford, Jay B. Baker, Sean P. Conley, Benjamin K. Potter, Travis M. Polk, Eric A. Elster, and Kyle N. Remick

Colonel Jennifer M. Gurney, USA, is Director of the Department of Defense (DOD) Joint Trauma System. Colonel Jeremy C. Pamplin, USA, is Director of the Telemedicine and Advanced Technology Research Center Headquarters. Second Lieutenant Mason H. Remondelli, USA, is an MD Candidate at the Uniformed Services University (USU). Colonel Stacy A. Shackelford, USAF, is the Trauma Medical Director at the Defense Health Agency. Colonel Jay B. Baker, USA, is Director of the DOD Joint Trauma Center, Combatant Command Trauma Systems Branch. Captain Sean P. Conley, USN, is an Assistant Professor at USU. Colonel Benjamin K. Potter, USA, is Professor and Chairman of the School of Medicine at USU. Captain Travis M. Polk, USN, is Director of the DOD JPC-6 Combat Casualty Care Research Program. Captain Eric A. Elster, USN (Ret.), is Professor and Dean in the School of Medicine at USU. Colonel Kyle N. Remick, USA (Ret.), is Professor of Surgery and Associate Chair for Operations at USU.

In *The Kill Chain: Defending America in the Future of High-Tech Warfare*, author Christian Brose describes a concept in which the speed that a combat force is effective at "closing the kill chain" will determine whether it wins or loses.[1] Brose proposes a redesign of our military combat infrastructure to "understand,

decide, and act" faster than the enemy to employ the required force (for example, lethal versus nonlethal) to achieve *operational overmatch.* Following his lead, we propose the concept of a "survival chain" as the medical equivalent that could provide combat casualty care support to the "kill chain" to gain and maintain *medical overmatch* on future battlefields.

The Department of Defense Joint Trauma System (JTS) was created to provide optimal care to the wounded on a battlefield. The current National Defense Strategy anticipates future threats of large-scale combat operations (LSCO) against peer adversaries that may limit overall freedom of maneuver for medical evacuation, increase survivability risk of medical units, and limit timeliness and robustness of critical medical logistics. Thus, the JTS must continue to evolve and embrace the concept of Medical Performance Optimization (MPO) to adapt to this new operational reality.

MPO captures the intent of the JTS as a "continuously learning health system" to evolve the speed at which it can cycle through near-real-time data capture, analysis, and adaptation of knowledge and material solutions to optimize battlefield trauma care. Like the "understand, decide, and act" of the kill chain, JTS MPO will be the survival chain that relies on rapidly closing the JTS MPO cycle via "observe, orient, decide [or understand], and act" (the JTS OODA loop).[2] Therefore, the purpose of this article is to inform military leadership about the risks to optimal combat casualty care in potential future LSCOs and to provide a focused discussion of potential solutions to gain and maintain medical overmatch in the survival chain on the 21st-century battlefields.

Reframing Current Challenges

Casualty care on the battlefield is based on the JTS performance improvement cycle (MPO) overlaid on the North Atlantic Treaty Organization's Roles of Care guidelines.[3] The JTS mission includes overall clinical care optimization of the battlefield trauma system by providing clinical data collection and analysis, "loop closure" feedback to medical commands, identification of gaps in knowledge and skills for further research, best practice clinical guidelines, quality improvement, and informing education/training.[4] The JTS MPO process must continuously and rapidly optimize battlefield trauma care—that is, continuously enhance the survival chain to gain and maintain medical overmatch to address the volume of casualties expected for an LSCO.

The crux of the current challenge is that the past two decades of war in the Middle East have resulted in the focus on a conflict in which there are robust medical resources, fixed Role 3 combat support (*Role 3 facilities* are equivalent to multidisciplinary general hospitals), field hospitals in relatively safeguarded locations, as well as a hierarchical trauma system in which casualties move along a continuum of care with increasing capability at each level of care (figure 2).

The JTS performed well in the recent conflicts, but the reality of future land or maritime LSCOs drives the challenges we now face to prepare the system to deliver the excellent care expected from our Servicemembers and our nation. Data integration and technology are integral to MPO for our system to observe (collect real-time, relevant data), orient (or understand via rapid data analysis), decide (increase speed and accuracy of decisions), and act (treat casualties) to meet the expectation of leaders to decrease force attrition from injury and maximize its lethality. As Brose notes, "The problems facing the U.S. military are now taking on a fundamentally different and greater sense of urgency, and it goes beyond emerging technologies."[5]

The goal of the JTS in preparing for LSCOs is a more effective survival chain not only to provide new technologies that improve the deployed medical system but also to continue to evolve the current system by enhancing real-time data acquisition for MPO. As Brose describes for increasing lethality, solutions that improve survival and force regeneration may involve novel medical innovations, new mechanisms by which to deliver already proven medical interventions, and modernization of trauma medical systems involving nontraditional architectures that are not platform-centric.[6] Therefore, in this article, we focus on the three most urgent challenges to providing a survival chain in support of future military operations:

- point-of-injury care
- casualty evacuation care
- surgical care.

Challenge 1: Point-of-Injury Care

Initial casualty care at the classic Role 1 (*Role 1 care* includes medical treatment, initial trauma care, and forward resuscitation) will face many challenges that are typical of a force-on-force battlespace.[7] We know from data developed during the war on terror that most preventable deaths (88 percent) occur in the *field*, that is, the time between the point of injury to the first treatment facility (Role 2).[8] Therefore, the challenges during this phase of trauma care will be essential to illuminate gaps in education, training, and research to gain overmatch in LSCOs.

Main Risks and Potential Mitigating Measures During Point-of-Injury Casualty Care.

- Death from massive bleeding
  - Increase Tactical Combat Casualty Care training for nonmedical personnel to control hemorrhaging and free up line medics to care for the more seriously wounded
  - Train and equip combat medics for blood transfusion, walking blood banks, and additional hemorrhage control techniques and simultaneously develop novel technological solutions for bleeding control and delivering blood[9]
  - Develop novel antishock drugs, blood products or alternatives, and advanced clotting technology to mitigate combat deaths from hemorrhage.[10]
- Large casualty volume
  - Ensure more sophisticated training for combat medics on knowledge

Soldiers assigned to Army Reserve participate in Tactical Casualty Combat Care course at Joint Base McGuire-Dix-Lakehurst, New Jersey, September 10, 2023 (U.S. Air Force/Matt Porter)

and skills in triage (the sorting of casualties by the severity of injury) involving an intentional transition from optimal care for each individual casualty to "the greatest good for the greatest number" in mass casualty incidents (when the number of casualties outstrips resources available)[11]
- Develop simpler and more functional models for triage that may involve swift identification of those who are ambulatory or dead first, then stable or unstable, and increasing knowledge of resources readily available to the triage team[12]
- Develop best practices in the care of the injured in mass casualty incidents to clear the battlefield of hundreds (or thousands) of casualties and simultaneously provide care and maximize the force.

- Lack of resources
  - Integrate remote-piloted aircraft or other technology for medical logistics support in denied and hostile environments
  - Develop clinical decision-support tools for personnel working with limited medical resources
  - Develop real-time monitoring and decision support tools for medical assessments and interventions.

Challenge 2: Casualty Evacuation Care

The next phase of care conventionally involves the movement of casualties from the immediate area of active conflict to one that can render more advanced trauma care and damage control resuscitation. However, during a large-scale force-on-force fight with adversaries that possess comparable long-range fire technology and airpower, challenges might arise that could diminish this potentially lifesaving evacuation capability. As a result, this phase of care, still classically considered Role 1 care, will include Prolonged Casualty Care (PCC) through eventual medical evacuation when available.[13] In this phase, medics will be faced with caring for casualties beyond doctrinal timelines with large volumes of casualties and resource constraints—in other words, more complex care with less resources.

Main Risks and Potential Mitigating Measures to Casualty Evacuation and Prolonged Casualty Care.

- Denied operating environment
  - Increase knowledge and skills required by combat medics to perform PCC to extend typical hold and evacuation times until a more advanced resuscitation and surgical care capability can arrive or be reached[14]
  - Develop the means to employ telehealth and decision support in austere environments to augment medical care further forward
  - Improve clinical data capture through real-time, automated documentation for ongoing care and for MPO.

- Risk of air maneuver/ground movement
  - Develop automated medical care technology for aerial and ground vehicles and include environmental surveys for railways as a potential means for medical evacuation of large numbers of casualties
  - Employ remote-piloted aircraft for medical resupply to include blood products that could be delivered on demand to forward locations
  - Evolve Patient Evacuation Coordination Cells that include real-time, intelligent tasking that accounts for both clinical and operational factors in optimal timing and destination for patient movements.

- Lack of communication/command and control
  - Develop counter-electronic/counter–cyber warfare technologies to protect and ensure clinical and operational medical communications are available and not compromised
  - Consider a battlefield medical command and control element, linked with the JTS, with real-time situational awareness of the battlefield and, with oversight to best match patient evacuation timing, clinical care required, as well as the right destination medical capability for the best outcomes
  - Develop a method of automated, real-time tracking of casualties across the battlespace.

Challenge 3: Surgical Care

Although most combat casualties who succumb to their injuries do so at Role 1 before they arrive at a surgical capability, the concept of Role 2 and Role 3 care remains critical to the remainder of survivable injuries.[15] Without damage control and definitive surgery, a casualty may initially survive but then die of bleeding or long-term trauma complications, such as infection and organ failure. For example, a casualty with a bleeding liver may receive the appropriate initial treatment to prolong life until reaching a facility capable of surgery, but that injury could only be more definitively controlled by a surgeon opening the abdomen and manually controlling the ongoing bleeding. Due to this situation, survival will be compromised without timely surgical intervention. However, on the potential peer contingency battlefield, Role 2 facilities and advanced surgical teams will face challenges.

Risks and Potential Mitigating Measures for Initial Lifesaving Surgical Care.

- Operational training/interoperability
  - Re-emphasize organizing, training, and equipping small surgical teams that could optimally perform as both a surgical team and as an operational element[16]
  - Optimize surgical teams that have access to work together in high-volume trauma centers and conduct specific training to attain the clinical and operational capability required
  - Conduct research and data analysis to better understand what capability is required and how

to best employ surgical teams in future operations
    - Improve the ability of surgical teams to capture data in future operations to be used for MPO.
- Maintaining casualty care expertise
    - Increase opportunities for deploying medical personnel to work individually and as teams in military Medical Treatment Facilities or in military-civilian partnerships
    - Continue to leverage the Joint Knowledge, Skills, and Abilities Program Management Office as the means to measure clinical specialty-specific medical readiness and provide clinical deployment readiness assessments
    - Research and develop technology that could augment clinical care through telementoring, telerobotics, augmented reality, or other emerging solutions.
- Risk of far-forward-deployment
    - Consider surgical teams with doctrine akin to a quick reaction force with the capability to move on the battlefield alongside operational elements to mass for casualty care at decisive points and then disperse when complete to minimize the risk of exposure
    - Establish international partnerships in geostrategic locations that could then be leveraged as a regional trauma capability while minimizing our military footprint[17]
    - Research and develop telesurgery capability for far-forward surgical locations to limit risk to surgeons and medical teams.

Conclusion: Closing the Survival Chain to Support the Kill Chain

The JTS has proved its effectiveness at decreasing death on the battlefield since its inception in 2005, and thus the organization was codified into doctrine in 2016. While the JTS provided tremendous advances over the past 20 years in combat, the next conflict might last for less than 2 years but have 10 times as many combat casualties as the last two decades. The JTS must continue to evolve through its MPO cycle to meet these anticipated challenges, most urgently for point-of-injury care, care during casualty evacuation, and surgical care as discussed.

We must actively seek to maintain our ability to optimize survival on the battlefield by decreasing warfighter attrition and thus producing the operational effect of maintaining combat strength. This is the mission of the Joint Trauma System. With the support of military leadership, the JTS could continue to evolve to support this critical role. The MPO concept is the cycle of near-real-time data collection and analysis, novel knowledge and/or material solutions, and rapid integration into battlefield trauma care (the JTS OODA) that would enable the JTS to adapt and react quickly when needed. By leveraging the existing processes of MPO and enhancing its speed of loop closure, the JTS would provide the survival chain that could gain and maintain medical overmatch on future battlefields regardless of the challenges presented. **JFQ**

Notes

[1] Christian Brose, *The Kill Chain: Defending America in the Future of High-Tech Warfare* (New York: Hachette Books, 2020).

[2] Ibid.

[3] Allied Joint Publication (AJP) 4.10(A), *Allied Joint Medical Support Doctrine* (Brussels: North Atlantic Treaty Organization, May 30, 2011), https://shape.nato.int/resources/site6362/medica-secure/publications/ajp-4.10(a).pdf.

[4] Jeffrey Bailey et al., eds., *The Joint Trauma System: Development, Conceptual Framework, and Optimal Elements* (Fort Sam Houston, TX: U.S. Army Institute of Surgical Research, January 2012), https://jts.health.mil/assets/docs/publications/Joint_Trauma_System_final_clean2.pdf.

[5] Brose, *The Kill Chain*.

[6] Ibid.

[7] AJP 4.10(A).

[8] Brian J. Eastridge et al., "Death on the Battlefield (2001–2011): Implications for the Future of Combat Casualty Care," *Journal of Trauma and Acute Care Surgery* 73, no. 6 (December 2012), S431–S437, https://doi.org/10.1097/TA.0b013e3182755dcc.

[9] Andrew D. Fisher et al., "Low Titer Group O Whole Blood Resuscitation: Military Experience from the Point of Injury," *Journal of Trauma and Acute Care Surgery* 89, no. 4 (October 2020), 834–841, https://doi.org/10.1097/TA.0000000000002863.

[10] Jonathan J. Morrison, Joseph J. Dubose, and Todd E. Rasmussen, "Military Application of Tranexamic Acid in Trauma Emergency Resuscitation (MAT-TERs) Study," *Archives of Surgery* 147, no. 2 (February 2012), 113–119, https://jamanetwork.com/journals/jamasurgery/article-abstract/1107351; I. Roberts et al., "The CRASH-2 Trial: A Randomised Controlled Trial and Economic Evaluation of the Effects of Tranexamic Acid on Death, Vascular Occlusive Events and Transfusion Requirement in Bleeding Trauma Patients," *Clinical Governance: An International Journal* 18, no. 3 (July 2013), https://doi.org/10.1108/cgij.2013.24818caa.005.

[11] Stacy A. Shackelford et al., "Evidence-Based Principles of Time, Triage and Treatment: Refining the Initial Medical Response to Massive Casualty Incidents," *Journal of Trauma and Acute Care Surgery* 93, no. 2S Suppl 1 (August 2022), S160–164, https://doi.org/10.1097/ta.0000000000003699.

[12] Ibid.

[13] "Prolonged Casualty Care Guidelines: Joint Trauma System," *JTSHealth.mil*, December 21, 2021, https://jts.health.mil/assets/docs/cpgs/Prolonged_Casualty_Care_Guidelines_21_Dec_2021_ID91.pdf.

[14] Nedas Jasinskas, Regan Lyon, and Jay Baker, "Unconventional Warfare Medicine Is the Ultimate Prolonged Field Care," *Medical Journal (Fort Sam Houston, TX)*, no. Per 22-04-05-06 (April–June 2022), 27–31.

[15] AJP 4.10(A).

[16] Jay B. Baker et al., "Austere Resuscitative and Surgical Care in Support of Forward Military Operations—Joint Trauma System Position Paper," *Military Medicine* 186, no. 1–2 (January–February 2021), 12–17, https://doi.org/10.1093/milmed/usaa358.

[17] Regan F. Lyon, "When the 'Golden Hour' Is Dead: Preparing Indigenous Guerrilla Medical Networks for Unconventional Conflicts" (Master's thesis, Naval Postgraduate School, December 2021), https://calhoun.nps.edu/handle/10945/68685.