Improving Patient Outcomes

Surviving in a contested and distributed operations environment

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Over the past two decades of global conflict, the Marine Corps and Navy Fleet Marine Force (FMF) have relied on the "Golden Hour" to save the lives of military personnel. If Navy medical providers can reach and provide surgery or advanced trauma life support within one hour of the patient sustaining the injury, the likelihood of survival and positive patient outcomes increases dramatically.

This has been an unprecedented time for military medicine, with casualty survival rates of 90 percent or more through advances in field medical treatment paradigms, new medical monitoring and treatment technologies, and the opportunity for regular and rapid patient evacuation. The latter aspect was the result of the U.S. military's uncontested dominance of the airspace and sea lanes.

This unprecedented control of the airspace and sea lanes afforded us more than just the frequent and timely evacuation of patients. It enabled the ability to provide steady and regular resupply of medical consumables from logistical staging areas and resupply vessels to advanced forward medical facilities.

The freedom of movement enabled the timely delivery of medical materiel, including bandages, medicine, fluids, and the batteries and generator fuel needed to power advanced but power-intensive medical technologies. Timely delivery, in turn, allowed for frequent application of new wound dressings and infusion of lifesaving drugs, fluids and, even blood products, which must be re-administered regularly to ensure patient safety and achieve good patient outcomes. It further facilitated reliable access to the advanced medical monitoring, and diagnostic and treatment technologies of a trauma center in a Forward Resuscitative Surgery System (FRSS).

This is a paradigm that we cannot rely upon in the next conflict. Near-peer conflicts will mean that the airspace and sea lanes will no longer remain uncontested. Emerging requirements for *Distributed Maritime Operations* (DMO) and *Expeditionary Advanced Base Operations* will require fewer Marines and Sailors to operate in a larger, more contested battlespace.

Littoral Operations in a Contested Environment will pose new operational constraints on the Marine littoral regiment (MLR), which will not be able to rely on the frequent, uncontested evacuation and resupply of the prior conflicts.

Under these constraints, the Golden Hour will be a rare luxury. Patient holding times of 72 to 96 hours may become the norm. Some are already calling this new paradigm the "Brass 96."

Logistical constraints posed by the new DMO battlespace will severely affect FMF medical corpsmen's ability to perform their medical mission. Clinical necessities for sterile, consumable medical supplies have traditionally required large logistics footprints.

Treating dozens of casualties over a 48-hour period traditionally requires a large logistical "front end," with frequent resupply to maintain the regular changes in medical consumables necessary to maintain patient life and health.

To illustrate the extent of the logistical front end, providing forward resuscitative surgical care for 18 patients over 48 hours, the requirement of the FRSS, currently requires cargo carrying capacity of over five MV-22 Osprey tilt-rotor transports. To resupply this medical capability to maintain another 18 patients will require another three to four MV-22s.

Under DMO, the inability to regularly evacuate casualties will exacerbate these issues. Ninety-six-hour holding times will double or triple the requisite on-hand medical supplies. Furthermore, limited bed space at medical facilities requires frequent casualty evacuation to prevent a mass casualty situation where the number of patients requiring treatment can quickly overwhelm the ability of attending medical personnel to treat them.

Additional patient holding capacity is possible but requires a larger logistical front-end and an even larger footprint on the ground. At far forward Role of Care I (ROC I) facilities such as the battalion aid station (BAS), which will be the likely ROC to support the MLR, these logistical constraints are exacerbated.

Supporting the current medical capability under DMO will be highly problematic. Increasing front-end logistics to give corpsmen the medical materiel needed to maintain an increasing stream of casualties for extended casualty holding durations will run contrary to the emerging requirements for smaller, more mobile, capable, and self-reliant forward units.

A new medical logistics, patient treatment and management paradigm must be developed and implemented to avoid a significant increase in combat-related fatalities and long-term disability among warfighters.

Enhancing the BAS

The embedded Field Medical Service Technicians (FMST) and Marine Corps combat life savers who assist the FMST at the point of injury are the tip of the spear for FMF field medical care.

The medical "leading edge" behind that tip is the ROC I facility, particularly the BAS. This facility, generally little more than a soft wall shelter or commandeered room, provides immediate life-saving critical care and triage to casualties. The BAS will feel the greatest burden from the DMO requirement and will require the most fundamental change in operations if it is to provide even a fraction of the medical capability it maintained over the past two decades.

The BAS is unlikely to have a reliable source of power and is thus almost entirely dependent upon battery and man-portable solar power. This dependency limits the use of medical diagnostic and treatment devices to simple triage and monitoring tools, such as fingertip pulse-oxygenation monitors, traditional non-powered stethoscopes, and blood pressure cuffs.

Advanced vitals monitoring equipment like electrocardiograms typically require AC power or have internal batteries with a limited run time that cannot be easily swapped out on the battlefield. Such systems tend to be bulky and often lack the environmental and transport hardening necessary to survive field operations.

The BAS is currently required to treat up to 50 casualties, including Level 1 trauma cases. To meet this capability, it employs one medical officer, one physician's assistant or independent duty corpsman, and a small team of FMSTs.

None of these available corpsmen are likely to have the training or tools to perform resuscitative interventions necessary for Level 1 trauma care. Even under the current paradigm, it is a challenge for the BAS corpsmen to meet these requirements. The BAS also lacks the supplies and bed space necessary to hold patients for an extended period of time.

To meet this evolving strategic requirement, Marine Corps Systems Command's Portfolio Manager Logistics Combat Element Systems, in partnership with the Marine Corps Warfighting Laboratory Expeditionary Medicine Team, Combat Development and Integration, the Naval Health Research Center, and the Naval Surface

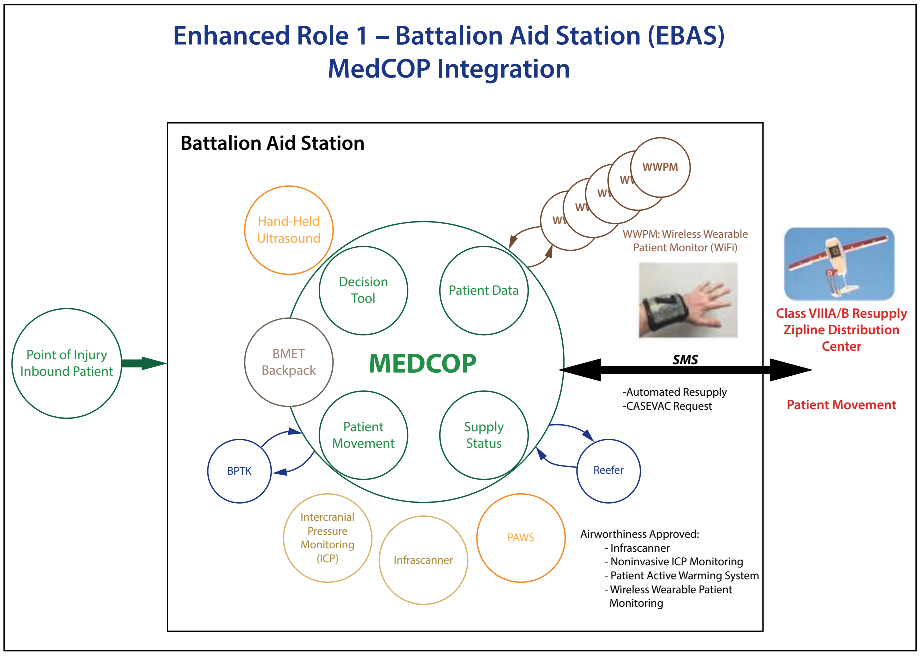

Figure 1. ***(Figure provided by author.)***

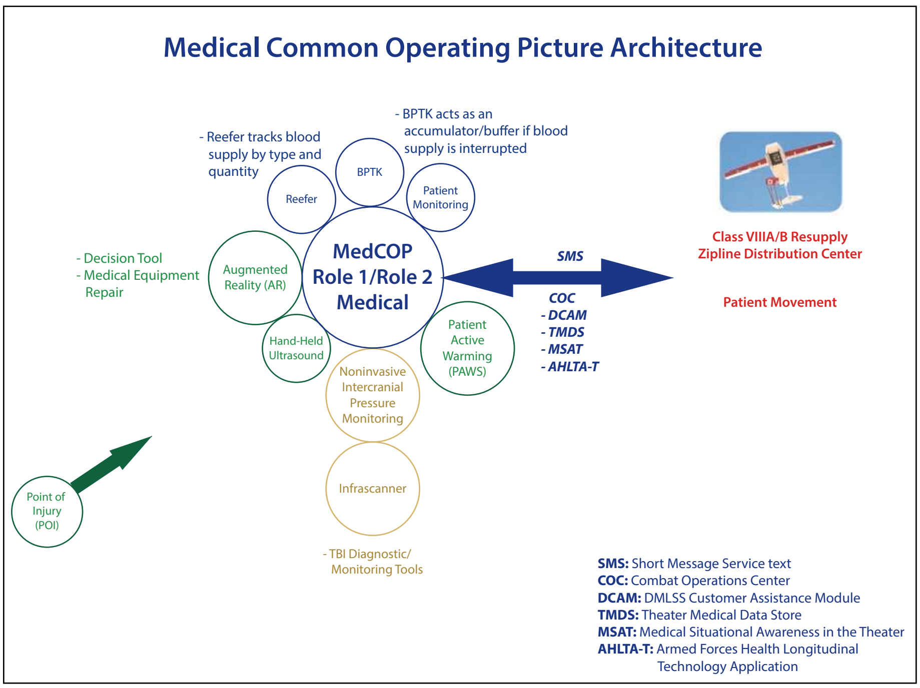

Figure 2. ***(Figure provided by author.)***

Warfare Center, Dahlgren Division, have initiated the Enhanced Battalion Aid Station (EBAS) and Medical Common Operating Picture (MedCOP) research and incremental development efforts.

The goal of EBAS is to empower the forward deployed hospital corpsmen by providing new compact and energy efficient expeditionary diagnostic, triage, and monitoring technologies to act as force multipliers in the MLR battlespace.

The MedCOP concept will use advanced, integrated information technology to empower decision makers by providing central patient monitoring and tracking, allowing for the patients with the greatest need to be routed where they can be best treated.

Adapting the ROC I to the DMO/Littoral Operations in a Contested Environment mission via EBAS and MedCOP will require new medical tools and technologies, and new ways of thinking about forward medicine. New technologies will be required to support the rapid and accurate diagnosis and triage of patients, the acquisition and storage of blood products, and the prolonged field care of combat casualties.

Many of these new technologies are under development. A new Expeditionary Medical Refrigeration Unit to be fielded in fiscal year 2021/2022 can run for 96 hours on three standard hot-swappable BB-2590 batteries or indefinitely with solar power.

Small, wearable AA battery-powered patient monitoring systems that can perform advanced diagnostic heart and vital signs monitoring are under advanced development. Rapid blood-borne pathogen detection will enhance the ability to maintain the "walking blood bank" for "buddy" transfusions.

Other technologies such as rugged, handheld ultrasound and X-ray systems will assist in diagnosis and triage. Already fielded systems for non-invasive intracranial hematoma detection may soon be supplemented with non-invasive monitoring of intracranial pressure and non-invasive detection of internal hemorrhage. Such "decision-making tools" will become of importance as isolated corpsmen are forced to make difficult decisions on where to allocate limited materiel and clinical resources.

New "griege cotton" bandages offer the potential for enhanced long-term anti-microbial and hemostatic function, in turn allowing for longer durations between dressing changes. Embedded anti-microbial substances released only in the presence of bacteria can fight infection while reducing the risk of antibiotic resistance and reducing infection risk from long-term use.

Advances in nanostructures and cytokine gradients may someday allow for advanced wound-healing bandages that can promote healing in and prevent fibrosis of wounds even under prolonged field care conditions.

Other technologies can enhance the ability of the forward corpsmen. Handheld medical monitoring and tracking systems such as the Air Force Battlefield Assisted Trauma Distributed Observation Kit (BATDOK) can allow for "nine-line" patient information to be electronically transmitted between corpsmen or remotely.

These technologies can enable a remote central "nurses' station" for monitoring patient vitals and location using wireless connectivity. This will be a force multiplier by allowing a minimal number of corpsmen to monitor a larger patient population, mitigating manpower issues in mass casualty and prolonged field care.

BATDOK technology can allow for the tracking of patients in transport as well as their conditions, allowing for real-time rerouting of casualties in response to contingencies.

Other technologies and capabilities can even enhance the medical interventions possible in Expeditionary Advanced Base Operations conditions. A small, pack-transportable forward resuscitative surgical capability similar to that deployed by Air Force Mobile Forward Surgical Teams offers enhanced forward resuscitative care options.

However, additional training and skill sets will be required to make use of this capability. In the absence of such training, future capabilities in remote telemedicine and enhanced reality glasses may enable "talk-through" guidance for corpsman required to provide emergency advanced medical care that goes beyond their level of training.

Man-portable, battery-powered full-sterilization systems such as the Portable Ruggedized Energy Efficient Medical Sterilizer, intended for ROC II (e.g., FRSS) deployment in fiscal year 2023/2024, could be sent forward to supplement ROC I resuscitative intervention.

Furthermore, a combination of radio frequency identification or other automated supply tracking technologies and artificial intelligence can be used to monitor the levels and rates-of-use for medical consumables and blood supplies. These technologies can drive automated "just in time" logistical resupply using unmanned systems or flights of opportunity to maintain an optimized level of materiel-on-hand while maintaining the small, maneuverable footprint required in contested environments. A smaller logistical front end can thus be implemented, maximizing the use of a limited footprint and transport capacity.

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The MedCOP

Combining remote patient monitoring, telemedicine, tracking and just in time logistical technologies will allow

Corpsmen receive extensive training at the Field Medical Training Battalion. ***(Photo by LCpl Laura Mercado.)***

for a MedCOP that will enhance the ability of FMF corpsmen to optimize battlefield care and transport, even in contested conditions.

Medical officers can see the local medical environment and patient population or the entire FMF continuum of care and battlespace, allowing for critical decisions to be made in real-time with flexibility to adjust to the changing battlespace. Medical officers can view in realtime the entire patient population's location, condition status, and, treatments administered while also monitoring the status of medical supplies, blood products, and resupply status.

Adjustments can be made on the fly to optimize the medical battlespace and adjust to shifting priorities. Bed space and manpower can be monitored and tracked across the battlespace and casualties rerouted to avoid mass casualty situations.

Radio frequency identification tracking of on-hand supplies and use rates augmented by machine learning can send out "pull" demand signals for new supplies. Pre-planning for upcoming contingencies such as an increasing operations tempo or short-fuse reaction to a known influx of new casualties can be pre-emptively supported through a logistical push.

However, such a MedCOP will require information infrastructure not currently available at ROC I or II facilities. This infrastructure must be operationally secure and cybersecure, and must be optimized for the limited bandwidth, which will likely be available.

Rather than implementing a new wireless architecture, which would be frequency, bandwidth, cost, and schedule prohibitive, existing wireless architectures must be employed. This requires coordination with existing command, control, communications, computers, and intelligence, surveillance, and reconnaissance stakeholders.

How the MedCOP is implemented can mitigate the limitations of a shared network. Use of artificial intelligence and pre-loaded information inside of the handheld MedCOP assets can allow for maximum visible information to be available to the warfighter while limiting transmissions to small "burst" communications of simple ASCII data with negligible bandwidth.

Use of multiple radio and satellite networks will add operational redundancy and reduce conflict with other warfighter applications. BATDOK and other emerging battlefield medical information technology systems already implement these mitigations.

The MedCOP and other technologies should be first implemented in the EBAS and other vulnerable ROC I facilities, but the concept is global by design. Future developmental increments can see these technologies implemented across the Joint Class VIII (Medical) enterprise. This will permit enterprise-wide optimization of the joint medical care continuity of operations.

Conclusion

Evolving battlefield requirements will pose a significant challenge to the implementation of FMF medical operations. Casualty evacuation will be constrained, and the Golden Hour will be replaced by the Brass 96.

Logistical resupply will be limited and deployment footprints reduced. All of this runs counter to the innate requirements for medical treatment in the field where large amounts of consumable medical materiel are required for casualty treatment. Adapting to this new paradigm will require the adoption of new technologies and new ways of approaching casualty management and logistical resupply.

The MedCOP and other technologies for triage, treatment, and monitoring/tracking of casualties will allow for an "enhanced" BAS, which will mitigate these new limitations at forward deployed ROC I facilities and improve casualty outcomes in the MLR even in a contested environment. These technologies can be further adapted to ROC II or higher facilities across the medical enterprise to maximize FMF medical efficiency across the battlespace.

The end result of these efforts will be the conceptual design and development of a "commando-like" construct with multi-functional medical teams capable of operating in a distributed environment, harnessing technological enablers to support point of need and prolonged field care in support of the MLR. This construct will require new ways of thinking about medical operations and logistics and a dedicated, long-term, incremental developmental effort. It will be a considerable undertaking, but the warfighter deserves nothing less.