Army Medicine and Artificial Intelligence

Transforming the Future Battlefield

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Artificial intelligence (AI), machine learning (ML), and robotics mutually enhance human performance and military readiness through the development of intelligent software and machines.[1] The ongoing evolution of AI and related technologies continue to influence popular culture, science, robotics, finance, marketing, supply chain, and health care.[2]

AI mimics human intellect and processing functions such as language, learning, and problem-solving, through repetitive pattern recognition.[3] ML and neural network processes ingest large data sets, which "train" algorithms and develop adaptive "intelligence."[4] Quantitative studies and applied research demonstrate the efficacy of AI, ML, and human-machine integration, and in military settings, human-machine integration increases lethality through range, endurance, payload, survivability, and adaptability, significantly changing employment strategies.[5]

In 2022, AI revolutionized modern culture and social dynamics through the release of ChatGPT by OpenAI. The generative AI platform established this once distant, science-fiction concept within the public domain, with widespread availability for anyone with a network connection. In the wake of such rapid developments, future applications provide unlimited potential, and in particular, this technology is assessed to support human cognition through enhanced military leaders' decision-making, improved situational awareness, and optimized resource replenishment to fight and win on current and future battlefields. AI provides military decision-makers with valuable insights and analysis based on algorithms that process vast amounts of high-velocity, high-volume data, identifying trends and patterns that outpace human cognition, especially on a mass scale and at echelon.

Of significant impact, AI could provide solutions for the extreme challenges of providing medical care

A patient is loaded into a UH-60A Black Hawk medevac aircraft. AI will play an integral role in increasing the accuracy and efficiency of patient movement by reducing the number of pilots and crew required for medevac missions as well as by performing administrative functions and monitoring patients en route. (Photo by Maj. David Preczewski, U.S. Army)

during large-scale combat operations (LSCO). Army Futures Command has described the challenges facing the Army Health System (AHS) in the future operational environment, including high casualty rates, delayed evacuation and replenishment, and the lethality of multidomain and novel complex terrain environments.[6] To mitigate the challenges, the AHS will support forces contested in all operational domains. Our enemies' antiaccess and aerial denial capabilities will limit U.S. air, land, and sea force projection. In the cyber domain, AHS assets are threatened by enemy access to force structure and patient data, weaponized misinformation, and cyberattacks that interrupt network access. During conflict, the AHS will face a hyperactive, lethal, and kinetic fight preventing stable and stationary medical treatment operations. These challenges of the future operational environment will strain the AHS's ability to complete its enduring mission to conserve the fighting strength.

Recent experiments indicate overwhelming casualty rates, which have not been suffered since World War II: in future LSCO, the Army could lose twenty-one thousand soldiers, a corps-size element, in seven days.[7] These experiments establish the need for the AHS to increase evacuation and treatment holding on the future battlefield while simultaneously conserving the force's lethality by returning a high percentage of service members with illness or injury to the front line as swiftly as possible.

The AHS has three operational imperatives to address the challenges of the future operational environment, each of which can be supported through the application of AI. First, the AHS must clear the battlefield of casualties as a means to unencumber the combat force to move and operate; mobility is paramount in future fights. To conserve fighting strength after clearing the battlefield, the AHS must maximize return to duty as far forward as possible, which starts in garrison with the AHS force health protection (FHP) task. Home station care provides medical readiness to reduce service member risk for complications from disease, exposure to infection, and injury, which ensures service members perform effectively even before deployment. In forward environments, the AHS incorporates a sustainment capability by treating those sick or injured through health service support (HSS) tasks performed by operational medical organizations. Finally, the AHS must overcome the expected threat of contested logistics. Military medical resupply will not outweigh resupply needs of the maneuver force, so the AHS system must remain agile and flexible in its management of medical logistics, especially in mitigating expected mass casualty events.[8] Only by addressing all three interwoven imperatives will the AHS fulfill its role in conserving the fighting strength, and AI will be a revolutionary instrument for the AHS to solve information, risk, and decision-making challenges of LSCO.

Command and Control

Just as technology growth has rapidly accelerated over the last few decades, the Army increasingly relies on data to inform decisions and gain information advantage. From a command-and-control (C2) perspective, there are opportunities to leverage AI to process data rapidly. This is seen today through deep learning, pattern recognition, decision-making through repetition, and AI ability to distinguish unique attributes and elements of an image.[9] Follow-on applications of deep learning lead to an ability to automate, incorporate unmanned systems, and reduce human error by offloading and accelerating information across a battlefield. AI accelerates the provision of data to warfighters via rendering faster computers, algorithmic improvements, and access to large amounts of highly-accurate and well-established data-enabled advances in ML and deep learning.[10]

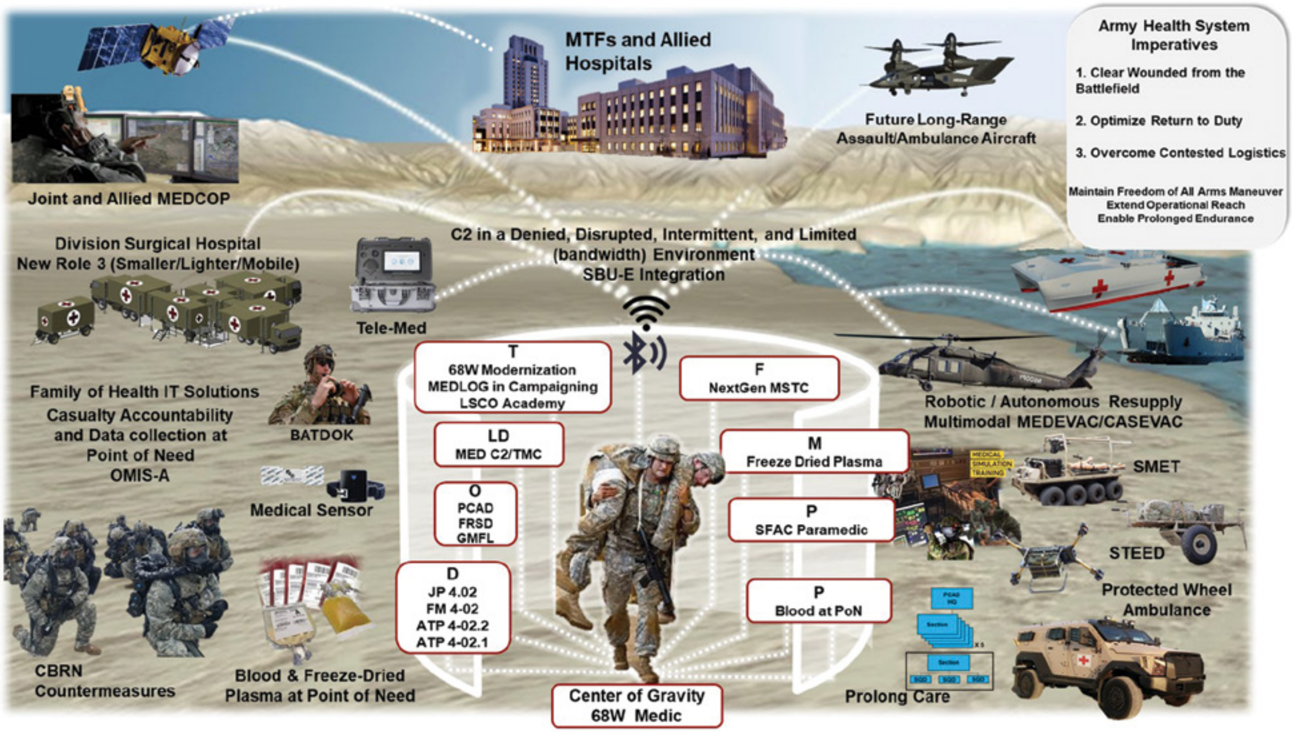
The U.S. military's ability to regain and maintain information and decision advantage relies on the Combined Joint All-Domain Command and Control (CJADC2) concept. CJADC2 provides a coherent approach for shaping joint force C2 and producing the warfighting capability to sense, make sense, and act at all levels and phases of war, across all domains, and with partners and allies to deliver the information advantage at the speed of relevance while acting inside an adversary's decision cycle.[11]

Sense is the ability to discover, collect, correlate, aggregate, process, and exploit data from all domains and sources—friendly, adversary, and neutral—and then share the information to support decision-making. Sensemaking refers to analyzing data to understand better and predict the operational environment, the actions and intentions of an adversary, and the actions of our friendly forces. Sensemaking data transforms into information, which transforms into knowledge that enhances the decisions of the joint force and partners.[12] When human assessment is combined with the technical means to perceive and understand, leaders are better able to take action against adversaries.

The intersection of AI and AHS can potentially revolutionize how military medical professionals operate on the battlefield.[13] With advancements in AI technology, health-care systems hold the potential to become more efficient, accurate, and responsive, saving lives and improving the overall outcomes for wounded soldiers. AI supports the AHS to meet the future challenges by improving surveillance, rapidly treating patients, moving wounded more efficiently, and enabling accurate resupply.

Maximize Return to Duty

Early, precise intervention maximizes a warrior's ability to functionally return to duty and increases survivability on and off the battlefield. Health-care technology constantly evolves: systems are more accurate, less expensive, faster, smaller, and can reach further than humans alone. Health care leverages data to support clinical decision-making acutely, routinely, and emergently; incorporating AI will add limitless value. Like most health systems, the AHS are trained professionals whose mission requires aggregating data quickly, often under immense pressure, to treat and save people and animals—our military warriors. These overarching functions rely on humans to capture, consolidate, interpret, analyze, and utilize data to inform care. The cornerstone of military health care remains its people, the most complex and expensive assets in the military organizations, however, given constrained resources and feasible data saturation expected in the future fight, AI will enhance manpower with machine power. AI across AHS will function as a health-care multiplier, enhancing cost-efficiency, bridging personnel shortages, expanding limited medical capabilities, reducing error, optimizing workflows, improving data processing and analysis, and facilitating precision medicine. AI has the clinical and operational potential to transform AHS health care across surveillance and delivery



BATDOK—Battlefield assisted trauma distributed observation kit
C2—Command and control
CBRN—Chemical, biological, radiological, and nuclear
CASEVAC—Casualty evacuation
FRSD—Forward resuscitative surgical detachment
GMFL—Global medical field laboratory
LSCO—Large-scale combat operations
MEDCOP—Medical common operating picture
MEDEVAC—Medical evacuation
MEDLOG—Medical logistics
MSTC—Medical Simulation Training Center
MTF—Medical treatment facility
NextGen—Next generation
OMIS-A—Operational medical and information system
PCAD—Prolonged care augmentation detachment
SBU-E—Sensitive but unclassified-encrypted
SFAC—Security Force Assistance Command

(Figure by authors)

Medical Capability Development Integration Directorate Concept to Support Army of 2030/2040

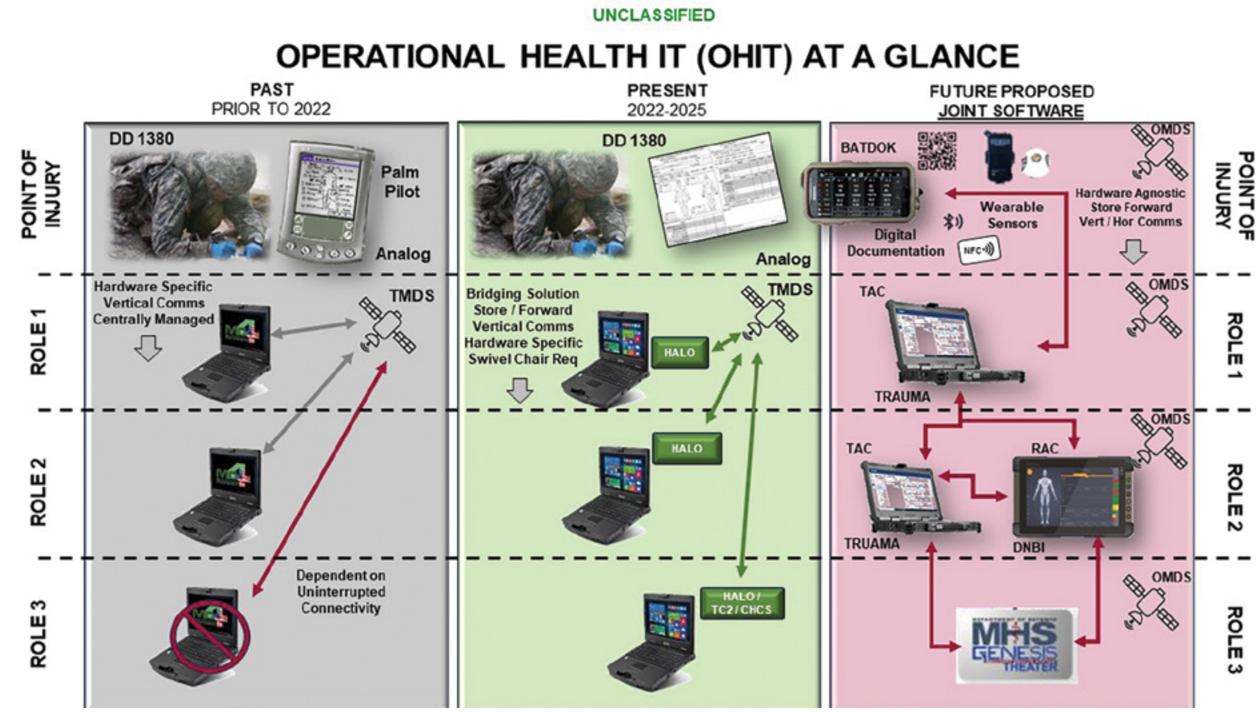
areas. AI will enhance productivity and efficacy of care across FHP at home and through HSS abroad while in the fight.

Force Health Protection: Surveillance

AI will enhance FHP through retrospective and prospective health surveillance and disease prevention programming. By analyzing data, AI informs medical planning and identifies potential health risks to populations and individuals.

AI applications range from predictive analytics to data consolidation to prediction of disease progression for those at high risk and prevention measure recommendations. These predictions will allow clinical and nonclinical leaders to intervene early and potentially reduce progression or prevent adverse outcomes altogether.

AI can also look at biometric data aggregation to inform disease processes, drug administration reactions, and the need to perform interventions or diagnostics early. One element that will increase data to provide treatment rests within wearable biometric sensor technology, like an individually worn wrist or ring monitor. This live-data source will give providers real-time and cumulative information and education to patients on how best to conduct their health,



BATDOK—Battlefield assisted trauma distributed observation kit

CS—Composite health care system

DNBI—Disease nonbattle injury

HALO—Health assessment lite operation

OMDS—Operational medicine data store

RAC—Routine ambulatory care

TC2—Tactical command and control

TAC—Trauma acute care

TMDS—Theater medical data store

(Figure by authors)

Operational Health Information Technology at a Glance

rehabilitation, and in battle inform treatment. More robustly, this wearable data source input within the military will provide physical and occupational therapists, nutritionists, behavioral health specialists, primary care providers, and emergency providers information to improve their treatment plans and help guide optimal interventions and therapies while automatically populating the patient's longitudinal health record.

Real-time medical surveillance with trends will accompany actionable recommendations for leaders by echelon. Clusters of abnormal vital signs may signal a man-made or natural environmental exposure and will alert appropriate leaders with suggested causes and related recommendations. These records, informed by aggregate data from all countries and all sources, including national ministries of health, the World Health Organization, and nongovernmental organizations, can provide a more comprehensive health intelligence preparation for the battlefield.

Clinical data from medical sensors will enable medical leaders across the battlespace to access clinical data and assess the performance of their respective organizations. AI will enable clinical data interpretation, identify patterns linked with outcomes, develop predictive analytics, and propose solutions to clinical and nonclinical leaders.

In military medical care, to include capabilities outside a hospital such as veterinary and dentistry capabilities, generating an AHS provider necessitates initial schooling, which is an intensive, manpower-heavy task, but AI can help ease this burden. Instead of individual public health and preventative screening exams such as monthly examinations conducted by AHS providers, screenings performed by nonmedical technicians assisted by AI could provide a cost-effective health risk assessment. Screenings are a public health activity that cannot give the individual patient a diagnosis for intervention but provides a risk assessment for how likely the person is to have a particular disease. A population-level oral disease surveillance system could enhance the screening process by eliminating human screening decision-making for tens of thousands of soldiers annually. Leveraging AI to inform this and other systems like it can expand the reach of a single trained dentist or provider across the AHS. Additionally, AI will utilize patient data to identify a soldier's risk factors throughout their career and additional health factors are added to the calculation. When a soldier is prepared for deployment, AI-enhanced risk assessment will again become helpful in identifying those most at risk of disease and referring them to a treatment facility for diagnosis and treatment. Within the behavioral health footprint alone, AI has the potential to identify those at risk early and often.

AI enhances FHP through retrospective and prospective health surveillance and disease prevention programming. AI in FHP informs medical planning.

Health Service Support: Treatment

Like nonmilitary health care and advances in medical uses for AI employment, AHS can leverage AI to improve treatment and hospital management. AI, deep learning, natural language processing, and ML capabilities have proven efficacy in nonoperational health-care settings through improved diagnostic accuracy, treatment plans, risk factor assessment, health communication, and health-care administration.[14] AI algorithms quickly identify trends, patterns, and insights. This is applicable at the point of injury, at the bedside, and for C2 oversights to inform survivability and future AHS improvements. The AHS and military medicine can benefit significantly from tailoring these analysis tools to operational medicine mission sets.

Fully expanding and incorporating the current levels of AI infrastructure available within health care will directly apply to treatment and care at war. Current integrated efforts include using ML algorithms for medical diagnostics, predictive modeling, and personalized treatment plans digesting inputs into electronic health records. Employing these tools and others will facilitate expanded clinical decision support systems, more widely incorporate evidence-based care, and rapidly narrow differential diagnoses while providing precision treatment plans at scale. Challenges of the future operational environment of warfare require the provision of prolonged care in a limited resource environment and incorporate evolving objective mass casualty plans. AI as a tool will empower AHS providers at any level of care to tailor care rapidly and adaptively to disease diagnostics and patient management and immediately advise within the triage process. For providers from combat medic to neurosurgeon, AI has the potential to synchronize and standardize care plans and systematically inform the most significant survivability potential with limited resources.

Today, the adoption of AI into military medicine is slow yet present, but incorporating AI in AHS will maximize return to duty and save lives, while also informing future clinical practice recommendations AI enables health-care teams at all levels to work at the top of their scope, saving lives by mitigating the austerity of future battlefields.

Clear the Battlefield

The unencumbering of maneuver forces relies significantly upon the ability to clear the battlefield and regulate patient flow throughout the AHS. AI will play an integral role in increasing the accuracy and efficiency of processing patient movement requests (PMR) . AI can drastically shift the movement of AHS patients, from initiating patient care enroute through providing definitive care.

When initiating a PMR or "9-Line," data input technologies such as a biometric wearable will transmit data into the Army data fabric. This early notification of PMR allows health-care teams to better prepare for patient needs, and data can be shared in near-real time through near-field communication devices or low-orbit satellites such as drones and balloons to ensure a common operating picture is available for decision-making. As the medic is alerted of a potential casualty, AI automatically completes triage and populates the PMR, allowing the medic to focus on patient care versus processing or dispatching administrative data. The AI algorithms consolidate and summarize injury patterns, survivability triage, transport times, medical supply accessibility, and available hospital bed spaces to inform the best evacuation movement decisions. This information will help the medic determine the appropriate care

A Sikorsky UH-60A Black Hawk flies over Fort Campbell, Kentucky, on 5 February 2022 during its first unmanned flight as part of the Defense Advanced Research Projects Agency's Aircrew Labor In-Cockpit Automation System program. (Photo courtesy of DARPA)

provision at the point of injury as well as the best patient packaging for transport. This is further supported by AI intelligently tasking a transport platform to the PMR and alerting all roles of care.

AI integration into evacuation platforms can take many forms. Fully autonomous vehicles can operate without requiring oversight from a human-in-the-loop. Semiautonomous platforms can reduce the number of drivers or pilots required for the platform by reducing the workload for the crew. Incorporating human machine teaming will unload the physical burden required of our medical forces.

Overcome Contested Logistics

Quality health care, no matter the environment, requires medical supplies (Class VIII). The issue of contested logistics encompasses the dichotomy of an obstructed supply chain with an inability to gain dominance in one or more domains on the battlefield. For medical logistics, there is a requirement to move blood rapidly and Class VIII across vast distances with a high probability that the equipment will not be flown due to a contested air domain thus increasing the delivery time between resupplies. Delivering health care in multidomain operations is further complicated by weather, road conditions, and water crossings, increasing the lag time. In this unforgiving battlefield landscape, integrating AI into the delivery of Class VIII becomes a key driver of innovation and efficiency. It is imperative to explore how AI and ML can revolutionize supply chain management in austere environments and reshape traditional processes that must be replicated in such conditions.[15]

To overcome contested logistics, AHS will require a robust and integrated medical C2 system that leverages data inputs from biometric wearable sensors, electronic health record systems, and sustainment systems to turn reactive logistics into predictive logistics when coupled with ML and AI.

AI has redefined how the civilian sector predicts and demands plans for decades. Like in health-care treatment, AI has enhanced supply chain management in non-war environments for years. AI algorithms provide significantly more precise demand forecasts by examining external factors, market trends, and historical data.[16] ML models, such as those used in shipping container yards, constantly learn and adapt to improve predictive logistics.[17] Incorporating AI and ML will help reduce excess inventory while enhancing overall supply chain output.

AI facilitates precise and effective inventory management for sustainers at the echelon. Through real-time data analysis and predictive analytics, AI can enable C2 and precision sustainment to optimize inventory levels, reduce processing times and costs, improve just-in-time distribution, and save lives. Planners will have the tools to detect patterns and variances, providing timely information for commanders to aid in proactive decision-making.[18] Units on the ground will limit the need to pull when it comes to resupply when AI will consolidate data and push anticipated needs easier.

ML, a branch of AI, can be leveraged to redefine forecasting and demand planning due to its ability to analyze enormous amounts of data in real-time. This will result in extraordinary accuracy, enabling sustainment organizations to adapt quickly at all levels.

ML can be crucial in autonomous decision-making in a contested environment where supply chains become increasingly complex. Algorithms will sift through intricate datasets and provide an operating picture that will guide strategic decisions, improving risk management and flexibility.[19] Leaders will possess the tools to identify potential risks and implement preemptive measures that strengthen supply chains against unforeseen threats.

Optimizing logistics challenges using AI, AHS, and the military can maximize the return to duty rate, increase survivability, and ultimately save warriors' lives on the battlefield.

Barriers to Artificial Intelligence in the Army Health System

Though the potential benefits of AI in supporting the AHS in LSCO are straightforward, several challenges remain. Communications are expected to be denied, degraded, intermittent, and of limited bandwidth; maneuver force data often retains bandwidth priority over health data transmission. Operational medicine generates significant amounts of data, but current AI systems may still need to be adequately capable of prioritizing high volumes and velocities of such health data. Similarly, AI and related applications crucially rely on large amounts of "training data" to discern patterns and relationships. Modern health-care data based on casualty flow, injury patterns, and health resources in LSCO and MDO do not yet exist to inform this pattern learning.[20] As a modern technology, AI tools and systems are not yet routinely available in all military medical training or clinical settings. The need for AI understanding in medical care and education is evident. However, military health-care teams will also require realistic training, updated instruction plans, and deliberate, sustained exposure to be ready to adopt AI processes and systems across all operational medicine functional areas.[21]

Electronic health-care data also requires additional safety and security protocols to ensure data security, as the HIPAA Security Rule describes, currently limiting the open transfer of health data across interoperable battle management command and control information systems.[22] Medical data generated in operational settings will be compiled within a service member's longitudinal service health record. While AI supports tools that improve operational health-care practice, evacuation, logistics, and return to duty, AI does not surmount the need for health data to be secure, private, unbiased, authentic, and accurate, together with being fed high-quality, reliable data.[23] Protection of operational health data is even more important than in garrison, as operational data may create risk by revealing troop locations, combat effectiveness, and even the identities of clandestine or high-value personnel.

Additional barriers to AI implementation in the AHS mirror the challenges of AI use in the civilian sector. AI relies on high-volume data storage systems that are accessible, secure, and extremely expensive.[24] In addition to the need for data stewardship and governance, AI in the AHS must comply with additional military-specific regulations while remaining valuable and relevant to operational needs.[25] Further, the development of AI tools and processes must still be well-integrated into Army operations as well as in austere health-care settings during conflict. Teams and professionals, such as graduates of the Army Software Factory, and the development of corps-level chief data officers promote the Army's data-centric culture.[26] Though the recognition of the need for technical specialists is present, this remains in nascent stages within AHS and without robust, dedicated technology teams to iteratively develop, deploy, and maintain such dynamic tools. While the benefits of AI are apparent in the provision of care, using such systems to support military medicine broadly requires significant investment in a larger military medical data strategy.

Ethics of Using Artificial Intelligence

Firms within the defense industrial base tend to coordinate with the U.S. government customers' legal and policy compliance experts to help ensure that AI systems comply. The defense industry's AI systems comply with effective utilization of traceable and reliable systems and continue to produce equitable, unbiased results throughout their mission life.

ML systems train on collected datasets that include bias and may exhibit these biases upon creating algorithmic bias. Human language is known as biased; machines trained on the human language are highly likely to be personal, which can lead to prejudices. Bias and prejudices are preventable using policies and datasets that do not contain discriminatory language. Despite uncertainties and unknowns in developing AI systems. the U.S. government has a work-in-progress to establish policies to determine if an AI model is sufficiently safe, secure, and ethical for Department of Defense use.[27]

Trusting the data allows warfighters to exercise their informed decision-making space to act and defeat adversaries during the mission. However, AI/ML algorithms will not fully compensate for gaps in physical understanding. While AI offers numerous benefits, there are ethical considerations to address. Questions arise regarding the moral implications of using AI in health care and the potential impact on human elements such as empathy and compassion. AI is a way to augment, rather than replace, the compassionate and dedicated provision of military operational health care.[28]

The consideration of using AI in the delivery of health care and health-care decision-making should require a policy update within the joint force. Army Medical Concepts for the Future articulates the necessity of incorporating automation into health care to ensure we do the greatest good for the greatest number of patients. The moral argument remains regarding how "involved" AI and humans remain in decision-making. On one hand, there is an ethical obligation to leverage emerging technologies to create the highest level of care for our soldiers.[29] Suppose emerging AI technologies provide greater good than harm, and the principle of immediacy deems algorithmic care triage and autonomous evacuation as a justified means in LSCO. In that case, one can argue that it is ethical so long that humans remain in the loop.[30]

Conclusion

Artificial intelligence, machine learning, and human-machine integration can provide information dominance on the battlefield and enable warfighters to make informed decisions at the speed of relevance while projecting power. AI facilitates a common operating picture across the battlefield; AI and ML are critical catalysts for fusing data. AI/ML significantly improve decision-making and the kill-chain timeline. Human machine teaming allows humans and machines to train together, ensuring the warfighter's trust in the machine. AI and human machine teaming reduce the warfighter's cognitive load, directly optimizing an informed decision-making process while enabling joint force overmatch.

The intersection of AI and AHS can revolutionize military medical support on the battlefield. AI holds immense potential for enhancing military operations and ensuring the well-being of every soldier. AI technologies such as algorithmic care, medical surveillance, evacuation, and predictive analytics can transform how medical support is provided to the frontlines. By deploying AI systems, the AHS can significantly improve the speed and accuracy of diagnostics, treatment, and decision-making processes. AI algorithms quickly analyze vast amounts of medical data, extending care and evacuation reach, reducing human error, mitigating the risks associated with high-stress combat environments, and enabling health-care professionals to improve outcomes for wounded soldiers and save lives.

AI can enhance the efficiency of logistics and supply chains in the AHS. By leveraging predictive analytics, AI algorithms can anticipate medical supply needs, optimize inventory management, and streamline the delivery of critical resources across the battlefield. This proactive approach ensures medical personnel have access to the necessary equipment and medications, enabling them to provide adequate and timely care to wounded soldiers.

AI continues to evolve, making it crucial to address the ethical implications and potential risks associated with its use on the battlefield. Safeguards and professional technical oversight must be implemented to ensure that AI systems are developed and used responsibly. Transparency, accountability, and a robust governance framework are essential in maintaining the ethical integrity of an AI-enabled AHS. By harnessing the immense power of AI technologies, the AHS has the potential to completely transform military medical support, leading to the preservation of countless lives and playing a critical role in achieving victory in future conflicts. ■

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