AI on the Front Lines: A Primer for the Military Health Professional

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ABSTRACT

Background:
Artificial Intelligence (AI) has become a key component of the U.S. Army Medical Modernization Strategy, which seeks to enhance military health care through innovative technologies. Within the Military Health System (MHS), AI applications in diagnostics, patient monitoring, logistical support, and trauma management are under active exploration.

Applications:
Key initiatives include AI-driven telementoring, decision support tools, automated trauma documentation, and remote patient monitoring. These technologies aim to improve care delivery and operational efficiency in combat zones, particularly during mass casualty incidents and in resource-limited environments.

Challenges:
Implementation faces significant obstacles, including the need for robust data collection methods, secure and interoperable storage solutions, and frameworks to address ethical and trust issues. Decentralized storage technologies, such as blockchain, and explainable AI systems are proposed to enhance reliability and transparency.

Strategic Considerations:
Advancements by near-peer adversaries, such as China and Russia, in AI-driven military health care underscore the urgency for the United States to accelerate its integration efforts. The U.S. Army Medical Modernization Strategy emphasizes interagency collaboration and targeted research as critical components for maintaining a strategic edge.

Conclusion:
Artificial Intelligence–driven automation offers a transformative pathway for military trauma care, enabling enhanced efficiency and resilience. Addressing implementation barriers and aligning efforts with the U.S. Army Medical Modernization Strategy are essential to ensure operational superiority and improved survival outcomes on the battlefield.

Synthetic Case Example. A soldier stumbles, feeling the searing pain of a bullet tearing through his leg. His pulse races, pounding against his chest as he scrambles for cover. Yet he is not alone in monitoring his condition—an AI-integrated wearable sensor has already detected his rising heart rate and blood pressure, transmitting the alert instantly to the nearest medic. The medic, stationed just hundreds of feet away, receives a series of alerts: the soldier's tachycardia, his precise GPS location, and real-time guidance on approaching the casualty site. As he moves, the soldier's battle buddy follows automated instructions through his own display, calmly stabilizing his friend's condition by applying direct pressure and preparing for shock management. Moments later, another alert comes through: 8 more casualties have been reported across the field. But the medic remains unfazed, focused, and prepared. With AI-enhanced sensors monitoring the vital signs of every soldier on the battlefield, he has real-time support for diagnostics and immediate access to resources previously unimaginable. Dirt and shrapnel kick up around him as he continues to check his tablet. The display shows that reinforcements and supplies are en route, estimated to arrive within minutes. Long gone are the days of anxiously hoping for the right equipment to be on hand. Now, a fully automated logistics system tracks real-time inventory across the network, sending resupply notifications and dispatching Class VIII essentials before stocks even dip. As he navigates the chaos, an AI-generated triage list organizes each casualty by urgency and location, directing him to his next assigned patient. Within seconds, he reaches the soldier with the leg wound. His focus sharpens; the surrounding noise, smoke, and debris fade as he begins stabilizing the injury. The systems do their job, giving him the calm and clarity to do his: saving lives. In the midst of the battlefield's unpredictability, there is a remarkable sense of control. The medic is equipped, informed, and prepared. Artificial Intelligence has transformed the way he fights to protect his team, ensuring that amidst the upheaval, there is a structure—one that lets him focus on what matters most. This,

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and much more, could be the future of military medicine with the complete integration of AI.

INTRODUCTION

Advances in technology have profoundly influenced medical practice over the past several decades, with military health care professionals similarly experiencing significant changes to practice even in austere environments. Artificial Intelligence (AI) seems on pace to continue this evolution, offering the potential to enhance diagnostics, patient monitoring, logistics, and trauma care in austere settings.[1] However, AI and the underpinning technology likely fall outside of the academic backgrounds of many military health professionals. As such, the potential for AI implementation may be lost on some practitioners.

Artificial Intelligence–based technologies could address critical challenges in military health care. For example, wearable sensors integrated with AI could monitor soldier vital signs in real time, transmitting alerts for abnormalities such as tachycardia or hypotension.[2] Automated logistics systems could track inventory and dispatch supplies before shortages occur, while AI-driven triage tools could assist medics in prioritizing casualties based on injury severity and proximity.[3] These tools collectively aim to improve efficiency, reduce the cognitive burden on clinicians, and enable timely, data-driven decisions in combat zones.

Despite its promise, the implementation of AI in military health care requires a thorough understanding of its capabilities, limitations, and associated challenges. Issues such as data reliability, computational requirements, and ethical considerations must be addressed to ensure the safe and effective deployment of these technologies.[4,5] Familiarizing military health professionals with AI's potential applications and limitations seems critical for successful integration into practice. By examining these aspects, this work aims to provide military health care providers with a comprehensive understanding of AI and its role in advancing the future of combat casualty care.

BACKGROUND

Artificial Intelligence has become a central feature of modern technology, transitioning from a specialized scientific concept to a fundamental part of various industries, including health care, finance, and transportation. Despite its widespread adoption, there remains a significant gap in understanding and acceptance of AI, even among military health providers.[6] The term "artificial intelligence" itself has been subject to evolving interpretations, reflecting the rapid advancements and diverse applications of the technology. For the purposes of this review, we adopt the definition provided by Gil de Zuniga et al., which describes AI as "the tangible real-world capability of non-human machines or artificial entities to perform, task solve, communicate, interact, and act logically as it occurs with biological humans."[7] This definition captures both the technical capabilities and the real-world applications of AI, demonstrating its potential to address complex challenges across multiple domains. The broadness of this definition, however, also highlights the variety of ways that AI may be applied to military health care. Its application is not limited to diagnostics or logistics but rather represents a style of computation and problem-solving that can change nearly any aspect of medicine. Although AI holds the promise to revolutionize

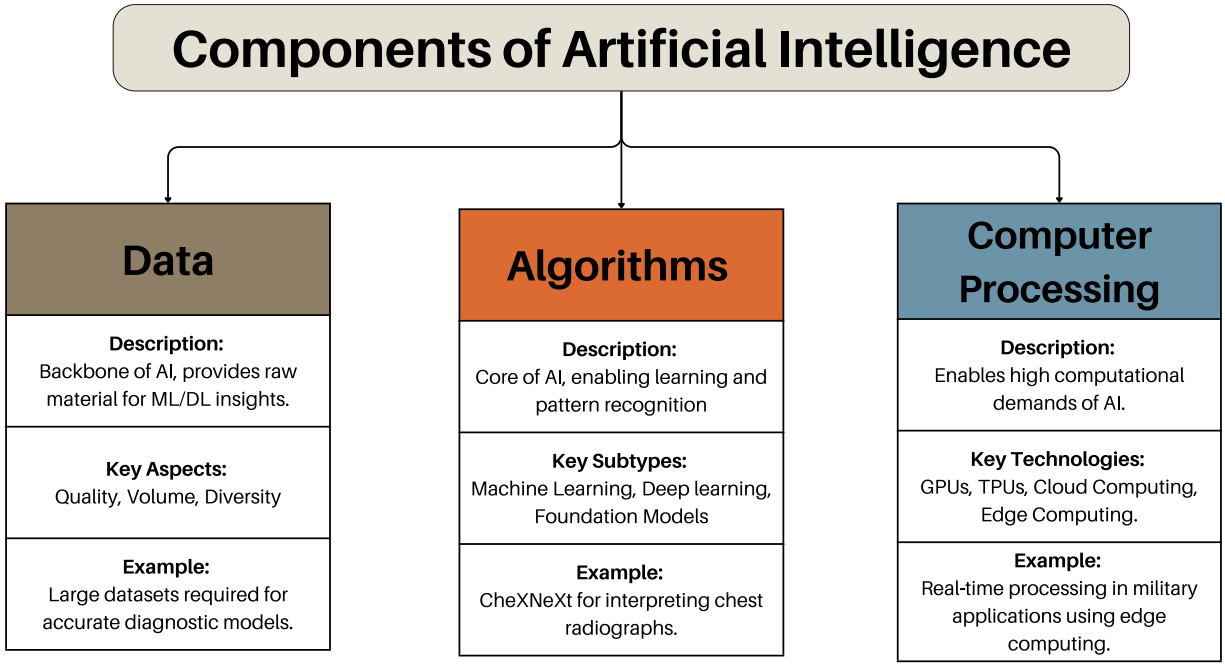


Figure 1. This figure highlights the 3 main components of AI: Data, Algorithms, and Computer Processing.

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many aspects of military medicine, understanding its core components – as outlined in Figure 1 –allows the military health professional to identify conditions necessary to apply and utilize the technology.

Data

Data are the backbone of any AI system, providing the raw material from which the algorithms derive their insights. The quality, volume, and diversity of data are critical factors that determine the accuracy and reliability of AI models. For instance, models designed to diagnose abnormalities in chest X-rays require large datasets—often consisting of thousands of images—to achieve reliable diagnostic performance.[8] More complex systems, such as those used for early sepsis detection or logistical predictions in military contexts, demand even larger datasets to capture the nuances of these tasks.[9,10] The need for accurate and descriptive data is further emphasized by the challenges of bias in data-driven systems. As noted by Ntoutsi et al., biases inherent in the data can lead to skewed outcomes if not properly addressed, making it essential to ensure the most accurate, unbiased information during the data collection process.[4]

The accuracy—and therefore the usefulness—of any AI system depends heavily on the quality of its input data. This is especially important when considering AI applications within the military health care system which operates from austere combat deployments to large, state-side tertiary care hospitals. Even in deployed environments, conditions can vary significantly based on factors like deployment location, phase of the operational cycle, and the nature of enemy encounters. For instance, the anticipated use of medical supplies may vary greatly between different field hospitals based on their proximity to combat operations, time of year, and current enemy activity. These complexities add layers to the already intricate relationships within health care datasets and therefore require more extensive and diverse data.

ALGORITHMS

Algorithms are at the core of AI, enabling machines to learn from data, identify patterns, and make predictions. These mathematical models have evolved significantly, from simple rule-based systems to complex neural networks that can process large datasets and perform intricate tasks.[11] Machine learning, a subset of AI, focuses on creating systems that can improve their performance as they are exposed to more data, which are advantageous for tasks requiring constant adaptation, such as language processing and image recognition.[10,11] Deep learning, a more advanced form of machine learning, uses layered neural networks to handle the vast amount of data and detect intricate patterns.[11] The development of open-source libraries and frameworks has further accelerated the growth of AI by providing access to these algorithms and tools that facilitate experimentation and innovation across various sectors.[12]

However, open-source tools come with a necessary caution: malicious code may be engrained into the content and difficult to detect.[13] With appropriate caution, AI is becoming more accessible with current research focusing on the needs of the opensource AI Community.[14] Several open-source tools are available, as described by Yang et al. and included in Table1.

Foundation models, a rapidly expanding component of AI, have also significantly eased the development process by reducing the need for entirely new algorithms with each application. These models, a subfield of deep learning, emphasize wide adaptability, enabling a single model to be repurposed across numerous tasks once trained.[15] Unlike earlier AI systems which often required task-specific designs, foundational models operate on vast datasets, typically using self-supervision to learn patterns and structures that generalize beyond their training context.[15] This capability allows them to perform a broad array of functions, including tasks they were not explicitly trained for. Foundational models underpin many of the recent advancements in AI, such as natural language processing and large language models like ChatGPT.

COMPUTER PROCESSING

Specialized algorithms, however, cannot function without adequate computational resources. Recent advancements in computing power have been pivotal in the development and application of AI technologies. Deep learning models require immense computational resources to process large datasets and perform complex calculations.[5] Historically, these demands limited the scope of AI applications, but the rise of high-performance computing (HPC) infrastructures, including GPUs (Graphics Processing Units) and TPUs (Tensor Processing Units), has made it possible to train and deploy sophisticated models efficiently. Moreover, cloud computing has democratized access to these resources, allowing smaller organizations and individual developers to harness the power

Table 1. Heading: Popular Open-Source Code Resources.

Product	Description
GitHub	Popular platform for hosting AI-related open-source code, facilitating collaboration, and issue tracking.
TensorFlow	Open-source framework widely used for machine learning and deep learning tasks, including neural network training.
PyTorch	Popular open-source deep learning framework
Hugging Face	Open-source platform providing pre-trained models, datasets, and tools.
Kaggle	Platform offering AI/ML datasets, competitions, and coding notebooks for collaboration and model evaluation.

This table shows several of the most popular open-source code resources. Caution should be used when accessing open-source material because of the possibility of malicious code.

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of AI without the need for extensive on-premises infrastructure.[16] This shift has enabled the integration of AI into everyday tools and services, increasing the technology's visibility and applicability.

Although cloud computing has been essential for managing data-intensive tasks, it may not be the sole solution to meet future AI application demands. Edge computing, an alternative approach, focuses on bringing computation closer to the end user, reducing reliance on central cloud resources.[17] This distributed model lowers response times, enables quicker results, and reduces the overall burden on cloud infrastructure. The benefits are particularly relevant for military applications, where personnel operate in widely dispersed environments and often require real-time processing on location. Edge computing allows data to be processed on devices at the network's edge, which is advantageous for latency-sensitive applications and those in bandwidth-constrained or high-security settings, such as those often encountered in military operations. This shift supports AI-driven decision-making in complex and varied environments, enhancing operational capabilities nearer the point of injury, where they are needed most.

FUTURE AI IMPLEMENTATION IN THE MHS

With AI revolutionizing so many various industries worldwide, integrating AI is a strategic imperative to maintain and improve patient care for the military health care system. The U.S. Army Medical Modernization Strategy (2022) emphasizes the critical role of AI in future medical operations, highlighting the need for innovation to improve patient outcomes and streamline processes.[1] LTG Richardson envisions that the Army Health System (AHS) will fundamentally transform into a semi-autonomous, integrated, networked capability that enables multi-domain operations (MDO). By embracing AI technologies, the MHS can enhance its capabilities in medical diagnostics, patient monitoring, and operational logistics, thereby maintaining a technological edge in military medicine.[1] Several areas of integration appear at the forefront of integration.

Telemedicine

Advances in technology now enable surgeons to extend their expertise directly to the point of injury through telementoring.[18] This capability allows novice practitioners to perform life-saving procedures under real-time guidance from experts remotely.[19,20] However, telementoring and telemedicine are highly dependent on reliable networks—often unavailable in austere or network-denied environments. Artificial Intelligence and computer vision could help bridge this gap, delivering critical expertise even when traditional communication networks are inaccessible. Current studies are using procedural videos to train large language models, teaching them to predict the next steps in procedures like chest tube insertion.[21] This development could turn telementoring into a spectrum based on connectivity: when a network is available, an expert can guide novice practitioners through complex procedures; in network-denied settings, an AI system can provide real-time instruction and support. This hybrid approach strengthens the flexibility and resilience of medical care at the point of injury, ensuring that expert guidance is available regardless of network connectivity situations that future military providers may face.

Decision Support Tools

Decision Support Tools (DSTs) assist health care providers by organizing clinical information, aiding in triage, and offering patient-specific recommendations.[22] For the MHS, DSTs are especially critical during mass casualty incidents (MCIs) from battlefield engagements, terrorism, or natural disasters. MCIs overwhelm medical resources, creating intense cognitive demands for providers.[23] Artificial Intelligence–powered DSTs help by analyzing data from wearable sensors, battlefield medical devices, and military health records to rapidly assess wounded service members. These tools can evaluate vital signs, detect injury patterns, and prioritize patients needing immediate intervention, significantly reducing cognitive strain and allowing providers to focus on lifesaving care.[24] The implementation of AI in DSTs could improve triage efficiency, ensuring critical interventions reach the most severely injured and optimizing limited medical resources.

Automated Documentation

Medics and first responders performing Tactical Combat Casualty Care (TCCC) are soldiers, balancing their own safety and mission objectives with the need to provide care. They are often required to document every detail of a patient's condition and treatment on the DD Form 1380, a paper form of combat casualty care medical records, even amid chaotic conditions.[25] These high-stress environments can complicate accurate and timely record-keeping. Documentation is essential to continuity of care, but studies show the accuracy of pre-hospital documentation on the DD Form 1380 drops to 85% even in low distraction simulated settings.[26] Artificial Intelligence can alleviate this burden by automating pre-hospital trauma documentation using large language models and natural language processing. These technologies capture data from verbal commands, gestures, or sensors to complete the documentation in real-time, ensuring more accurate record-keeping and freeing medics to focus on care.[27] Automation ensures essential information on injuries, treatments, and patient response is captured and transferred along the care continuum.[28]

Remote Patient Monitoring and Treatment

Artificial Intelligence is poised to transform combat casualty care through the Internet of Medical Things (IoMT), a network of interconnected medical devices and sensors designed for real-time, responsive health care delivery.[29] In combat settings, IoMT could include wearable sensors on soldiers that continuously monitor vital signs, smart devices to track

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medical supplies, and autonomous equipment like ventilators and IV pumps that can adjust to a patient's needs.[2] The constant data flow from IoMT to centralized systems enables AI to process the data and provide instant, actionable insights. For instance, AI could forecast which supplies or interventions will be required based on casualty trends. This foresight allows proactive decision-making, enhancing overall readiness. In austere conditions, AI-powered IoMT systems could possibly assist by automating critical care elements. By reducing hands-on intervention time, IoMT potentially serves as a future force multiplier, enabling fewer medics to effectively care for more soldiers.[2]

CHALLENGES TO AI IMPLEMENTATION IN THE MHS

Data Collection, Storage, and Processing

Artificial Intelligence systems rely on vast quantities of accurate, real-time data, which requires large-scale infrastructure to store. For AI to automate critical processes such as casualty triage, resource allocation, and decision support, there must be a fundamental shift in how data are collected, managed, and used across the continuum of care. To support AI systems effectively, the MHS must transition to passive data collection.[28] This involves utilizing wearable devices, sensors, cameras, and other unobtrusive monitoring technologies that continuously collect data without human intervention. These systems can capture crucial details like vital signs, injury patterns, caregiver interventions, and environmental context.[28] The concept of digital twins—virtual models that simulate a casualty's physical journey through various levels of care—exemplifies the potential of passive data collection in combat casualty care.[30] By feeding real-time data into these digital twins, AI can simulate different care scenarios, predict resource requirements, and optimize treatment plans for each individual casualty.

Once provided with high-quality data, infrastructure, and storage become essential for AI. Sensors and monitoring devices need to be deployed across all care levels, from the point of injury to higher echelons of medical support. Integrating data from wearable devices, medical equipment, and battlefield systems into a unified platform where it can be processed for real-time AI-driven decision-making is essential. Infrastructure investments will be crucial; the MHS must develop systems to capture, store, and process the extensive data needed for AI adoption. This includes hardware such as sensors and cloud storage, as well as network capabilities that can transmit data securely and efficiently, even in network-denied environments.[2]

Despite a wide array of sensors, current datasets may still fall short. The past 2 decades of conflict have generated data that may not align with the realities of a conflict involving a peer or near-peer adversary.[31] Modeling the effects of large-scale combat with such opponents is inherently challenging without a robust dataset. Medical operations in the face of adversaries with conventional weapon systems require new data to simulate potential scenarios where AI could be employed effectively. Without datasets that capture the impact of near-peer, conventional combat on military health care, any related AI platforms would likely lack the reliability and adaptability needed for meaningful application. Although data collected from the early stages of a large-scale conflict could eventually help train AI models, relying on this approach alone risks leaving military health care unprepared and missing critical opportunities for AI integration.

One potential solution, or at least a bridge to real-world data for large-scale combat operations, is through large military training exercises. These exercises, along with computer-generated simulations, offer insights into potential future datasets.[32,33] However, these solutions come with their own challenges. Training scenarios are constructed based on planners' expectations, while mass casualty models rely on existing data or expert inputs—neither of which may fully capture the evolving landscape of a future battlefield. As a result, simulated data should be viewed as a provisional resource that warrants careful evaluation for reliability and authenticity. Ideally, such data should be ready to be phased out as more accurate, real-world data become available.

Challenges also arise in storing and managing these vast amounts of data. Large-scale data storage demands robust infrastructure to securely handle sensitive information, especially in health care, where data may be targeted by adversaries. Advanced security frameworks like blockchain offer solutions for secure, decentralized storage, protecting against breaches and ensuring data integrity.[34] Blockchain's decentralized architecture enhances data security and transparency by preventing any single entity from controlling the data, reducing risks of unauthorized access, or tampering. This approach builds trust in the system through transparent, logged transactions.[34,35] Federated learning models further address privacy concerns by allowing collaborative AI training without raw data sharing, keeping data decentralized, minimizing breach risks, and supporting effective AI training.[35]

Trust, Ethics, and Oversight

Beyond technical barriers, there are significant challenges related to trust, oversight, and ethical considerations in implementing AI within the military health care system. Acceptance of AI in daily medical practice remains uncertain, as practicing physicians need to understand and trust that AI algorithms will provide safe, reliable outputs before fully integrating them into clinical workflows.[6] Building this trust requires transparency and explainability in AI systems, where health care providers can understand how an algorithm reaches a decision. The concept of explainable AI (XAI) emphasizes this need, highlighting that physicians must be able to interpret and verify AI outputs, especially in life-critical scenarios.[36]

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There are also ethical concerns about the collection and use of patient data within medical systems.[36] Issues such as autonomy, privacy, and the delegation of critical decision-making to non-human machines must be carefully considered. Ethical frameworks and regulations need to be developed to address concerns, such as data consent and the implications of allowing AI systems to make clinical decisions.[37] However, developing a comprehensive oversight framework that addresses all aspects of AI ethics and trust may take time.

UNITED STATES, PEER, AND ADVERSARY AI EFFORTS

AI developments within military medicine are not limited to the United States: near-peer competitors, such as China and Russia are also investing. The United States leads globally in AI research, with a $67.2 billion investment in 2023—8.7 times China's spending.[38] However, China is closing the gap, leading in AI patents with 61.1% of global origins in 2022 compared to the United States's 20.9%.[38] Under the 2017 New Generation AI Development Plan, China aims to become the world's AI leader by 2030, advancing in fields like diagnostics and biotechnology to improve health care access, especially in rural areas. China's success in remote robotic surgery highlights its potential in battlefield medicine, enabled by 5 G technology and a civil-military integration strategy.[39] This dual use of AI strengthens China's military medicine capabilities and challenges U.S. superiority.

Russia, too, is making strides in military AI. In 2018, it launched an AI research initiative to enhance tactical, operational, and strategic capabilities. Focusing on autonomous and robotic systems, Russia aims to automate battlefield roles.[40] Its "Moscow Experiment" in medical AI, launched in 2020, has streamlined diagnostics in radiology through over 5.6 million imaging analyses, showing how AI-driven clinical support systems can improve triage and resource management in both civilian and military medicine.[41]

The United States, China, and Russia are racing to leverage AI to reduce casualties and maintain resilience, underlining AI's strategic importance in sustaining military superiority. The ability to remain at the forefront depends on quick implementation, thoughtful design, and collaborative efforts across the U.S. Military and health care sectors.

CONCLUSION

The implementation of AI into military trauma care, as outlined in the U.S. Army Medical Modernization Strategy, offers opportunities to enhance efficiency and precision in the MHS. By automating tasks such as resource allocation, data capture, predictive modeling, and documentation, AI may help reduce cognitive demands on combat-zone personnel, allowing greater focus on clinical decision-making and life-saving interventions. These capabilities may likely become more important for maintaining effectiveness, particularly as adversaries advance their own AI technologies.

Despite its potential, AI integration faces challenges in data collection, system interoperability, secure storage, and ethical concerns. Addressing these issues requires targeted solutions, regulatory development, and cross-sector collaboration.

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Z.W.R, J.V.E, A.A.K, and H.K all assisted in the formation and formatting of the manuscript. Z.W.R, H.K, and J.V.E. provided the literature review and analysis. H.K. also crafted Figure 1 and assisted with manuscript review and insight. J.R.B provided oversight from the manuscript's inception to final review. All authors read and approved the final manuscript.

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There are no associated clinical trials with this manuscript.

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