Journal of
Kerman University of Medical Sciences

https://jkmu.kmu.ac.ir
doi:10.34172/jkmu.4124
JKMU 2026;33:4124

Review Article

Open Access
Publish Free

What Will Be the Future of Military Medicine Through the Lens of the International Orientation: A Systematic Review and Meta-Synthesis

Atousa Poursheikhali[1], Ali Masoud[2*], Amir jahanbin[3], Nader Markazi Moghaddam[4], Mina Ghasemi moghadam[5], Mousa Bamir[1]

[1]Department of Future Studies, Health Services Management Research Center, Institute for Futures Studies in Health, Kerman University of Medical Sciences, Kerman, Iran
[2]National Center for Health Insurance Research, Tehran, Iran
[3]Department of Health Services Management, School of Health Management and Information Sciences, Iran University of Medical Sciences, Tehran, Iran
[4]Department of Critical Care Quality Improvement Research Center, Shahid Modarres Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[5]Department of Health Management and Economics, School of Medicine, AJA University of Medical Sciences, Tehran, Iran

*Corresponding Author: Ali Masoud, Email: Ali.masoudmj@gmail.com

Abstract

Introduction: The evolving character of warfare, technological acceleration, and growing systemic uncertainty are reshaping the landscape of military medicine. Anticipating these transformations requires structured foresight-oriented analysis. This study aimed to identify and synthesize future-oriented trends shaping military medicine from an international perspective.

Method: A qualitative systematic review and meta-synthesis were conducted in accordance with the PRISMA 2020 guidelines. The synthesis followed Sandelowski and Barroso's methodological framework. Between May and July 2023, peer-reviewed English-language studies published from 2000 to 2022 were retrieved from PubMed, Web of Science, Scopus, Cochrane Library, and Google Scholar. The search strategy was structured using the SPIDER framework. Extracted data were analyzed using inductive thematic meta-synthesis supported by content analysis.

Results: Forty-one studies met the inclusion criteria. The synthesis revealed four overarching domains shaping the future of military medicine: (1) increasing uncertainty, multidimensional complexity, and evolving social dynamics; (2) technological convergence across domains such as robotics, cognitive science, simulation, telemedicine, and digital platforms; (3) expansion into emerging subfields including brain science, autonomous systems, and advanced trauma systems; and (4) strategic and governance-oriented adaptation mechanisms. Short- to medium-term priorities emphasize scalable digital integration and simulation-based preparedness, while advanced human–machine integration and autonomous systems represent longer-term structural transformations.

Conclusion: Future military medicine is evolving into a complex adaptive system driven by technological convergence, distributed models of care, and an expanding operational scope that extends beyond conventional battlefield settings. To remain prepared for future challenges, military health systems should integrate technological innovation with adaptive governance, scenario-based strategic planning, and international collaboration. Embedding foresight methodologies into military health system planning can strengthen resilience and enhance preparedness for both combat and non-combat crises.

Keywords: Military medicine, Military health services, Strategic planning, Uncertainty, Telemedicine, Cognitive science

Citation: Poursheikhali A, Masoud A, jahanbin A, Markazi Moghaddam N, Ghasemi moghadam M, Bamir M. What will be the future of military medicine through the lens of the international orientation: a systematic review and meta-synthesis. Journal of Kerman University of Medical Sciences 2026;33:4124. doi:10.34172/jkmu.4124

Received: February 23, 2026, **Accepted**: June 27, 2026, **ePublished:** July 4, 2026

Introduction

Military medicine represents a unique integration of science and practice, encompassing both general medical care and highly specialized services delivered within military contexts. Its primary mission is to safeguard the health of armed forces personnel and to support operational effectiveness under conditions of conflict and crisis (1). Military medical professionals must therefore be prepared to function in high-stress and resource-constrained environments, including naval vessels, remote deployments, and active battlefields (2,3). The risks associated with such environments are substantial; in 2017 alone, 701 attacks were reported against military medical personnel across 23 countries, resulting in the deaths of 101 staff members and 293 patients (4).

Beyond direct security threats, military medicine faces

© 2026 The Author(s); Published by Kerman University of Medical Sciences. This is an open-access article distributed under the terms of the Creative Commons Attribution License (https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

structural and systemic challenges. These include escalating healthcare costs, an aging retiree population, growing demand for high-quality services, expanding access expectations, increased utilization of military medical facilities by civilian communities, and the rising cost of advanced pharmaceuticals and technologies (5,6). Despite these pressures, military medical systems must maintain a constant state of preparedness to meet operational requirements and respond to existential security threats. At the international level, additional complexities arise from multinational joint operations, cultural and structural differences among armed forces, and restrictions on the transfer of advanced medical technologies. In such contexts, harmonizing treatment protocols, standardizing care practices, and facilitating knowledge exchange become increasingly challenging due to political and security considerations (1).

Simultaneously, the character of warfare is undergoing profound transformation. Future conflicts are anticipated to occur across highly complex and technologically advanced battlefields, increasingly characterized as multi-domain operations spanning land, sea, air, cyber, and space environments (7). These evolving operational landscapes are reshaping military medical research priorities, driving innovation in trauma care, evacuation systems, digital technologies, and multidisciplinary clinical collaboration. Over recent decades, significant advances have been achieved in injury management, including the deployment of portable imaging systems, advanced diagnostic tools, and integrated surgical teams within modern military field hospitals (8).

Given these transformations, adopting forward-looking, anticipatory approaches has become essential to maximize opportunities and mitigate emerging risks (9,10). Strategic foresight tools—such as environmental scanning, horizon scanning, and structured trend analysis—enable continuous monitoring of internal and external system dynamics. Systematic analysis and classification of emerging developments help translate potential changes into operational strategies. Such anticipatory capacity supports policymakers and military health leaders in adopting proactive rather than reactive approaches, thereby strengthening system awareness and preparedness for future disruptions.

To meaningfully anticipate developments in military medicine, it is necessary to clearly define and operationalize the concept of "future-oriented trends." In this study, trends are systematically identified, extracted, and synthesized using a structured analytical framework. The objective is not merely to describe technological advancements but to generate an integrated and coherent understanding of the structural, technological, and organizational transformations that may shape military medicine in the coming decades.

Accordingly, this study employed a systematic review and qualitative meta-synthesis to identify emerging patterns and overarching future-oriented trends in military medicine. By synthesizing diverse strands of evidence, the study seeks to provide a structured foundation for foresight-informed strategic planning in military health systems.

Methods

Study Design

This study employed a qualitative systematic review and meta-synthesis approach to identify and synthesize future-oriented trends in military medicine. The review followed the PRISMA 2020 guidelines to ensure transparency and methodological rigor. The research question guiding the review was: *What are the future-oriented trends shaping military medicine worldwide?*

The synthesis process was conducted in accordance with the methodological framework proposed by Sandelowski and Barroso (11), integrating systematic review procedures with inductive thematic meta-synthesis.

Search Strategy

A comprehensive literature search was conducted between May and July 2023 across PubMed, Web of Science, Scopus, Cochrane Library, and Google Scholar. The search was limited to peer-reviewed journal articles published in English between 2000 and 2022.

The search strategy was developed using the SPIDER framework (12) to ensure conceptual relevance and methodological consistency Table 1. The keywords included combinations related to military settings, healthcare, future-oriented concepts, foresight, trends, and driving forces.

Study Selection

The study selection process was conducted according to the PRISMA 2020 framework and included four main stages: Identification, screening, eligibility assessment, and inclusion.

Studies were included if they

1. Were published in peer-reviewed journals between 2000 and 2022;
2. Were written in English;
3. Explicitly addressed future-oriented developments, trends, or foresight-related concepts in military

Table 1. Search strategy keywords to identify the future trends of military medicine using the SPIDER guideline

Sample			Operator	Phenomenon of Interest	Evaluation	
Keywords	Operator	Keywords		Keywords	Operator	Keywords
"Military" OR "Army" OR "Combat"	AND	"medicine" OR "medical" OR "Health care" OR "Health System" OR "Hospital" OR "Clinic" OR "consultary care"	AND	"Future" OR "upcoming" OR "emergent" OR "Foresight"	AND	"Horizon" OR "Trend" OR "Driving force"

medicine;
4. Included substantive discussion of anticipated technological, structural, or strategic transformations.

Studies were excluded if they:
1. Focused exclusively on historical analyses without future-oriented perspectives;
2. Addressed purely clinical outcomes without discussion of future implications;
3. Were editorials, commentaries, conference abstracts, or lacked accessible full texts.

All titles, abstracts, and full texts were independently screened by two reviewers based on predefined eligibility criteria. Any disagreements were resolved through discussion, and unresolved conflicts were adjudicated by a third senior reviewer.

Data Extraction

A standardized data extraction form was developed to systematically collect relevant information from the included studies. Extracted data included:
- Author(s)
- Year and country of publication
- Study design
- Identified future trends
- Technological domains
- Strategic and policy implications
- Key contextual drivers

All relevant future-oriented statements from the Results and Discussion sections of the included studies were extracted verbatim and imported into MAXQDA 2018 for qualitative analysis.

Critical Appraisal

The methodological quality of included studies was assessed using the Critical Appraisal Skills Programme (CASP) tool (13,14). Each study was evaluated based on key domains, including clarity of research aims, appropriateness of methodology, rigor of data collection, ethical considerations, coherence of findings, and overall contribution.

Each appraisal domain was scored using a three-point scale:

0 = Not addressed,
1 = Partially addressed,
2 = Fully addressed.

The appraisal scores were used to evaluate methodological robustness and transparency rather than as exclusion criteria. Overall, the included studies demonstrated moderate to high methodological quality.

Data Analysis and Meta-Synthesis

An inductive thematic meta-synthesis was conducted using constant comparison techniques. Two researchers independently performed open coding on an initial subset of studies to generate preliminary codes. Following comparison and discussion, a structured coding framework was developed.

The refined codebook was subsequently applied to all included studies, with iterative revisions where necessary. Codes were grouped into related subcategories and abstracted into higher-order themes.

The final synthesis generated three overarching analytical domains:
1. Future-Oriented Trends (macro-level structural and environmental dynamics);
2. Technology Fields (emerging scientific and technological domains shaping military medicine);
3. Strategic and Operational Implications (adaptive and policy-level responses).

An evidence-to-theme mapping procedure was conducted to enhance analytical transparency by linking extracted meaning units to codes, subcategories, and final themes. Coding discrepancies were resolved through discussion and third-party adjudication when required.

Methodological Limitations

Several limitations should be acknowledged. Restricting the search to English-language publications may have resulted in the omission of relevant studies published in other languages. Exclusion of inaccessible full texts may have introduced publication bias. Moreover, reliance on indexed databases limited access to gray literature and classified military health documents. These limitations should be considered when interpreting the findings.

Results

In the identification phase of the systematic review, 852 duplicate records were removed by EndNote, and 1508 records entered the screening phase. The screening phase consists of three steps. At first, 1366 were excluded based on title and abstract screening, 142 records entered the full-text screening, and 60 entered the critical appraisal step. Finally, 40 studies were included via databases. In parallel, one record entered the study by searching known websites active in the future of military medicine. The PRISMA (15) flow diagram is presented in Figure 1.

The data extracted from included studies were content-analyzed using MAXQDA 2018 in four main themes: Future trends, technology fields, fields of study, and strategies. The future trends contain four principal codes: Increasing uncertainty, complexity, social trends, and collaboration and non-military players.

Future trends of military medicine

Increasing uncertainty

Military medicine is highly uncertain due to the numerous elements of future wars that need updated, responsive solutions. Emerging and re-emerging infectious diseases are not new matters, but the time and the pattern of occurrence cannot be predetermined. Governments do not merely own conventional weapons. Technology development has increased the complexity of weapons and types of wars and attacks by states or non-states.

Complexity

The type and depth of injuries in future wars, besides clinical progress and emerging health technologies, are

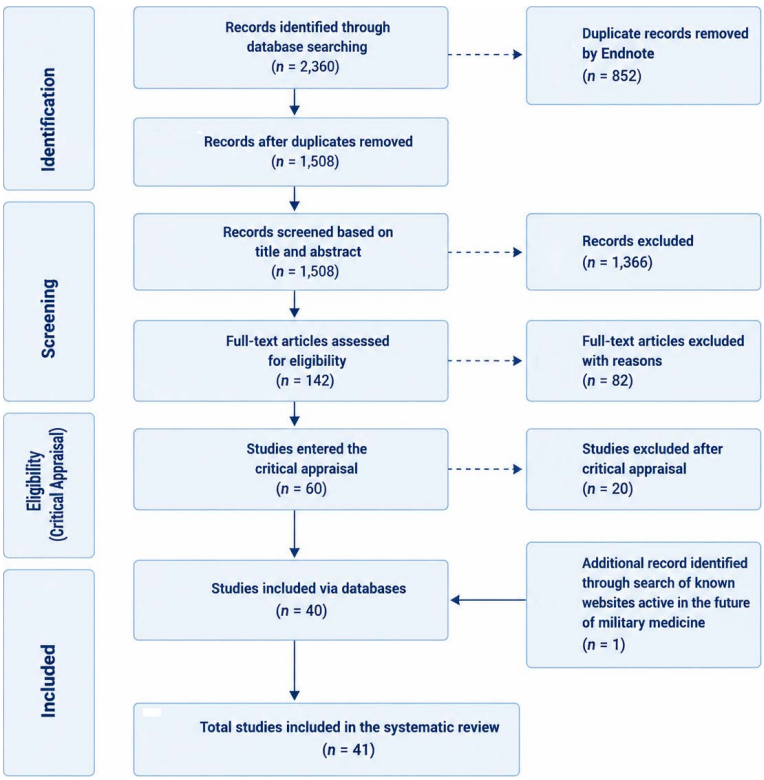


Figure 1. Flow diagram of Systematic review PRISMA 2020

rooted in many elements that make it a complex issue for the health-related aspects. These elements must be monitored dynamically and analyzed through scenarios to deal with the complexity.

Social trends

The new generation of military force is coming with further sexual diversity and more participation of women with their particular kind of care, especially mental-health-related ones. The new generation has different worldviews captured from society and more expectations of medical care.

Collaboration and non-military players

The military medicine teams will expand their networks both inside and outside the team. The team will be more varied in specialty and rank, with more transdisciplinary collaborations. From the outside viewpoint, the military must collaborate nationally and internationally with different organizations. The common risks will increase, so nations need to have a plan to cooperate in dealing with threats and crises. The other important point is that non-military players will have more access to emerging military-oriented technologies and unconventional weapons, which is another reason for international collaboration.

Technology fields of military medicine

New technological achievements affect military medicine in different aspects of prevention, detection and diagnosis, screening, and new models of delivering remote or on-site services; robots, sensors, nanotechnology-based devices, and artificial intelligence play a prominent role in this regard. New technologies will be competitive advantages in future war as they empower the staff physically and cognitively, reduce the access time, increase the possibility of accessing hard-to-reach areas, and deliver the services with less time, cost, risk, and errors.

Technology development is a trend with less uncertainty but much uncertainty in its development pattern from the military aspect. By expanding the branches and the convergence of science, nations can not focus on all fields of technology, and there will be more variants in countries' competitive advantages. However, some areas with more emphasis and practice in military medicine from the science and technology aspect have been mentioned as follows.

Cognitive science

Using cognitive science for military purposes focuses on linking humans, technology, and machines, with more practice in military brain science pioneered by the USA, European Union, and China. It works on knowing the human brain and how it can be monitored, injured, protected, repaired, strengthened, simulated, and armed. The realization of these goals leads to human empowerment from a cognitive and physical point of view for military applications.

Robots and automation

The machine-learning-trained robots, like surgical or transporter robots, will retrieve hard-to-access areas and reduce injuries for the military medical team. They help to deliver services with less time, errors, invasion, and losses. Micro- and Nano-scale robots can help examine the body and repair vital organs. Medical drones are also another

considered use of robots for military purposes.

Simulation

The most important use of simulation is in educating and training the military medical staff, monitoring and improving their performance for real situations by simulating different scenarios. It can be used for machine learning in no-enough-data so high-risk environments for humans. The simulations can be physical, virtual, or mixed to simulate various situations and create a virtual desktop. The next important application of simulators is in transferring patients.

Telemedicine

Telemedicine can be used for military-medicine purposes like remote dermatology, surgeries, psychiatry, cardiology, nuclear medicine/radiology, pharmacology, dentistry, ophthalmology, and delivering services for geography and limited environmental conditions. It helps deliver prevention-type services, follow-up for chronic diseases, detection, diagnosis, and treatment for staff and their family. Wearables and sensors are technologies that facilitate telemedicine and are on the technology development agenda of countries for military medicine.

Application and platforms

The application and platform are developed for purposes like pain control, training, personal care, enhancing the health service provider team skills, accurate time service delivery, extensive data management, mobile health, enabling preventive care, and simulation matters.

Military medicine fields of study

To provide a clearer understanding of the thematic landscape of contemporary military medicine research, the most frequently investigated fields identified through the systematic review are summarized in Table 2. These categories represent the dominant scientific and operational priorities reflected across the included studies. Presenting these fields enables a structured overview of the main research trajectories and emerging areas of focus within military medicine, facilitating a more coherent interpretation of the subsequent analyses.

To offer a comprehensive overview of how future trends in military medicine have been conceptualized and operationalized across the reviewed studies, the general characteristics of the included articles—along with the associated trends and strategies—are summarized in Table 3. This table integrates bibliographic details with the identified forward-looking themes and strategic recommendations, enabling a clearer understanding of how individual studies contribute to the broader landscape of future-oriented military medical research. Presenting these elements together provides a structured basis for comparing research directions, methodological orientations, and proposed strategic pathways within the field.

Discussion

The findings of this review indicate that the future of military medicine is shaped by structural transformations in warfare patterns, increasing uncertainty, and multidimensional complexity (16). The diversification of warfare—from conventional combat to cyber and electronic warfare (17) reflects a transition toward less predictable and more volatile operational environments. In futures studies terminology, this corresponds to environments characterized by deep uncertainty, where linear forecasting becomes insufficient and adaptive, scenario-based planning becomes essential.

The paradigm shift from large-scale conventional forces toward lighter, mobile units and near-point-of-injury care models (18) represents not merely an operational adjustment but a systemic reconfiguration of military medical delivery. Continuous monitoring of environmental

Table 2. The most frequent military-medicine-related fields of study obtained from reviewing the records

Number	Field of study	Number	Field of study
1	Military brain science	16	Drones
2	Warrior Physiological Status Monitoring Systems	17	Autonomous or semi-autonomous casualty treatment systems
3	Advanced trauma support	18	Patient transfer
4	ICT development	19	Using simulation in educating the staff
5	Educational standardization based on deep learning technologies	20	Telemedicine
6	Medical evacuation system using big data and information technology to optimize transportation systems and allocate human resources	21	Advanced surgery
7	Freeze-dried plasma	22	Bleeding control
8	Orthopedic trauma	23	Pain control
9	Pathophysiology, vaccine production, and bioterrorism	24	Care on the way
10	Assessment of risk and resilience in members	25	Emerging infectious diseases and antimicrobial resistance
11	Large-scale military action	26	Sexual health of soldiers
12	Wound infection	27	Mental health and Military psychology
13	Natural disaster	28	Acute infectious diseases
14	Environmental medicine	29	Rehabilitation medicine in wars
15	Post-traumatic stress disorder	30	Flexible military medicine

Table 3. Analytical Synthesis of Future Trends and Strategic Directions in Military Medicine (2000–2021)

No.	Year	First Author	Main Future Trend Identified	Strategic/Operational Implication	Technology Domain
1	2021	Gonzalez	Robotic and semi-automated battlefield surgery	Reduce provider risk; enable remote surgical capability	Robotics
2	2021	Eubanks	Expansion of simulation-based military training	Institutionalize VR/AR-based competency training	Simulation/VR
3	2021	Schubert	Mixed-reality casualty handoff systems	Standardize patient transfer protocols	Mixed Reality
4	2021	Thomas	Increasing combat casualty complexity	Agile surgical teams; drone-supported logistics	Drones/Trauma Systems
5	2021	Schafrank	AI-enabled teledermatology	Integrate AI into remote specialty services	AI/Telemedicine
6	2020	Wong	Battlefield medical smartphone platforms	Deploy field-ready digital decision tools	mHealth
7	2020	López	Expansion of military telemedicine ecosystems	Integrate telehealth with EHR and wearable systems	Telemedicine
8	2020	Tan	Virtual care expansion	Increase primary care capacity via telehealth	Virtual Care
9	2020	Cornfeld	Operational Virtual Health as force multiplier	Reduce medical evacuation; extend mission endurance	Telehealth
10	2020	Wilson	Mobile applications for pain management	Enhance self-management and clinical monitoring	mHealth
11	2019	Lanteri	Emerging infectious diseases & AMR	Strengthen epidemic preparedness research	Infectious Disease Research
12	2019	Selig	Growth of mobile health technologies	Integrate wearables with military EHR systems	mHealth/Sensors
13	2019	Adirim	Structural reform of Military Health System	Consolidate departments for efficiency	Health System Reform
14	2019	Braun	Medical drone evacuation systems	Develop mixed manned–unmanned evacuation	Drones
15	2018	Miller	AR-supported telesurgery	Enhance distributed surgical education	AR/Telepresence
16	2018	Hai Jin	Military brain science development	Promote international neuro-military collaboration	Cognitive Science
17	2018	Hwang	Secure teledermatology platforms	Expand remote specialty access	Telemedicine
18	2018	D'Angelo	Future trauma system innovation	Implement mobile surgical and advanced blood systems	Trauma Innovation
19	2017	Roberts	Rising orthopedic trauma burden	Prioritize advanced trauma specialization	Orthopedic Trauma
20	2017	Zhang	Knowledge mapping in military health research	Focus on mental health and resilience research	Research Strategy
21	2017	Malish	Human–technology integration	Enhance cognitive and physical performance	Human Performance
22	2017	Pei	Modernized rescue and evacuation systems	Implement tiered rescue ladder; integrate big data	Big Data/Logistics
23	2017	Durakovic	Radiological weapon preparedness	Develop response protocols for dirty bomb attacks	CBRN Preparedness
24	2015	Nigel	Personal technology in mental health	Leverage digital tools for psychological support	Digital Mental Health
25	2015	Withnall	Feminization of military workforce	Adapt recruitment and healthcare policy	Workforce Strategy
26	2015	Tien	Multinational modular care systems	Standardize coalition trauma protocols	Multinational Coordination
27	2015	Connolly	Resource scarcity & WMD proliferation	Strengthen crisis readiness & robotics integration	Strategic Foresight
28	2014	Hodgetts	Translating battlefield lessons into innovation	Institutionalize operational learning systems	Knowledge Translation
29	2013	Dufty	Sexual health challenges in forces	Enhance targeted hygiene education	Preventive Medicine
30	2012	Hodgetts	Future character of military medicine	Address gender care & ethical complexity	Strategic Planning
31	2012	Schmitt	VR neurosurgical training	Strengthen cognitive surgical simulation	VR/Neurosimulation
32	2010	Dunne	3D virtual learning platforms	Develop immersive military training systems	Virtual Learning
33	2010	Trego	Women's military health agenda	Establish sex- and gender-specific research programs	Women's Health
34	2008	Sakorafas	Evolution of war surgery	Mandate advanced trauma training programs	Surgical Training
35	2006	Lam	Micro/nano robotics & telesurgery	Invest in robotic and remote surgical systems	Robotics/Nano
36	2006	James	Mobile trauma pods & teletriage	Integrate LSTAT with telemedicine	Tele-Triage
37	2005	Ritter	Simulation for trauma education	Institutionalize ATLS simulator-based training	Simulation
38	2004	Jenkins	Rise of unconventional warfare	Expand bioterrorism research preparedness	Biodefense
39	2002	Leitch	Simulation system advancement	Integrate VR in peacetime training	Simulation
40	2002	Satava	Early surgical robotics & telesurgery	Maintain surgical innovation during peacetime	Robotics
41	2000	Burton	Telemedicine for remote populations	Establish virtual specialty clinics	Telemedicine

change, as emphasized in several studies (16), aligns with foresight methodologies that prioritize horizon scanning and iterative strategy refinement in uncertain contexts.

Technological convergence emerges as a dominant adaptive response among leading countries in military medicine. Cognitive science initiatives aim to integrate humans, technology, and machines as a competitive advantage (19), reflecting a systems-level approach to

performance enhancement. Robotics and semi-automated systems accelerate response time, reduce provider risk, and expand service reach in remote or hostile environments (20), including casualty transportation, robotic-assisted care, and operational data management (21–23). From a systems thinking perspective, these technologies alter feedback loops, reduce system latency, and increase operational resilience.

Simulation technologies, including platforms such as the Virtual People Factory (24) and virtual work environments (25), enhance training and human–machine performance evaluation (20,26,27). These developments align with resilience theory, which emphasizes preparedness for high-risk, low-frequency events through controlled modeling of complex scenarios. Similarly, telemedicine applications—including telesurgery (21,28–30), teledermatology (31), virtual clinics, infection control (32), and remote transmission of diagnostic data such as imaging and physiological parameters (21)—enable distributed care models that reduce exposure risk and increase accuracy outside active combat zones (21,31). Within complex adaptive systems, such decentralization enhances redundancy and adaptability.

Digital applications and software platforms further reinforce this transformation. Their uses in skill enhancement, pain management (33), mobile health delivery (34,35), and electronic health record management (34) demonstrate the centrality of data integration. The technological trajectory identified across studies indicates that data governance and interoperability are critical structural components, particularly for less developed countries facing infrastructure constraints.

Strategic reforms in experienced military systems illustrate institutional adaptation to complexity. For example, the establishment of centralized management structures for military hospitals and clinics in the United States (36), and Singapore's development of ICT infrastructures to support telemedicine (32), reflect governance-level restructuring consistent with systems-based transformation. Military brain science (MBS) initiatives in the United States, China, and the European Union (37,38) further demonstrate strategic investment in cognitive enhancement as a long-term competitive domain.

Beyond technological modernization, the literature emphasizes shifting conflict patterns. Drones and robotic systems remain critical in high-intensity or CBRN-related conflicts (16,38,39). However, prolonged, low-intensity conflicts increase the relevance of psychological resilience and mental health support for soldiers and their families (40,41). The inclusion of families within the scope of military medicine (42) reflects a transition toward a whole-of-force health model. Likewise, the growing participation of women in combat forces (16,43) introduces gender-specific physical, psychological, and preventive health requirements, requiring adaptive policy frameworks.

Importantly, most identified activities focus on intergovernmental conflict preparedness, including prevention, monitoring, diagnosis, treatment, evacuation, and data management during wartime (16). However, futures-oriented analysis suggests that military medicine must also anticipate non-combat crises, including natural disasters, internal conflicts, and large-scale public emergencies. This aligns with multi-hazard and systemic risk models, which emphasize preparedness for cascading disruptions across civilian and military domains.

Although cognitive science, robotics, simulation, telemedicine, and digital platforms were identified as the principal technological domains shaping the future of military medicine (19,20,33–35,37,38,21–23,28–32), these fields should not be interpreted as independent trajectories. Rather, the synthesis suggests a pattern of technological convergence and sequential maturation. Simulation technologies (20,24, 27) function as foundational capacity-builders, preparing human capital for increasingly complex human–machine integration environments. Robotics and semi-automated systems (20–23) extend this integration into operational settings, while telemedicine and digital platforms (21,28–35) institutionalize distributed service delivery through networked infrastructures. Cognitive science initiatives (19,37,38) represent a higher-order strategic layer focused on performance optimization and long-term capability enhancement. From a foresight perspective, this progression reflects a movement from capability augmentation (training and simulation) toward systemic transformation (networked, data-driven, and semi-autonomous medical ecosystems).

The policy implications of this convergence are substantial. As these domains increasingly interact, military medical systems transition from isolated technological adoption toward integrated digital health architectures requiring interoperable data governance, regulatory adaptation, ethical oversight, and multinational coordination. In futures studies terms, this trajectory corresponds to a shift from incremental innovation toward paradigm-level change, where institutional design must evolve alongside technological advancement. Therefore, the future of military medicine should be conceptualized not only in terms of technological diffusion but also as a staged transformation process affecting doctrine, logistics, workforce training, international collaboration, and health system governance. Without embedding these developments within scenario-based strategic planning frameworks (16,38,39), technological expansion risks remaining fragmented rather than systemically transformative.

Beyond technological advancement, the transformation of military medicine requires a parallel evolution in governance structures. As uncertainty intensifies and technological convergence accelerates, military health systems must adopt adaptive governance models capable of managing interoperability, cybersecurity risks, ethical and regulatory oversight, and multinational coordination. Within complex adaptive systems, governance mechanisms serve not merely as administrative controls but also as integrative and stabilizing forces that align technological innovation with operational doctrine, regulatory

frameworks, and long-term strategic planning. In this sense, governance constitutes a dynamic transformation pathway through which technological and organizational changes are institutionalized and sustained.

Building upon this systems-level interpretation, the relationships among structural drivers, technological enablers, transformation pathways, and governance mechanisms can be conceptualized as an integrated framework (Figure 2). The framework does not introduce new components; rather, it synthesizes the identified themes into a structured model that clarifies their interdependencies and staged logic of transformation. By visualizing these relationships, the model reinforces the argument that the future of military medicine depends on coordinated evolution across technological, organizational, and governance domains rather than isolated innovation trajectories.

Conclusion

The findings of this review indicate that future military medicine is evolving within an environment defined by uncertainty, multidimensional complexity, and technological convergence. As discussed, the transformation of warfare patterns and the diversification of operational contexts require military health systems to function as complex adaptive systems rather than linear service structures. In this setting, technologies such as robotics, cognitive science, simulation, telemedicine, and digital platforms represent interconnected components of a broader socio-technical transformation rather than isolated innovations.

However, the strategic implications of these domains are not uniform. Technologies that strengthen distributed care, data integration, and simulation-based preparedness appear more immediately applicable for enhancing resilience under uncertain and geographically dispersed conditions. In contrast, more advanced domains—such as cognitive enhancement and autonomous systems—reflect longer-term structural shifts that require careful governance, ethical regulation, and sustained investment. Therefore, the future of military medicine depends not only on technological advancement but also on prioritization, adaptive policy design, and integration within scenario-based strategic planning frameworks.

Ultimately, the evolution of military medicine should be conceptualized as a staged and system-wide transition shaped by uncertainty, complexity, and intersectoral interdependence. Embedding foresight methodologies, systems modeling, and adaptive governance within military health planning will be essential to ensure preparedness across both combat and non-combat crises.

Acknowledgments

The authors would like to thank Kerman University of Medical Sciences, Kerman, Iran.

Authors' Contribution

Conceptualization: Ali Masoud, Atousa Poursheikhali
Data Curation: Ali Masoud, Amir Jahanbin, Nader Markazi Moghaddam
Investigation: Ali Masoud, Atousa Poursheikhali, Mina Ghasemi Moghadam, Mousa Bamir
Methodology: Ali Masoud, Mousa Bamir, Mohammad Jafari Sirizi
Project Administration: Atousa Poursheikhali
Resources: Mousa Bamir, Amir Jahanbin, Mohammad Jafari Sirizi
Software: Mousa Bamir, Nader Markazi Moghaddam

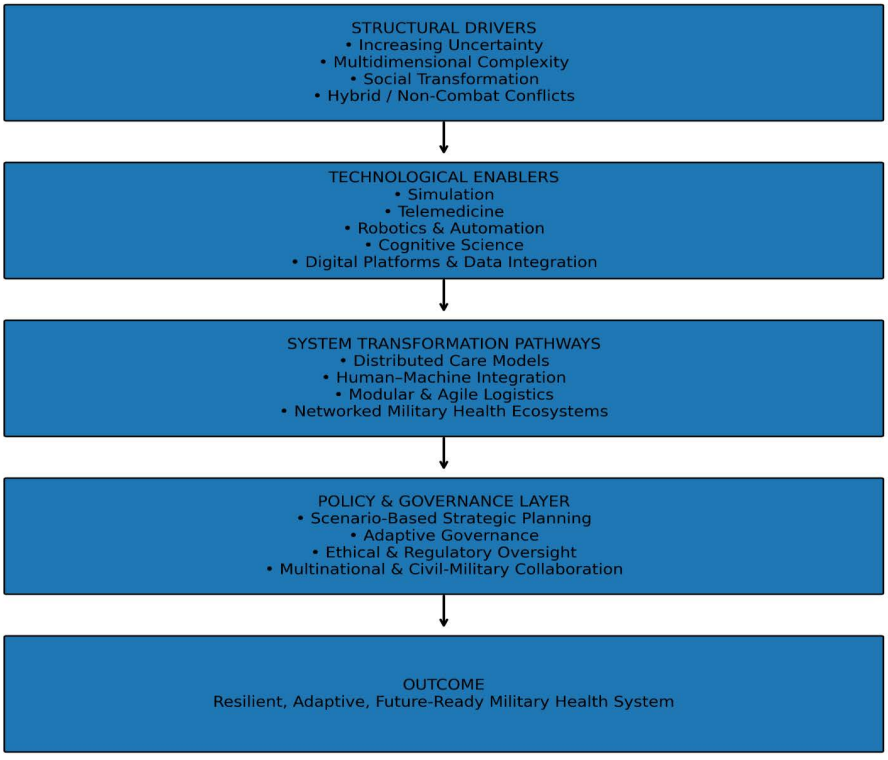


Figure 2. Integrated Systems Framework Illustrating Structural Drivers, Technological Enablers, and Governance Pathways Shaping the Future of Military Medicine

Supervision: Atousa Poursheikhali
Validation: Ali Masoud, Atousa Poursheikhali
Writing–Original Draft: Ali Masoud, Mina Ghasemi Moghadam, Mousa Bamir
Writing–Review & Editing: Ali Masoud, Mina Ghasemi Moghadam, Mousa Bamir, Atousa Poursheikhali, Amir Jahanbin, Nader Markazi Moghaddam

Competing Interests
The authors declare that they have no conflict of interest.

Data Availability Statement
The data analyzed in this study were derived from publicly available peer-reviewed publications. The extracted data and synthesis materials generated during the present study are available from the corresponding author upon reasonable request.

Ethical Approval
Not applicable.

Funding
None.

References

1. Liu GD, Wang N, Wang HM, Li X, Shao JJ, Liu ZF, et al. Military medical research on internal diseases in modern warfare: new concepts, demands, challenges, and opportunities. Mil Med Res 2021;8(1):20. doi:10.1186/s40779-021-00313-8
2. Anagnostou E, Michas A, Giannou C. Practicing military medicine in truly austere environments: what to expect, how to prepare, when to improvise. Mil Med 2020;185(5-6): e656-61. doi:10.1093/milmed/usz467
3. Sonesson L, Boffard K, Lundberg L, Rydmark M, Karlgren K. The challenges of military medical education and training for physicians and nurses in the Nordic countries - an interview study. Scand J Trauma Resusc Emerg Med 2017;25(1):38. doi:10.1186/s13049-017-0376-y
4. Safeguarding Health in Conflict Coalition (SHCC). Violence on the Front Line: Attacks on Health Care in 2017. SHCC; 2018. Available from: https://www.safeguardinghealth.org/sites/shcc/files/SHCC2018final.pdf.
5. Aristotle F. On total force fitness in war and peace. Mil Med 2010;175(Suppl 8):1-2. doi:10.7205/milmed-d-10-00246
6. Whitley J. Five Actions to Improve Military Hospital Performance. IBM Center for the Business of Government; 2017.
7. U.S. Army Training and Doctrine Command, U.S. Marine Corps. Multi-Domain Battle: Combined Arms for the 21st Century. 2017. Accessed October 28, 2026. Available from: https://dupuyinstitute.org/wp-content/uploads/2019/03/U.S.-Army-Marine-Corps-Multi-Domain-Battle-Combined-Arms-For-The-21st-Century-2017.pdf
8. Davis MR, Rasmussen TE. Winds of change in military medicine and combat casualty care. J Trauma Acute Care Surg 2019;87(1S Suppl 1): S1-2. doi:10.1097/ta.0000000000002349
9. Butland B, Jebb S, Kopelman P, McPherson K, Thomas S, Mardell J, et al. Tackling Obesities: Future Choices-Project Report. London: Department of Innovation, Universities and Skills; 2007. p. 1-161
10. Johnston R. Research foresight: priority-setting in science by Ben R. Martin and John Irvine (Pinter Publishers, London, 1989) pp.ix+366, ISBN 0 86187 510 9. Prometheus 1990;8(1):199-202. doi:10.1080/08109029008631897
11. Sandelowski M, Barroso J. Handbook for Synthesizing Qualitative Research. Springer Publishing Company; 2007.
12. Cooke A, Smith D, Booth A. Beyond PICO: the SPIDER tool for qualitative evidence synthesis. Qual Health Res 2012;22(10):1435-43. doi:10.1177/1049732312452938
13. Hannes K, Lockwood C, Pearson A. A comparative analysis of three online appraisal instruments' ability to assess validity in qualitative research. Qual Health Res 2010;20(12):1736-43. doi:10.1177/1049732310378656
14. Critical Appraisal Skills Programme (CASP). CASP checklist: for systematic reviews. 2024. Available from:https://casp-uk.net/casp-checklists/CASP-checklist-systematic-reviews-checklist-2024.pdf
15. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi:10.1136/bmj.n71
16. Hodgetts TJ. The future character of military medicine. J R Army Med Corps 2012;158(3):271-8. doi:10.1136/jramc-158-03-25
17. Jenkins I. The changing world of military health care. J R Nav Med Serv 2004;90(3):153-8.
18. D'Angelo M, Welder M, Chauhan R, Kearns MJ. Future trends in trauma care: through the lens of the wounded how lessons from the battlefield may be used at home. Anesthesiol Clin 2019;37(1):183-93. doi:10.1016/j.anclin.2018.09.008
19. Malish RG. The importance of the study of cognitive performance enhancement for US national security. Aerosp Med Hum Perform 2017;88(8):773-8. doi:10.3357/amhp.4795.2017
20. Gonzalez GT, Kaur U, Rahman M, Venkatesh V, Sanchez N, Hager G, et al. From the dexterous surgical skill to the battlefield-a robotics exploratory study. Mil Med 2021;186(Suppl 1):288-94. doi:10.1093/milmed/usaa253
21. Lam DM, Curley KC. Research for the soldier: bringing science fiction medicine to life. Telemed J E Health 2006;12(4):432-8. doi:10.1089/tmj.2006.12.432
22. Satava RM. Surgical robotics: the early chronicles: a personal historical perspective. Surg Laparosc Endosc Percutan Tech 2002;12(1):6-16. doi:10.1097/00129689-200202000-00002
23. Sakorafas GH, Peros G. Principles of war surgery: current concepts and future perspectives. Am J Emerg Med 2008;26(4):480-9. doi:10.1016/j.ajem.2007.05.009
24. Schubert R, Bruder G, Tanaka A, Guido-Sanz F, Welch GF. Mixed reality technology capabilities for combat-casualty handoff training. In: Chen JY, Fragomeni G, eds. Virtual, Augmented and Mixed Reality. Vol 12770. Cham: Springer International Publishing; 2021. p. 695-711. doi:10.1007/978-3-030-77599-5_47
25. Leitch RA, Moses GR, Magee H. Simulation and the future of military medicine. Mil Med 2002;167(4):350-4.
26. Davila U, Price A. Past present and future of simulation in pediatrics. In: StatPearls [Internet]. Treasure Island, FL: StatPearls Publishing; 2026.
27. Matt Ritter E, Bowyer MW. Simulation for trauma and combat casualty care. Minim Invasive Ther Allied Technol 2005;14(4):224-34. doi:10.1080/13645700500243703
28. Miller GT, Harris T, Choi YS, DeLellis SM, Nelson K, Magee JH. Augmented reality and telestrated surgical support for point of injury combat casualty care: a feasibility study. In: Schmorrow D, Fidopiastis C, eds. Augmented Cognition: Intelligent Technologies. Vol 10915. Cham: Springer International Publishing; 2018. p. 395-405. doi:10.1007/978-3-319-91470-1_32
29. Schmitt PJ, Agarwal N, Prestigiacomo CJ. From planes to brains: parallels between military development of virtual reality environments and virtual neurological surgery. World Neurosurg 2012;78(3-4):214-9. doi:10.1016/j.wneu.2012.06.014
30. Pei Y, Song Y, Yu M. A new approach to organization and implementation of military medical treatment in response to military reform and modern warfare in the Chinese army. Mil Med 2017;182(11): e1819-23. doi:10.7205/milmed-d-17-00051
31. Schafrank LA, Falkner RC, Lam TK, Meyerle JH. Teledermatology in military settings. Curr Dermatol Rep 2021;10(2):33-9. doi:10.1007/s13671-021-00330-9
32. Tan NG, Yang LW, Tan MZ, Chng J, Tan MH, Tan C. Virtual

care to increase military medical centre capacity in the primary health care setting: a prospective self-controlled pilot study of symptoms collection and telemedicine. J Telemed Telecare 2022;28(8):603-12. doi:10.1177/1357633x20959579
33. Wilson MA, Fouts BL, Brown KN. Development of a mobile application for acute pain management in US military healthcare. Appl Nurs Res 2021;58:151393. doi:10.1016/j.apnr.2020.151393
34. Selig DJ, Collins J, Church TL, Zeman J. An editorial review of mobile health: implications for the US Military Health System. Mil Med 2019;184(7-8): e253-8. doi:10.1093/milmed/usz073
35. Wong KH, Bayarsaikhan S, Levine BA, Mun SK. Prototype of a Military medic smartphone medical graphical user interface for use by medics in deployed environments. Mil Med 2020;185(Suppl 1):536-43. doi:10.1093/milmed/usz225
36. Adirim T. A military health system for the twenty-first century. Health Aff (Millwood) 2019;38(8):1268-73. doi:10.1377/hlthaff.2019.00302
37. Jin H, Hou LJ, Wang ZG. Military Brain Science - how to influence future wars. Chin J Traumatol 2018;21(5):277-80. doi:10.1016/j.cjtee.2018.01.006
38. Braun J, Gertz SD, Furer A, Bader T, Frenkel H, Chen J, et al. The promising future of drones in prehospital medical care and its application to battlefield medicine. J Trauma Acute Care Surg 2019;87(1S Suppl 1): S28-34. doi:10.1097/ta.0000000000002221
39. Thomas B. Preparing for the future of combat casualty care: opportunities to refine the military health system's alignment with the national defense strategy. Rand Health Q 2022;9(3):18.
40. Connolly MJ. Health service support in the future operating environment 2035. J R Army Med Corps 2015;161(1):32-5. doi:10.1136/jramc-2013-000225
41. Zhang XM, Zhang X, Luo X, Guo HT, Zhang LQ, Guo JW. Knowledge mapping visualization analysis of the military health and medicine papers published in the web of science over the past 10 years. Mil Med Res 2017;4:23. doi:10.1186/s40779-017-0131-8
42. Burton R, Boedeker B. Application of telemedicine in a pain clinic: the changing face of medical practice. Pain Med 2000;1(4):351-7. doi:10.1046/j.1526-4637.2000.00039.x
43. Trego L, Wilson C, Steele N. A call to action for evidence-based military women's health care: developing a women's health research agenda that addresses sex and gender in health and illness. Biol Res Nurs 2010;12(2):171-7. doi:10.1177/1099800410375299