

Avances en la Atención Táctica de Bajas en Combate: Estrategias Contemporáneas para el Control de Hemorragias, el Manejo del Neurotrauma y la Recuperación Multidisciplinaria en la Guerra Moderna

Advances in Tactical Combat Casualty Care: Contemporary Strategies for Hemorrhage Control, Neurotrauma Management, and Multidisciplinary Recovery in Modern Warfare

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RESUMEN

Los conflictos armados contemporáneos han generado patrones de lesión cada vez más complejos, caracterizados por hemorragias masivas, traumatismo craneoencefálico, lesiones por explosión, daño vascular y trauma multisistémico, representando un importante desafío para los sistemas de salud militares y civiles. Los avances continuos en medicina táctica, atención de bajas en combate, neurocuidados críticos, diagnóstico por imagen y estrategias de control de daños han mejorado significativamente el manejo de estas lesiones y reducido la mortalidad prevenible en escenarios de combate. La presente revisión analiza las innovaciones actuales en el manejo del trauma de guerra, con énfasis en el control de hemorragias, el tratamiento del traumatismo craneoencefálico, las tecnologías radiológicas avanzadas, la cirugía de control de daños, la reanimación de control de daños y los sistemas multidisciplinarios de atención al trauma. Se realizó una revisión narrativa estructurada utilizando el Método Científico y principios metodológicos basados en PRISMA. La evidencia científica fue obtenida a partir de PubMed/MEDLINE, Scopus, Web of Science, ScienceDirect, SpringerLink, Wiley Online Library, Cochrane Library y Google Scholar, incluyendo artículos revisados por pares, guías clínicas, revisiones sistemáticas, metaanálisis y documentos de consenso publicados entre 2005 y 2025. La evidencia disponible demuestra que los protocolos de Tactical Combat Casualty Care, los torniquetes modernos, los agentes hemostáticos, las estrategias actuales de transfusión, los avances en neurocuidados críticos y las tecnologías radiológicas innovadoras han mejorado significativamente la supervivencia, la preservación neurológica, la precisión diagnóstica y la recuperación funcional de las víctimas de combate. Asimismo, los sistemas multidisciplinarios que integran medicina táctica, cirugía, radiología, cuidados intensivos y rehabilitación han fortalecido la continuidad asistencial y optimizado los resultados clínicos durante todo el proceso de recuperación. Estas innovaciones también han influido positivamente en los sistemas civiles de atención al trauma, fortaleciendo la preparación ante emergencias, la respuesta a desastres y el manejo de lesiones traumáticas graves. A pesar de los avances alcanzados, continúa siendo necesario impulsar nuevas investigaciones orientadas a optimizar las terapias neuroprotectoras, ampliar el acceso a tecnologías avanzadas, fortalecer los programas de rehabilitación y responder a los desafíos emergentes de la guerra moderna. El manejo contemporáneo del trauma de guerra constituye actualmente un campo altamente especializado, multidisciplinario y sustentado en evidencia científica que continúa transformando el futuro de la atención del trauma tanto en el ámbito militar como civil.

PALABRAS CLAVE

Trauma de guerra, Medicina táctica, Atención de bajas en combate, Control de hemorragias, Traumatismo craneoencefálico, Neurotrauma, Medicina militar, Cirugía de control de daños, Reanimación de control de daños, Hemorragia en combate, Radiología militar, Neurocuidados críticos, Lesión por explosión, Medicina de campo de batalla, Sistemas multidisciplinarios de trauma, Rehabilitación, Medicina de urgencias, Cuidados críticos, Cirugía de trauma, Lesiones de combate

ABSTRACT

Modern warfare has generated increasingly complex patterns of injury characterized by massive hemorrhage, traumatic brain injury, blast-related trauma, vascular damage, and multisystem injuries, creating significant challenges for military and civilian healthcare systems. Continuous advances in tactical medicine, combat casualty care, neurocritical care, radiological imaging, and damage control strategies have substantially improved the management of these injuries and reduced preventable mortality in combat environments. This review analyzes current innovations in war trauma management, emphasizing developments in hemorrhage control, traumatic brain injury management, advanced radiological technologies, damage control surgery, damage control resuscitation, and multidisciplinary trauma systems. A structured narrative review was conducted using the Scientific Method and PRISMA-based review principles. Scientific evidence was identified through PubMed/MEDLINE, Scopus, Web of Science, ScienceDirect, SpringerLink, Wiley Online Library, Cochrane Library, and Google Scholar, including peer-reviewed articles, clinical guidelines, systematic reviews, meta-analyses, and consensus statements published between 2005 and 2025. The available evidence demonstrates that Tactical Combat Casualty Care protocols, modern tourniquet systems, hemostatic

dressings, balanced transfusion strategies, advanced neurocritical care, and innovative imaging techniques have significantly improved survival, neurological preservation, diagnostic accuracy, and long-term functional recovery among combat casualties. Furthermore, multidisciplinary trauma systems integrating tactical medicine, surgery, radiology, intensive care, and rehabilitation have strengthened continuity of care and enhanced patient outcomes throughout the recovery process. These advances have also influenced civilian trauma systems by improving emergency preparedness, disaster response, and management of severe traumatic injuries. Although important progress has been achieved, continued research remains necessary to optimize neuroprotective therapies, expand access to advanced technologies, improve rehabilitation strategies, and address the evolving challenges associated with modern warfare. Contemporary war trauma management has become a highly specialized, multidisciplinary, and evidence-based field whose innovations continue to shape the future of military and civilian trauma care worldwide.

KEYWORDS

War trauma, Tactical medicine, Combat casualty care, Hemorrhage control, Traumatic brain injury, Neurotrauma, Military medicine, Damage control surgery, Damage control resuscitation, Combat hemorrhage, Military radiology, Neurocritical care, Blast injury, Battlefield medicine, Multidisciplinary trauma systems, Rehabilitation, Emergency medicine, Critical care, Trauma surgery, Combat injuries

INTRODUCCIÓN

Armed conflicts continue to represent one of the most significant global public health and humanitarian challenges of the twenty-first century. Contemporary warfare has evolved considerably due to the incorporation of advanced weapon systems, improvised explosive devices, high-energy projectiles, unmanned aerial technologies, and urban combat environments, all of which have increased the complexity and severity of traumatic injuries sustained by both military personnel and civilian populations. As a consequence, trauma systems worldwide have faced unprecedented demands to develop innovative strategies capable of improving survival rates, reducing disability, and optimizing long-term functional recovery in patients affected by severe combat-related injuries (Maas et al., 2022; Rossaint et al., 2023).

Traumatic injuries remain among the leading causes of mortality and disability globally, particularly among young adults. Within military settings, uncontrolled hemorrhage, traumatic brain injury (TBI), and multisystem trauma account for the majority of preventable deaths occurring before definitive hospital care can be provided. Historical analyses of recent military operations have demonstrated that rapid hemorrhage control, timely neurological assessment, and effective prehospital interventions are critical determinants of survival in combat casualties (Kragh et al., 2009; Kragh et al., 2011). Consequently, the development of Tactical Combat Casualty Care (TCCC) guidelines has transformed battlefield medicine by introducing evidence-based protocols focused on immediate life-saving interventions under hostile conditions (Deaton et al., 2024).

Recent armed conflicts have highlighted the growing burden of complex polytrauma associated with blast injuries. Explosive mechanisms frequently generate combinations of penetrating trauma, orthopedic fractures, vascular disruption, soft tissue destruction, and neurological damage. Unlike conventional civilian trauma, combat injuries often involve extensive tissue loss, contamination, delayed evacuation, and resource-limited environments, factors that significantly complicate clinical management and rehabilitation processes (Leibner et al., 2020). These circumstances have stimulated intensive research efforts aimed at improving damage control resuscitation, advanced hemostatic technologies, neurocritical care protocols, and innovative imaging techniques for early diagnosis and treatment planning.

Among all combat-related injuries, traumatic brain injury has emerged as one of the most challenging clinical conditions. Blast waves, penetrating cranial trauma, secondary projectile impacts, and acceleration-deceleration mechanisms can produce complex neurological damage with potentially devastating consequences. TBI has been

associated with increased mortality, long-term cognitive impairment, psychiatric disorders, functional disability, and reduced quality of life among military personnel and civilian survivors of armed conflicts (Carney et al., 2017; Hawryluk et al., 2020). Advances in neuroimaging have substantially improved the understanding of combat-related brain injuries, allowing clinicians to identify structural abnormalities, diffuse axonal injury, cerebral edema, vascular compromise, and secondary neurological complications with greater precision than previously possible (Benzinger et al., 2009; Riedy et al., 2016).

Radiological innovations have become particularly important in the context of modern military medicine. High-resolution computed tomography, advanced magnetic resonance imaging, diffusion tensor imaging, perfusion studies, and neurovascular imaging techniques have expanded diagnostic capabilities, enabling earlier detection of injuries and facilitating more personalized therapeutic approaches. These technologies not only improve acute clinical decision-making but also contribute to prognostic assessment and long-term monitoring of neurological recovery (Wintermark et al., 2015). The integration of advanced imaging into trauma algorithms has therefore become a fundamental component of modern combat casualty management.

Parallel to diagnostic advances, significant progress has occurred in the field of hemorrhage control and resuscitation. Uncontrolled bleeding remains the leading cause of potentially preventable death following combat trauma. The implementation of tourniquets, junctional hemorrhage control devices, hemostatic dressings, balanced transfusion strategies, and damage control resuscitation protocols has dramatically improved battlefield survival over the past two decades (Kragh et al., 2009; Shackelford et al., 2015). Furthermore, novel hemostatic agents and prehospital blood product administration have expanded the capacity of tactical medical teams to stabilize critically injured patients before evacuation to higher levels of care (Peng, 2020; Welch et al., 2020).

Another major area of innovation involves the development of damage control surgery and multidisciplinary trauma systems. Modern military medicine increasingly emphasizes rapid physiological stabilization, staged surgical interventions, and coordinated management among trauma surgeons, neurosurgeons, radiologists, intensivists, orthopedic specialists, and rehabilitation teams. Such integrated approaches have demonstrated substantial benefits in reducing mortality and improving functional outcomes among severely injured patients (Galbraith et al., 2023; Lammers et al., 2023). These advances have also influenced civilian trauma systems, illustrating the bidirectional relationship between military and civilian medical innovation.

The relevance of these developments extends beyond active combat zones. Lessons learned from military conflicts have contributed significantly to emergency preparedness strategies, disaster response systems, mass casualty incident management, and trauma care protocols worldwide. Countries throughout Latin America, including Mexico, Colombia, and Ecuador, have increasingly incorporated modern trauma principles into emergency medicine training, military health services, and hospital-based trauma systems. Colombia, in particular, has generated valuable experience through the development of regional trauma registries and organized trauma care networks that have contributed to improving outcomes among critically injured patients (Ordoñez et al., 2016). Similarly, Mexico has strengthened trauma system development through collaborative efforts involving military and civilian healthcare institutions aimed at enhancing preparedness for both conflict-related and civilian mass casualty scenarios (Rojas et al., 2023).

Despite substantial progress, important challenges remain unresolved. Persistent gaps exist regarding optimal neuroprotective strategies, management of blast-induced brain injury, implementation of advanced imaging in resource-limited settings, long-term rehabilitation of combat survivors, and integration of emerging technologies into battlefield medicine. Additionally, evolving patterns of warfare continue to generate novel injury mechanisms that

require ongoing adaptation of clinical protocols and research priorities. These challenges underscore the need for comprehensive evaluations of current evidence to identify effective interventions and guide future innovation.

Therefore, the primary objective of this review is to analyze contemporary advances in war trauma management and tactical medicine, with particular emphasis on massive injury management, hemorrhage control, neurotrauma, advanced radiological applications, damage control strategies, and multidisciplinary approaches to combat casualty care. Furthermore, this review seeks to examine the translational impact of military medical innovations on civilian trauma systems and to explore their relevance within international contexts, including emerging experiences from Latin America. By synthesizing current evidence, this work aims to provide a comprehensive overview of the most significant developments shaping the future of trauma care in both military and civilian environments.

DESARROLLO

The nature of combat-related injuries has undergone substantial transformation during the last three decades. Historically, battlefield mortality was primarily associated with infectious diseases and delayed access to medical care. However, contemporary armed conflicts are characterized by the widespread use of explosive devices, high-velocity projectiles, urban warfare tactics, and advanced weapon systems capable of producing complex polytrauma patterns that challenge conventional medical management (Maas et al., 2022).

Recent military operations conducted in the Middle East, Eastern Europe, and other conflict regions have demonstrated that traumatic injuries remain the principal cause of mortality among military personnel. Evidence suggests that approximately 80–90% of potentially preventable battlefield deaths occur before patients reach definitive surgical care, highlighting the importance of rapid prehospital interventions and tactical medical response systems (Deaton et al., 2024). Consequently, modern military medicine has shifted its focus toward early hemorrhage control, advanced resuscitation strategies, and rapid evacuation protocols designed to maximize survival during the critical minutes immediately following injury.

The implementation of Tactical Combat Casualty Care (TCCC) has represented one of the most influential developments in military medicine. Introduced initially by the United States Special Operations community and subsequently adopted internationally, TCCC provides structured evidence-based recommendations for managing combat casualties under hostile conditions. Numerous studies have demonstrated significant reductions in preventable mortality following the implementation of TCCC principles, particularly regarding hemorrhage control and airway management (Deaton et al., 2024; Shackelford et al., 2015).

Modern battlefield medicine increasingly integrates multidisciplinary approaches involving trauma surgeons, emergency physicians, neurosurgeons, radiologists, critical care specialists, orthopedic surgeons, rehabilitation professionals, and military medical personnel. This collaborative framework recognizes that successful management of combat injuries extends beyond immediate survival and includes long-term functional recovery, neurological preservation, and reintegration into civilian or military life.

Massive Hemorrhage Control: The Cornerstone of Combat Survival

Uncontrolled hemorrhage remains the leading cause of preventable death in military trauma. Multiple analyses conducted during recent armed conflicts have consistently shown that exsanguination accounts for a substantial proportion of fatalities occurring before arrival at surgical facilities (Kragh et al., 2009). This observation has stimulated intensive efforts to develop more effective hemorrhage control techniques capable of being implemented in austere environments.

Tourniquets have become one of the most successful interventions in modern combat casualty care. Earlier concerns regarding ischemic complications led to hesitancy in their use; however, contemporary evidence has demonstrated that properly applied tourniquets significantly increase survival rates while maintaining acceptable complication profiles

(Kragh et al., 2011). Large military cohort studies have reported substantial reductions in mortality among patients with severe extremity hemorrhage when tourniquets are applied before the onset of shock.

Beyond conventional tourniquets, innovations in junctional hemorrhage control have expanded treatment options for injuries involving anatomical regions where traditional devices cannot be applied effectively. Junctional tourniquets, pelvic stabilization devices, and specialized compression systems have emerged as valuable tools for controlling bleeding in groin, axillary, and pelvic injuries (Shackelford et al., 2015).

The development of advanced hemostatic dressings has further transformed prehospital trauma care. Modern agents containing kaolin, chitosan, or other procoagulant substances facilitate rapid clot formation and improve bleeding control in complex wounds. Systematic reviews have demonstrated superior hemostatic efficacy compared with standard gauze dressings, particularly in environments where immediate surgical intervention is unavailable (Boulton et al., 2018; Welch et al., 2020).

Simultaneously, damage control resuscitation has emerged as a fundamental principle in combat medicine. This approach emphasizes permissive hypotension, balanced blood component therapy, minimization of crystalloid administration, and early correction of trauma-induced coagulopathy. Clinical evidence indicates that these strategies improve physiological stabilization and reduce mortality among severely injured patients (Leibner et al., 2020).

Traumatic Brain Injury in Modern Combat Environments

Traumatic brain injury represents one of the most complex and devastating consequences of contemporary warfare. The widespread use of explosive devices has introduced injury mechanisms rarely encountered in civilian settings, including blast overpressure exposure, primary blast injury, secondary projectile penetration, and tertiary acceleration-deceleration trauma (Benzinger et al., 2009).

TBI is associated with significant short-term and long-term consequences affecting cognitive, behavioral, emotional, and physical functioning. Survivors frequently experience persistent neurological deficits, post-traumatic stress symptoms, depression, chronic headaches, memory impairment, and reduced occupational performance (Maas et al., 2022). These complications contribute substantially to the long-term burden of combat-related disability.

Current understanding recognizes TBI as a dynamic pathological process rather than a single event. Primary injury occurs at the moment of trauma, whereas secondary injury develops through complex biochemical and physiological mechanisms involving cerebral edema, inflammation, oxidative stress, excitotoxicity, and impaired cerebral perfusion (Carney et al., 2017). Consequently, modern neurocritical care strategies focus not only on preventing additional neurological damage but also on optimizing cerebral oxygenation and perfusion throughout the acute phase of injury.

Advances in intracranial pressure monitoring, multimodal neuromonitoring, and neurocritical care protocols have improved outcomes among patients with severe TBI. Updated international guidelines emphasize individualized treatment approaches based on physiological parameters rather than uniform intervention thresholds, reflecting growing recognition of patient-specific variability in neurological responses to trauma (Hawryluk et al., 2020).

Radiological Innovations and Precision Diagnosis

Radiology has become indispensable in the diagnosis and management of combat-related injuries. Conventional imaging techniques continue to play important roles; however, significant technological advances have expanded diagnostic capabilities beyond what was previously possible.

Computed tomography remains the primary imaging modality during the acute assessment of severe trauma due to its speed, availability, and ability to identify life-threatening injuries. Whole-body CT protocols have demonstrated substantial benefits in trauma populations by facilitating rapid identification of injuries involving multiple organ systems and supporting timely surgical decision-making (Wintermark et al., 2015).

Magnetic resonance imaging provides superior characterization of neurological injuries and has become increasingly important in the evaluation of military TBI. Advanced MRI techniques such as diffusion tensor imaging, susceptibility-

weighted imaging, and functional MRI allow clinicians to detect microstructural abnormalities that may not be visible using conventional imaging methods (Riedy et al., 2016).

Emerging technologies including artificial intelligence-assisted image interpretation, automated lesion detection, quantitative neuroimaging, and machine learning-based prognostic models are further enhancing diagnostic precision. These innovations may contribute to earlier intervention, more accurate outcome prediction, and personalized treatment planning in both military and civilian trauma settings.

Portable imaging systems have also expanded diagnostic capabilities within austere environments. Point-of-care ultrasound and deployable imaging technologies allow healthcare providers to perform rapid assessments in battlefield settings, facilitating triage decisions and improving resource allocation during mass casualty incidents.

Damage Control Surgery and Multidisciplinary Management

The concept of damage control surgery has revolutionized trauma care by prioritizing physiological stabilization over definitive anatomical reconstruction during the initial phases of treatment. Combat casualties frequently present with profound hypothermia, acidosis, and coagulopathy, collectively known as the “lethal triad,” which significantly increases mortality risk if not addressed promptly (Galbraith et al., 2023).

Damage control surgery involves abbreviated operative interventions focused on hemorrhage control, contamination prevention, and temporary stabilization. Definitive surgical reconstruction is deferred until physiological conditions improve. This staged approach has demonstrated substantial reductions in mortality among critically injured trauma patients (Lammers et al., 2023).

Successful implementation of damage control principles requires seamless coordination among trauma surgeons, anesthesiologists, neurosurgeons, radiologists, intensivists, rehabilitation specialists, and nursing personnel. Such multidisciplinary collaboration has become a defining characteristic of modern combat casualty care and represents one of the principal factors responsible for improved survival rates observed during recent military conflicts.

Furthermore, rehabilitation strategies now begin during the earliest phases of treatment. Early mobilization, neurological rehabilitation, psychological support, and prosthetic integration programs contribute significantly to functional recovery and quality of life among survivors of severe combat injuries. These interventions reflect a broader shift toward patient-centered care models that emphasize long-term outcomes alongside immediate survival.

Global and Latin American Perspectives

Although many innovations in tactical medicine originated within military contexts, their impact extends far beyond active conflict zones. Civilian trauma systems have increasingly adopted military-derived principles, including tourniquet use, damage control resuscitation, massive transfusion protocols, and multidisciplinary trauma management frameworks.

In Latin America, trauma remains a major public health challenge. Countries such as Mexico, Colombia, and Ecuador continue to strengthen trauma care capabilities through professional training, trauma registry development, emergency preparedness initiatives, and international collaboration. Colombian trauma centers have contributed valuable regional evidence regarding organized trauma systems and outcome monitoring through trauma registry implementation (Ordoñez et al., 2016).

Mexico has likewise expanded trauma system development through academic institutions, military medical services, and specialized trauma centers that integrate contemporary evidence-based practices into emergency care. These efforts illustrate the growing relevance of military medical innovations within broader healthcare systems and underscore the importance of continued international collaboration aimed at improving trauma outcomes worldwide (Rojas et al., 2023).

OBJETIVO GENERAL Y OBJETIVOS ESPECÍFICOS

General Objective

To critically analyze current innovations in war trauma management and tactical medicine, emphasizing advances in hemorrhage control, traumatic brain injury management, radiological technologies, damage control strategies, and multidisciplinary approaches that contribute to improved survival, neurological preservation, and functional recovery in patients affected by complex combat-related injuries.

Specific Objectives**Cognitive Domain**

1. To identify and describe the principal mechanisms of injury associated with contemporary warfare, including blast trauma, penetrating injuries, multisystem trauma, and combat-related neurological damage.
2. To examine the current scientific evidence regarding Tactical Combat Casualty Care (TCCC) and its impact on reducing preventable mortality in military and civilian trauma settings.
3. To analyze the pathophysiological processes involved in traumatic brain injury and their implications for acute management, neurocritical care, and long-term neurological outcomes.
4. To evaluate the role of advanced radiological technologies, including computed tomography, magnetic resonance imaging, diffusion tensor imaging, and emerging artificial intelligence applications, in the diagnosis and management of combat-related injuries.
5. To compare contemporary hemorrhage control strategies, including tourniquets, hemostatic dressings, blood product administration, and damage control resuscitation protocols, based on current evidence reported in the scientific literature.
6. To assess the contribution of multidisciplinary trauma systems in improving patient outcomes during the acute, surgical, and rehabilitation phases of care.

Psychomotor Domain

1. To illustrate the practical application of Tactical Combat Casualty Care principles during the management of battlefield casualties and mass casualty incidents.
2. To describe the procedural implementation of modern hemorrhage control techniques, including tourniquet placement, junctional hemorrhage management, and hemostatic dressing utilization.
3. To examine the integration of advanced imaging modalities into trauma assessment algorithms and clinical decision-making processes.
4. To demonstrate the operational sequence of damage control resuscitation and damage control surgery within contemporary military trauma systems.
5. To analyze the workflow of multidisciplinary trauma teams involved in the diagnosis, stabilization, treatment, and rehabilitation of patients with severe combat-related injuries.

Affective Domain

1. To recognize the humanitarian, ethical, and social implications associated with the care of patients affected by armed conflicts and severe traumatic injuries.
2. To promote appreciation for the importance of evidence-based medicine in improving survival and quality of life among combat trauma victims.
3. To encourage interdisciplinary collaboration among healthcare professionals involved in trauma care, neurosurgery, radiology, rehabilitation, and military medicine.
4. To foster awareness regarding the long-term physical, cognitive, psychological, and social consequences experienced by survivors of war-related injuries.
5. To value the importance of continuous research, innovation, and international cooperation in advancing trauma care systems and improving patient outcomes worldwide.

OBJETO DE ESTUDIO

The object of study of this review is the set of clinical, surgical, radiological, neurological, and tactical interventions currently employed in the management of war-related trauma, with particular emphasis on innovations designed to improve survival, reduce preventable mortality, minimize neurological damage, and enhance functional recovery among individuals exposed to severe combat injuries.

Specifically, this study focuses on the evolution of modern tactical medicine and the scientific advances that have transformed the management of complex battlefield trauma during the twenty-first century. These advances include hemorrhage control technologies, Tactical Combat Casualty Care (TCCC) protocols, damage control resuscitation, damage control surgery, advanced neurocritical care, innovative imaging techniques, multidisciplinary trauma systems, and rehabilitation strategies developed to address the unique challenges associated with combat-related injuries.

The phenomenon under investigation is the progressive transformation of military trauma care resulting from the incorporation of evidence-based practices, technological innovation, and integrated healthcare systems. This transformation has generated substantial improvements in combat casualty survival rates and has significantly influenced civilian trauma care worldwide.

Population of Interest

The population addressed in this review includes military personnel, combatants, civilian victims of armed conflicts, emergency responders, tactical medical teams, and patients exposed to high-energy traumatic events that produce severe physical and neurological injuries.

Particular attention is given to individuals affected by:

- Blast-related injuries.
- Penetrating trauma caused by firearms and shrapnel.
- Polytrauma involving multiple organ systems.
- Severe traumatic brain injury.
- Spinal cord injuries.
- Vascular injuries associated with massive hemorrhage.
- Complex orthopedic trauma.
- Crush injuries and soft tissue destruction.
- Mass casualty incidents occurring in military and civilian environments.

Although many of the analyzed interventions were originally developed for military settings, the study also considers their application within civilian trauma systems due to the increasing transfer of military medical innovations into emergency medicine, disaster response, and critical care practices.

Clinical and Healthcare System Context

Modern war trauma management extends beyond isolated clinical interventions and must be understood as part of an integrated trauma care system. Therefore, the object of study also encompasses the organizational structures, protocols, technologies, and multidisciplinary teams involved in combat casualty management across the continuum of care.

This system includes:

- Prehospital tactical medical care.
- Point-of-injury interventions.

- Battlefield evacuation systems.
- Forward surgical teams.
- Damage control surgical units.
- Intensive care services.
- Neurosurgical and trauma specialty services.
- Radiological diagnostic platforms.
- Rehabilitation and recovery programs.

The interaction among these components directly influences patient outcomes and constitutes a fundamental aspect of contemporary military medicine.

Conceptual Dimensions of the Study

To facilitate a comprehensive analysis, the object of study is examined through five interrelated dimensions.

1. Tactical Medicine Dimension

This dimension focuses on battlefield medical interventions performed during the earliest stages following injury. It includes Tactical Combat Casualty Care principles, hemorrhage control measures, airway management, field triage, casualty evacuation procedures, and operational medical decision-making under hostile conditions.

2. Trauma Surgery Dimension

This dimension evaluates surgical strategies employed in the management of severe combat injuries. Particular emphasis is placed on damage control surgery, vascular repair techniques, orthopedic stabilization, management of penetrating injuries, and staged surgical reconstruction.

3. Neurotrauma Dimension

The neurotrauma component examines traumatic brain injury and other neurological complications associated with warfare. This includes mechanisms of injury, diagnostic approaches, intracranial pressure management, neuroprotective interventions, decompressive surgical procedures, and long-term neurological outcomes.

4. Radiological Innovation Dimension

This dimension investigates the role of modern imaging technologies in combat casualty care. It encompasses computed tomography, magnetic resonance imaging, diffusion tensor imaging, angiographic techniques, portable imaging systems, and emerging artificial intelligence applications that support diagnosis and treatment planning.

5. Rehabilitation and Functional Recovery Dimension

This component addresses post-acute recovery processes, including physical rehabilitation, cognitive rehabilitation, psychological support, prosthetic integration, functional restoration, and long-term quality-of-life outcomes among survivors of severe trauma.

Scope of the Study

The temporal scope of this review primarily focuses on scientific evidence published during the last two decades, a period characterized by substantial advancements in military medicine driven by experiences from contemporary armed conflicts. However, seminal studies and landmark publications that significantly influenced current practices are also incorporated when relevant.

The geographical scope is international, encompassing evidence from North America, Europe, Asia, the Middle East, and Latin America. Special consideration is given to experiences and developments relevant to Mexico, Colombia, and Ecuador, reflecting the growing interest in strengthening trauma systems and emergency preparedness across the Latin American region.

The thematic scope includes:

- War trauma.
- Tactical medicine.
- Massive hemorrhage management.
- Combat casualty care.
- Traumatic brain injury.
- Neurocritical care.
- Military radiology.
- Damage control surgery.
- Damage control resuscitation.
- Rehabilitation after combat injury.
- Military-civilian trauma system integration.

Study Relevance

Understanding the current state of war trauma management has become increasingly important due to the changing nature of modern conflicts and the growing complexity of combat-related injuries. Simultaneously, many innovations developed within military medicine have demonstrated significant value in civilian trauma care, emergency response systems, and disaster medicine.

METODOLOGÍA

This study was conducted as a comprehensive narrative review with a structured methodological approach based on the Scientific Method and the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The methodology was designed to ensure transparency, reproducibility, and rigorous identification of scientific evidence related to war trauma, tactical medicine, neurotrauma, military radiology, damage control strategies, and multidisciplinary management of combat-related injuries.

The review aimed to synthesize current scientific knowledge regarding innovations in the management of massive traumatic injuries and neurological damage occurring in military and combat environments. Through a systematic process of literature identification, screening, selection, analysis, and synthesis, relevant evidence was collected and critically evaluated.

Methodological Approach

The Scientific Method was selected as the primary methodological framework because it allows the organized exploration, analysis, interpretation, and synthesis of existing scientific evidence. The process involved observation of the problem, formulation of research questions, systematic collection of data, critical analysis of findings, and development of evidence-based conclusions.

Simultaneously, PRISMA-based review principles were incorporated to strengthen methodological rigor during literature identification and selection procedures.

The methodological process was divided into five major stages:

1. Problem Identification and Definition.
2. Literature Search and Evidence Collection.
3. Screening and Selection of Studies.
4. Data Extraction and Evidence Analysis.
5. Synthesis and Interpretation of Findings.

Research Question Development

The review was guided by the following central research question:

What are the current innovations in war trauma and tactical medicine that contribute to improved management of massive injuries, hemorrhage control, neurotrauma, radiological diagnosis, and functional recovery among combat casualties?

Secondary questions included:

- How have Tactical Combat Casualty Care protocols influenced survival outcomes?
- What advances have improved hemorrhage control in military settings?
- How are neurotrauma and traumatic brain injuries currently diagnosed and managed?
- What role do modern radiological technologies play in combat casualty care?
- How have damage control surgery and multidisciplinary trauma systems evolved during recent conflicts?
- How can military medical innovations be translated into civilian healthcare systems?

Information Sources

A comprehensive search strategy was implemented using internationally recognized scientific databases with high academic credibility.

The databases consulted included:

- PubMed/MEDLINE.
- Scopus.
- Web of Science.
- ScienceDirect.
- SpringerLink.
- Wiley Online Library.
- Cochrane Library.
- Google Scholar (for supplementary searches).

These databases were selected due to their extensive coverage of medical, surgical, neurological, radiological, trauma, military medicine, and critical care literature.

Search Strategy

Searches were conducted using combinations of Medical Subject Headings (MeSH) and free-text keywords.

Examples of search terms included:

- “War trauma”
- “Combat casualty care”
- “Tactical medicine”
- “Tactical Combat Casualty Care”
- “Battlefield injuries”
- “Military medicine”
- “Traumatic brain injury”
- “Blast injury”
- “Damage control surgery”
- “Damage control resuscitation”
- “Combat hemorrhage”
- “Military radiology”
- “Neurotrauma”
- “Mass casualty management”
- “Combat rehabilitation”

Boolean operators were applied to optimize retrieval:

- AND
- OR
- NOT

Examples:

(“War Trauma” AND “Traumatic Brain Injury”)

(“Combat Casualty Care” AND “Hemorrhage Control”)

(“Military Medicine” AND “Damage Control Surgery”)

(“Blast Injury” AND “Neuroimaging”)

Inclusion Criteria

Studies were included if they met the following criteria:

1. Published in peer-reviewed scientific journals.

2. Available in English or Spanish.
3. Focused on military trauma, tactical medicine, neurotrauma, military radiology, damage control surgery, or combat casualty care.
4. Published between 2005 and 2025.
5. Presented original research, systematic reviews, meta-analyses, consensus statements, clinical guidelines, or high-quality narrative reviews.
6. Included evidence relevant to adult populations.
7. Reported clinical, diagnostic, surgical, neurological, or rehabilitation outcomes.

Exclusion Criteria

Studies were excluded when they:

1. Lacked scientific peer review.
2. Presented insufficient methodological information.
3. Focused exclusively on veterinary or experimental animal models without clinical relevance.
4. Were duplicate publications.
5. Included unrelated trauma mechanisms without applicability to combat or tactical medicine.
6. Consisted solely of conference abstracts without full-text availability.

Study Selection Process

The study selection process followed four sequential stages adapted from PRISMA recommendations.

Stage 1: Identification

Potentially relevant articles were identified through database searches using predefined keywords and search strings.

Stage 2: Screening

Titles and abstracts were reviewed to determine initial relevance.

Articles clearly unrelated to combat trauma, tactical medicine, neurotrauma, or military medical innovations were excluded.

Stage 3: Eligibility Assessment

Full-text versions of eligible articles were retrieved and evaluated according to the inclusion and exclusion criteria.

Methodological quality, scientific relevance, and contribution to the review objectives were considered during this phase.

Stage 4: Final Inclusion

Studies meeting all eligibility criteria were incorporated into the final evidence synthesis.

Data Extraction

Data extraction was performed using a structured review matrix developed specifically for this study.

The following variables were collected:

- Author(s).
- Year of publication.
- Country of origin.
- Study design.
- Sample characteristics.
- Type of injury investigated.
- Intervention evaluated.
- Diagnostic method utilized.
- Main findings.
- Clinical implications.
- Limitations identified.

This standardized process facilitated comparison across studies and enhanced consistency during evidence synthesis.

Data Analysis

A qualitative thematic analysis approach was employed to organize and interpret the collected evidence.

Studies were classified into major thematic categories:

Category 1

Tactical Combat Casualty Care and Prehospital Interventions.

Category 2

Hemorrhage Control Technologies and Damage Control Resuscitation.

Category 3

Traumatic Brain Injury and Neurocritical Care.

Category 4

Radiological Innovations and Diagnostic Advances.

Category 5

Damage Control Surgery and Multidisciplinary Trauma Systems.

Category 6

Rehabilitation and Long-Term Functional Recovery.

Thematic grouping facilitated identification of recurring findings, emerging innovations, clinical trends, and evidence gaps within the literature.

Reliability and Validity

To strengthen scientific rigor, evidence was obtained exclusively from reputable databases and peer-reviewed sources.

Preference was given to:

- Clinical guidelines.
- Systematic reviews.
- Meta-analyses.
- Multicenter studies.
- Consensus statements.
- High-impact scientific journals.

Cross-comparison among studies was performed to verify consistency of findings and reduce potential interpretation bias.

Ethical Considerations

This review utilized exclusively secondary data obtained from publicly available scientific publications.

No human participants, biological samples, confidential records, or personal information were directly involved in the investigation.

Therefore, formal ethical committee approval and informed consent procedures were not required.

Nevertheless, ethical principles related to scientific integrity, transparency, accurate citation practices, responsible interpretation of evidence, and respect for intellectual property were maintained throughout the research process.

Replicability of the Study

The methodological procedures described in this review were intentionally documented in detail to facilitate reproducibility by future researchers.

The use of clearly defined research questions, standardized search strategies, explicit eligibility criteria, structured data extraction procedures, and systematic evidence synthesis allows independent investigators to replicate the review process, update findings with newly published literature, or adapt the methodology to related topics within military medicine, trauma surgery, neurotrauma, emergency medicine, and critical care research.

FASES DEL DESARROLLO

Phase 1. Problem Identification and Definition

The first phase of the investigation consisted of identifying and defining the central problem addressed by the review. Contemporary armed conflicts have generated increasingly complex patterns of injury due to the widespread use of explosive devices, high-energy projectiles, urban combat operations, and advanced military technologies. These mechanisms frequently produce multisystem trauma involving severe hemorrhage, traumatic brain injury, orthopedic destruction, vascular compromise, and extensive soft tissue damage.

Despite substantial advances in military medicine over recent decades, combat-related trauma continues to represent a major cause of mortality and long-term disability worldwide. Reports from recent military operations indicate that hemorrhage and traumatic brain injury remain among the leading causes of preventable battlefield deaths. Furthermore, survivors often experience prolonged physical, cognitive, neurological, and psychological consequences that require extensive rehabilitation and multidisciplinary care (Maas et al., 2022; Deaton et al., 2024).

The identification of this problem highlighted the need to comprehensively evaluate current innovations in tactical medicine and combat casualty management. Particular attention was directed toward emerging strategies that have demonstrated potential to improve survival rates, optimize neurological outcomes, enhance diagnostic accuracy, and facilitate functional recovery among severely injured patients.

Based on this problem identification process, the review was designed to investigate how modern advances in hemorrhage control, neurocritical care, radiological imaging, damage control surgery, and integrated trauma systems have transformed contemporary management of war-related injuries.

The outcomes of this phase included:

- Definition of the study focus.
- Identification of major clinical challenges.
- Formulation of research questions.
- Delimitation of thematic boundaries.
- Establishment of review objectives.

These elements provided the conceptual foundation for subsequent stages of the investigation.

Phase 2. Literature Search and Evidence Collection

Following problem identification, a comprehensive literature search strategy was developed to obtain high-quality scientific evidence relevant to the study objectives.

The search process was designed to maximize sensitivity while maintaining specificity regarding military trauma, tactical medicine, neurotrauma, radiological innovation, and damage control approaches. Multiple internationally recognized databases were consulted, including PubMed/MEDLINE, Scopus, Web of Science, ScienceDirect, SpringerLink, Wiley Online Library, Cochrane Library, and Google Scholar.

A structured combination of Medical Subject Headings (MeSH) and free-text keywords was employed. Search terms were selected based on their relevance to the principal concepts under investigation.

Examples included:

- War trauma.
- Combat casualty care.
- Tactical medicine.
- Tactical Combat Casualty Care.
- Battlefield injuries.
- Military medicine.
- Traumatic brain injury.
- Blast injury.
- Combat hemorrhage.
- Damage control surgery.
- Neurocritical care.
- Military radiology.
- Combat rehabilitation.

Boolean operators were utilized to refine search results and improve retrieval efficiency. Various combinations of keywords were tested to ensure comprehensive coverage of the available literature.

The search process generated a broad collection of scientific publications encompassing clinical trials, observational studies, systematic reviews, meta-analyses, consensus statements, military medical guidelines, and expert recommendations.

Special emphasis was placed on identifying publications addressing:

- Battlefield hemorrhage control.
- Blast-induced neurotrauma.
- Advanced diagnostic imaging.
- Combat surgery innovations.
- Tactical prehospital care.
- Military rehabilitation strategies.
- Integration of military and civilian trauma systems.

This phase ensured the acquisition of a robust evidence base capable of supporting a comprehensive evaluation of contemporary advances in combat casualty management.

Phase 3. Screening, Eligibility Assessment, and Study Selection

The third phase focused on the systematic evaluation of all retrieved publications to determine their suitability for inclusion in the review.

Initially, titles and abstracts were screened to identify studies directly relevant to the predefined research questions. Publications unrelated to military trauma, tactical medicine, neurotrauma, radiological innovation, or damage control management were excluded during this preliminary assessment.

Subsequently, full-text articles were obtained for detailed eligibility evaluation. Each study was assessed according to predefined inclusion and exclusion criteria.

The evaluation process considered several methodological factors, including:

- Study design.
- Sample characteristics.
- Scientific relevance.
- Methodological rigor.
- Clinical applicability.
- Consistency with review objectives.

Priority was given to high-level evidence such as:

- Clinical practice guidelines.
- Systematic reviews.
- Meta-analyses.

- Multicenter studies.
- Consensus documents.
- Landmark military medicine publications.

Particular attention was paid to studies investigating innovations that demonstrated measurable impacts on mortality, morbidity, neurological preservation, diagnostic performance, or rehabilitation outcomes.

During this stage, duplicate records were removed, methodological limitations were assessed, and evidence quality was considered to ensure the reliability of the final synthesis.

The final selection process resulted in a focused body of literature representing the most relevant and scientifically robust evidence available regarding modern war trauma and tactical medicine.

Phase 4. Data Extraction and Thematic Analysis

After final study selection, a structured data extraction process was conducted to facilitate systematic analysis of the collected evidence.

A standardized review matrix was developed to ensure consistency across all included studies. Relevant information was extracted and organized according to predefined variables.

These variables included:

- Author information.
- Publication year.
- Geographic origin.
- Study design.
- Population characteristics.
- Injury type.
- Intervention investigated.
- Diagnostic methods.
- Clinical outcomes.
- Main conclusions.
- Identified limitations.

Once data extraction was completed, thematic analysis was performed to identify recurring concepts, innovations, trends, and evidence gaps across the literature.

The analysis revealed several dominant themes that consistently emerged throughout the reviewed studies.

The first major theme involved advances in Tactical Combat Casualty Care and battlefield interventions. Numerous investigations demonstrated the effectiveness of early hemorrhage control, rapid casualty assessment, and evidence-based prehospital management protocols.

The second theme focused on innovations in hemorrhage control technologies. Tourniquets, hemostatic dressings, junctional hemorrhage devices, blood product administration, and damage control resuscitation strategies were repeatedly associated with improved survival outcomes.

A third thematic area involved traumatic brain injury management. Studies highlighted advances in neurocritical care, intracranial pressure monitoring, decompressive surgery, and individualized neurological treatment approaches.

Radiological innovation constituted a fourth major category. Research demonstrated the growing importance of advanced neuroimaging, whole-body computed tomography, magnetic resonance imaging, diffusion tensor imaging, and emerging artificial intelligence-assisted diagnostic systems.

Damage control surgery emerged as another critical theme. Evidence consistently supported staged surgical approaches designed to prioritize physiological stabilization before definitive reconstruction.

Finally, rehabilitation and functional recovery were identified as essential components of modern combat casualty care. Increasing attention has been directed toward long-term neurological recovery, psychological support, prosthetic integration, and quality-of-life outcomes.

This thematic framework provided the organizational structure for evidence synthesis and interpretation.

Phase 5. Evidence Synthesis and Interpretation of Findings

The final phase consisted of integrating the extracted evidence into a coherent scientific narrative capable of addressing the review objectives and research questions.

During this stage, findings from diverse studies were compared, contrasted, and interpreted within the broader context of contemporary military medicine and trauma care.

The synthesis revealed that one of the most significant achievements in modern combat casualty management has been the substantial reduction in preventable battlefield deaths through implementation of Tactical Combat Casualty Care principles. Improvements in hemorrhage control have played a particularly important role in these outcomes.

Evidence also demonstrated that advances in neurocritical care and traumatic brain injury management have contributed to better neurological preservation and long-term functional recovery. Improved understanding of secondary brain injury mechanisms has facilitated more targeted therapeutic interventions and enhanced patient monitoring.

RESULTADOS Y DISCUSIÓN

Figure 1.

Major Innovations Identified in Contemporary War Trauma and Tactical Medicine

Innovation Area	Principal Advances	Reported Clinical Impact
Hemorrhage Control	Combat tourniquets, junctional tourniquets, hemostatic dressings	Reduction in preventable deaths from exsanguination
Tactical Combat Casualty Care (TCCC)	Standardized battlefield protocols	Improved prehospital survival
Neurotrauma Management	Advanced neuromonitoring, decompressive craniectomy, neurocritical care	Better neurological outcomes
Military Radiology	Whole-body CT, advanced MRI, diffusion tensor imaging	Earlier and more accurate diagnosis
Damage Control Surgery	Staged surgical interventions	Increased survival among critically injured patients
Rehabilitation Programs	Early multidisciplinary rehabilitation	Improved functional recovery

The findings presented in Figure 1 demonstrate that modern war trauma management has evolved from isolated emergency interventions into a comprehensive multidisciplinary system focused on improving survival and long-term recovery. Among all innovations identified in the reviewed literature, advances in hemorrhage control emerged as one of the most influential factors responsible for reducing preventable battlefield mortality. Multiple investigations

reported that rapid application of combat tourniquets and modern hemostatic dressings substantially decreased deaths related to exsanguination, particularly during the prehospital phase where immediate surgical care is unavailable (Kragh et al., 2009; Kragh et al., 2011).

The implementation of Tactical Combat Casualty Care protocols represented another major advancement. Evidence consistently demonstrated that standardized battlefield algorithms improved decision-making under hostile conditions by prioritizing hemorrhage control, airway management, and timely casualty evacuation. The widespread adoption of TCCC principles has been associated with measurable improvements in combat survival rates across several military operations, reinforcing the importance of evidence-based tactical medicine in contemporary warfare (Deaton et al., 2024).

Neurotrauma management also showed significant progress throughout the reviewed studies. Historically, traumatic brain injury was associated with extremely poor outcomes in combat settings due to delayed diagnosis and limited therapeutic options. However, advances in neurocritical care, intracranial pressure monitoring, and decompressive surgical techniques have substantially improved neurological preservation and reduced secondary brain injury. Current evidence suggests that individualized management strategies contribute to improved cognitive and functional outcomes among survivors of severe traumatic brain injury (Carney et al., 2017; Hawryluk et al., 2020).

Radiological innovations emerged as another transformative component of modern combat medicine. The integration of whole-body computed tomography, advanced magnetic resonance imaging, and specialized neuroimaging techniques has increased diagnostic precision while accelerating treatment planning. These technologies enable clinicians to rapidly identify life-threatening injuries involving multiple organ systems and improve the detection of subtle neurological abnormalities that might otherwise remain undiagnosed (Wintermark et al., 2015; Riedy et al., 2016).

Similarly, damage control surgery has fundamentally altered the management of critically injured combat casualties. Rather than pursuing definitive surgical reconstruction during the initial phase of treatment, contemporary approaches prioritize physiological stabilization through abbreviated procedures aimed at controlling hemorrhage and contamination. This strategy has demonstrated substantial reductions in mortality among severely injured patients and has become a cornerstone of both military and civilian trauma systems (Galbraith et al., 2023; Lammers et al., 2023).

Finally, the reviewed literature highlighted the growing importance of rehabilitation programs as an integral component of trauma care. Advances in physical rehabilitation, neurological recovery programs, psychological support, and prosthetic integration have expanded the focus of military medicine beyond survival alone. Modern trauma systems increasingly recognize that successful outcomes depend not only on acute management but also on the restoration of functional independence and quality of life among survivors of severe combat injuries (Maas et al., 2022).

Figure 2.

Impact of Hemorrhage Control Strategies on Preventable Battlefield Mortality

Hemorrhage Control Strategy	Main Application	Reported Benefit
Extremity Tourniquets	Severe limb bleeding	Significant reduction in preventable deaths
Junctional Tourniquets	Groin and axillary hemorrhage	Improved control of non-compressible bleeding
Hemostatic Dressings	Deep and irregular wounds	Faster clot formation and bleeding control
Whole Blood Transfusion	Severe hemorrhagic shock	Enhanced oxygen delivery and hemostatic support
Damage Control Resuscitation	Polytrauma with massive bleeding	Improved physiological stabilization
Massive Transfusion Protocols	Critical hemorrhage	Reduced trauma-induced coagulopathy

The findings summarized in Figure 2 demonstrate that hemorrhage control remains the most critical intervention for reducing preventable mortality in modern combat environments. Across the reviewed literature, uncontrolled bleeding was consistently identified as the leading cause of potentially survivable battlefield deaths, particularly during the prehospital phase of care. As a result, substantial scientific and operational efforts have been directed toward developing more effective strategies capable of controlling hemorrhage before definitive surgical treatment becomes available (Kragh et al., 2009; Rossaint et al., 2023).

One of the most influential innovations identified was the widespread adoption of extremity tourniquets. Historical concerns regarding ischemic injury and limb loss limited their use in earlier military conflicts. However, evidence generated during recent military operations demonstrated that appropriately applied tourniquets significantly improve survival while maintaining acceptable complication rates. Studies conducted among combat casualties showed that early tourniquet application before the onset of hemorrhagic shock was associated with markedly improved survival outcomes compared with delayed intervention (Kragh et al., 2011). These findings have led to the universal incorporation of tourniquets into contemporary Tactical Combat Casualty Care protocols.

The literature also highlighted the importance of junctional hemorrhage control devices. Unlike extremity injuries, hemorrhage occurring in anatomical transition zones such as the groin, pelvis, neck, and axilla presents unique challenges because conventional tourniquets cannot be effectively applied. Junctional tourniquets and specialized compression systems have emerged as valuable alternatives for managing these injuries, reducing blood loss and improving stabilization during evacuation (Shackelford et al., 2015). The development of such technologies reflects the increasing sophistication of battlefield medical equipment and the adaptation of trauma care to the realities of modern warfare.

Another major advancement involves the use of hemostatic dressings. Multiple studies demonstrated that dressings impregnated with procoagulant agents such as kaolin or chitosan accelerate clot formation and improve bleeding control when compared with standard gauze dressings. Their effectiveness has been particularly notable in deep, irregular, or anatomically complex wounds where direct compression alone may be insufficient. Systematic reviews have consistently reported improved hemostatic performance and greater success in controlling life-threatening hemorrhage under austere conditions (Boulton et al., 2018; Welch et al., 2020).

Beyond mechanical bleeding control, the reviewed evidence emphasized the transformative role of modern transfusion practices. Recent military experiences have supported the reintroduction of whole blood transfusion as an effective strategy for managing severe hemorrhagic shock. Whole blood provides red blood cells, plasma, and platelets

simultaneously, thereby addressing oxygen delivery deficits and coagulopathy more efficiently than isolated blood components. Several investigations reported improved hemodynamic stability and enhanced survival among critically injured patients receiving early whole blood transfusions (Leibner et al., 2020).

Damage control resuscitation emerged as another cornerstone of contemporary hemorrhage management. This strategy emphasizes permissive hypotension, balanced blood component administration, minimization of crystalloid infusion, and early correction of trauma-induced coagulopathy. Evidence suggests that these principles reduce dilutional coagulopathy, improve tissue perfusion, and mitigate the physiological deterioration associated with severe trauma. Importantly, damage control resuscitation functions synergistically with damage control surgery, creating an integrated approach that prioritizes physiological stabilization during the most critical stages of injury management (Galbraith et al., 2023).

The reviewed studies further demonstrated the importance of massive transfusion protocols in addressing severe combat hemorrhage. Standardized protocols facilitate rapid administration of blood products in predetermined ratios, reducing delays in treatment and improving coordination among trauma teams. These protocols have been associated with lower mortality rates and improved correction of coagulopathy, particularly among patients experiencing massive blood loss (Lammers et al., 2023).

An additional observation from the literature is that advances in hemorrhage control have not remained confined to military settings. Many techniques initially developed for combat casualty care have been adopted by civilian emergency medical systems, trauma centers, and disaster response organizations worldwide. This transfer of knowledge illustrates the profound influence of military medicine on modern trauma care and underscores the broader public health significance of innovations originating from battlefield experiences.

Figure 3.

Contemporary Approaches to Traumatic Brain Injury Management in Combat Casualties

Clinical Component	Current Innovations	Expected Clinical Benefit
Early Neurological Assessment	Standardized combat neurological evaluation protocols	Faster identification of severe injuries
Neuroimaging	Whole-body CT, advanced MRI, diffusion tensor imaging	Improved diagnostic accuracy
Intracranial Pressure Monitoring	Continuous multimodal monitoring systems	Early detection of secondary brain injury
Neurosurgical Management	Decompressive craniectomy and advanced surgical techniques	Reduction of intracranial hypertension
Neurocritical Care	Individualized cerebral perfusion strategies	Improved neurological preservation
Rehabilitation	Early cognitive and physical rehabilitation programs	Enhanced long-term functional recovery

The results presented in Figure 3 highlight the remarkable progress achieved in the diagnosis, monitoring, treatment, and rehabilitation of traumatic brain injury (TBI) within modern military medicine. Among all combat-related injuries, TBI remains one of the most challenging conditions due to its complex pathophysiology, high mortality rate, and potential for long-term neurological disability. The reviewed literature consistently identified TBI as a major contributor to morbidity among military personnel and civilian victims exposed to explosive devices, high-velocity projectiles, and blast waves associated with contemporary warfare (Maas et al., 2022).

One of the most important developments identified in the literature involves the implementation of standardized neurological assessment protocols during the earliest stages of care. Rapid recognition of neurological deterioration is critical because delayed diagnosis increases the risk of secondary brain injury, which often contributes more significantly to poor outcomes than the primary traumatic event itself. Tactical medicine guidelines increasingly emphasize systematic neurological evaluation during casualty assessment, allowing healthcare providers to identify severe injuries and prioritize urgent interventions during evacuation and definitive treatment (Deaton et al., 2024).

Advances in neuroimaging have dramatically improved the understanding and management of combat-related TBI. Computed tomography remains the cornerstone of acute evaluation because it provides rapid identification of intracranial hemorrhage, skull fractures, cerebral edema, and mass lesions requiring urgent intervention. However, the reviewed studies demonstrated that advanced magnetic resonance imaging techniques have expanded diagnostic capabilities beyond conventional imaging. Diffusion tensor imaging, susceptibility-weighted imaging, and functional MRI can detect subtle microstructural abnormalities and diffuse axonal injuries that may not be visible on standard CT scans (Wintermark et al., 2015; Riedy et al., 2016).

These technological developments are particularly relevant in military settings because blast-related injuries frequently produce complex neurological damage that may be difficult to identify using traditional imaging approaches. Blast exposure can generate microscopic structural changes affecting neuronal pathways and white matter integrity, leading to cognitive and behavioral impairments even in the absence of obvious radiological findings. Advanced neuroimaging techniques therefore play an essential role in improving diagnostic precision and supporting individualized treatment planning (Benzinger et al., 2009).

The reviewed evidence also highlighted substantial progress in intracranial pressure monitoring. Elevated intracranial pressure is a major determinant of mortality following severe TBI because it compromises cerebral perfusion and promotes secondary neurological injury. Contemporary monitoring systems allow continuous assessment of intracranial dynamics, enabling clinicians to identify physiological deterioration before irreversible damage occurs. This proactive approach facilitates timely therapeutic interventions aimed at preserving cerebral function and preventing neurological decline (Carney et al., 2017).

Neurosurgical innovations emerged as another critical component of modern combat casualty care. Decompressive craniectomy has become an important therapeutic option for patients experiencing refractory intracranial hypertension. Several studies reported that carefully selected patients benefit from surgical decompression through reduced intracranial pressure, improved cerebral perfusion, and enhanced survival. Although long-term functional outcomes vary according to injury severity and patient characteristics, evidence supports the role of decompressive procedures within comprehensive neurocritical care strategies (Hawryluk et al., 2020).

Modern neurocritical care extends beyond surgical intervention and increasingly emphasizes individualized physiological management. Rather than relying on uniform treatment thresholds, current approaches focus on optimizing cerebral perfusion pressure, oxygen delivery, metabolic support, and neurological monitoring according to patient-specific characteristics. This personalized model reflects growing recognition that traumatic brain injury is a heterogeneous condition requiring tailored therapeutic strategies to maximize neurological recovery (Meyfroidt et al., 2022).

An equally important finding from the reviewed literature concerns the growing role of rehabilitation in TBI management. Historically, trauma care focused primarily on acute survival; however, contemporary military medicine increasingly recognizes that functional recovery represents a crucial determinant of long-term outcomes. Early cognitive rehabilitation, physical therapy, occupational therapy, speech therapy, and psychological support have demonstrated benefits in improving neurological function, independence, and quality of life among survivors of severe brain injury. Rehabilitation programs initiated during the early phases of recovery appear particularly effective in promoting neuroplasticity and reducing long-term disability (Maas et al., 2022).

The evidence further suggests that advances in combat-related TBI management have generated substantial benefits for civilian healthcare systems. Techniques developed in military environments have been incorporated into civilian trauma centers, neurocritical care units, and emergency medicine protocols worldwide. This transfer of knowledge has contributed to broader improvements in brain injury management beyond the battlefield, illustrating the reciprocal relationship between military and civilian medical innovation.

Figure 4.

Contributions of Advanced Radiology and Diagnostic Technologies to Combat Trauma Management

Diagnostic Technology	Primary Application	Clinical Contribution
Whole-Body Computed Tomography (WBCT)	Rapid assessment of polytrauma	Early identification of life-threatening injuries
Conventional Magnetic Resonance Imaging (MRI)	Neurological and soft tissue evaluation	Improved lesion characterization
Diffusion Tensor Imaging (DTI)	Detection of diffuse axonal injury	Enhanced evaluation of traumatic brain injury
CT Angiography	Vascular injury assessment	Rapid diagnosis of arterial damage
Portable Ultrasound (POCUS)	Battlefield and prehospital evaluation	Immediate bedside decision-making
Artificial Intelligence-Assisted Imaging	Automated image analysis	Increased diagnostic efficiency and precision

The findings presented in Figure 4 demonstrate that advances in radiological technologies have become fundamental components of contemporary combat trauma management. Modern warfare frequently produces highly complex injury patterns involving multiple organ systems, vascular structures, musculoskeletal tissues, and the central nervous system. Under these circumstances, rapid and accurate diagnosis becomes essential for guiding treatment decisions, prioritizing interventions, and improving patient outcomes. The reviewed literature consistently identified radiological innovation as one of the major contributors to advances in military medicine over the last two decades (Wintermark et al., 2015).

Among the diagnostic modalities evaluated, whole-body computed tomography (WBCT) emerged as one of the most influential developments in trauma assessment. Combat casualties often present with polytrauma involving simultaneous injuries to the head, thorax, abdomen, pelvis, and extremities. Traditional sequential diagnostic approaches may delay identification of critical injuries, thereby increasing morbidity and mortality. WBCT protocols enable rapid comprehensive evaluation of the entire body within minutes, facilitating immediate recognition of hemorrhage, organ damage, fractures, vascular disruption, and neurological injury. Several studies reported that early utilization of WBCT improves diagnostic efficiency and contributes to more timely surgical decision-making in severely injured patients (Wintermark et al., 2015).

Magnetic resonance imaging has also become increasingly important, particularly in the assessment of neurological and soft tissue injuries. Although MRI is generally less accessible during the acute phase of combat casualty care, its superior soft tissue contrast allows detailed characterization of injuries that may not be adequately visualized through

computed tomography. The reviewed evidence indicates that MRI contributes significantly to the evaluation of spinal cord trauma, ligamentous injuries, cerebral lesions, and long-term neurological complications associated with blast exposure and penetrating trauma (Riedy et al., 2016).

One of the most notable innovations identified in the literature is diffusion tensor imaging. DTI represents an advanced MRI technique capable of evaluating white matter integrity and detecting diffuse axonal injury, one of the most common yet difficult-to-diagnose consequences of traumatic brain injury. Conventional imaging frequently fails to identify microscopic neuronal damage despite the presence of significant neurological symptoms. DTI provides a more sensitive method for detecting these abnormalities, thereby improving diagnostic accuracy and enhancing understanding of the underlying mechanisms responsible for persistent cognitive and behavioral deficits observed among combat survivors (Benzinger et al., 2009).

The reviewed studies also emphasized the growing importance of CT angiography in military trauma care. Vascular injuries represent a major cause of mortality and limb loss following combat trauma. Rapid identification of arterial disruption is crucial because delays in diagnosis may result in catastrophic hemorrhage, tissue ischemia, and irreversible damage. CT angiography offers a fast and highly accurate method for evaluating vascular integrity, enabling clinicians to identify injuries requiring immediate surgical or endovascular intervention. Its widespread implementation has significantly improved the management of vascular trauma in both military and civilian settings (Wintermark et al., 2015).

Portable ultrasound technology has introduced another important advancement, particularly in prehospital and battlefield environments. Point-of-care ultrasound (POCUS) allows healthcare providers to perform rapid bedside assessments in austere settings where access to advanced imaging may be limited. The literature demonstrated that portable ultrasound contributes to the detection of internal bleeding, thoracic injuries, cardiac tamponade, and other life-threatening conditions requiring urgent intervention. Its portability, speed, and ease of use make it especially valuable during casualty evacuation and mass casualty incidents (Meyfroidt et al., 2022).

A particularly emerging area of interest involves the integration of artificial intelligence into radiological practice. Recent investigations have explored machine learning algorithms capable of assisting clinicians in image interpretation, lesion detection, injury classification, and outcome prediction. Artificial intelligence-assisted imaging systems have shown promise in reducing diagnostic delays, increasing accuracy, and supporting decision-making during high-volume trauma scenarios. Although many applications remain under development, the reviewed evidence suggests that AI may become an increasingly important component of future military medical systems (Maas et al., 2022).

An additional finding from the literature concerns the strategic role of radiology in multidisciplinary trauma care. Diagnostic imaging no longer functions solely as a tool for confirming injuries; instead, it actively guides treatment planning, surgical prioritization, critical care management, and rehabilitation strategies. The integration of advanced imaging findings into clinical decision-making processes has improved communication among trauma surgeons, neurosurgeons, radiologists, intensivists, and rehabilitation specialists, thereby enhancing overall patient management.

The reviewed studies further indicate that innovations initially developed for military applications have rapidly influenced civilian trauma systems. Whole-body CT protocols, portable ultrasound programs, advanced neuroimaging techniques, and AI-assisted diagnostic tools are increasingly utilized in emergency departments, trauma centers, and

disaster response systems worldwide. This transfer of technology illustrates the broader impact of military medical research on global healthcare delivery.

Figure 5.
Multidisciplinary Trauma Systems and Their Influence on Survival and Functional Recovery

Component of the Trauma System	Principal Function	Impact on Patient Outcomes
Tactical Combat Casualty Care Teams	Immediate battlefield stabilization	Reduced prehospital mortality
Forward Surgical Teams	Rapid surgical intervention near combat zones	Earlier hemorrhage and injury control
Damage Control Surgery Units	Physiological stabilization of critical casualties	Improved short-term survival
Intensive Care and Neurocritical Care Services	Management of severe systemic and neurological injuries	Reduced complications and secondary injury
Rehabilitation Programs	Physical, cognitive, and psychological recovery	Enhanced long-term functionality
Integrated Multidisciplinary Networks	Coordination among specialties	Improved continuity of care and recovery outcomes

The findings presented in Figure 5 demonstrate that modern combat casualty care extends far beyond isolated medical interventions and increasingly relies on highly coordinated multidisciplinary trauma systems. The reviewed literature consistently emphasized that survival and recovery following severe war-related injuries depend not only on individual treatments but also on the effectiveness of the healthcare network responsible for managing patients throughout the entire continuum of care. This evolution represents one of the most important paradigm shifts in military medicine during the twenty-first century (Galbraith et al., 2023).

One of the first critical elements identified in the literature is the role of Tactical Combat Casualty Care teams operating at the point of injury. These personnel are responsible for delivering immediate life-saving interventions under highly challenging conditions. Early hemorrhage control, airway management, casualty assessment, and rapid evacuation decisions significantly influence subsequent clinical outcomes. Studies conducted during recent military operations demonstrated that improvements in tactical prehospital care contributed substantially to reductions in preventable battlefield deaths, particularly among patients suffering from severe hemorrhage and traumatic brain injury (Deaton et al., 2024).

The reviewed evidence also highlighted the importance of forward surgical teams positioned near combat zones. These units represent a major innovation in military healthcare because they allow definitive surgical interventions to occur much closer to the site of injury than was historically possible. Rapid access to surgery reduces delays in hemorrhage control, vascular repair, decompression procedures, and stabilization of life-threatening injuries. Several investigations reported that shorter times between injury and surgical intervention were associated with improved survival and lower complication rates among combat casualties (Leibner et al., 2020).

Damage control surgery units emerged as another essential component of modern trauma systems. The reviewed studies consistently demonstrated that severely injured patients benefit from staged surgical approaches that prioritize

physiological stabilization rather than immediate definitive reconstruction. This strategy is particularly important in combat environments where patients frequently present with hypothermia, acidosis, and coagulopathy. By focusing initially on hemorrhage control and contamination prevention, damage control surgery allows restoration of physiological stability before more extensive reconstructive procedures are attempted, thereby reducing mortality and improving overall outcomes (Lammers et al., 2023).

Intensive care and neurocritical care services were identified as equally important contributors to survival. Following initial stabilization and surgery, many combat casualties require prolonged monitoring and advanced organ support. The literature demonstrated that contemporary intensive care units play a central role in managing respiratory failure, hemodynamic instability, infections, coagulopathy, and neurological complications. In patients with severe traumatic brain injury, specialized neurocritical care protocols help prevent secondary brain injury through continuous monitoring of cerebral physiology and individualized therapeutic interventions (Carney et al., 2017; Meyfroidt et al., 2022).

An especially important finding concerns the expanding role of rehabilitation within military trauma systems. Historically, trauma care focused primarily on acute survival. However, advances in battlefield medicine have increased survival rates among patients with injuries that were previously fatal, creating a growing population of individuals requiring long-term rehabilitation services. The reviewed studies consistently emphasized that physical therapy, occupational therapy, neurocognitive rehabilitation, psychological support, prosthetic training, and social reintegration programs significantly influence long-term outcomes. Early initiation of rehabilitation interventions has been associated with improved mobility, cognitive function, psychological adjustment, and quality of life among survivors of severe combat trauma (Maas et al., 2022).

The literature further revealed that integrated multidisciplinary networks represent the defining characteristic of contemporary trauma systems. Modern combat casualty management increasingly depends upon collaboration among emergency physicians, trauma surgeons, neurosurgeons, radiologists, intensivists, rehabilitation specialists, psychologists, nurses, and allied healthcare professionals. This collaborative framework facilitates continuity of care and ensures that treatment decisions are informed by multiple areas of expertise. Evidence suggests that multidisciplinary coordination improves clinical efficiency, reduces complications, and promotes more comprehensive recovery pathways for severely injured patients (Galbraith et al., 2023).

Another significant observation is the growing convergence between military and civilian trauma systems. Many organizational principles originally developed within military medicine—including trauma networks, rapid transport systems, damage control approaches, and integrated rehabilitation programs—have been successfully adopted by civilian healthcare systems worldwide. This exchange of knowledge has contributed to improvements in emergency preparedness, disaster response, and trauma care delivery across diverse healthcare environments. Countries such as Mexico, Colombia, and Ecuador have increasingly incorporated these principles into trauma education, emergency medicine training, and hospital preparedness initiatives, reflecting the global influence of military medical innovation (Ordoñez et al., 2016; Rojas et al., 2023).

The reviewed evidence also identified several challenges that continue to affect multidisciplinary trauma systems. These include disparities in access to advanced technologies, logistical difficulties in austere environments, variability in rehabilitation resources, and the need for continued education and training among healthcare professionals. Additionally, evolving patterns of warfare and emerging injury mechanisms require ongoing adaptation of trauma systems to ensure continued effectiveness in future conflicts.

DISCUSIÓN

The present review provides a comprehensive analysis of current innovations in war trauma and tactical medicine, highlighting how advances in hemorrhage control, neurotrauma management, radiological technologies, damage control strategies, and multidisciplinary trauma systems have transformed the care of combat casualties. The findings demonstrate that modern military medicine has evolved from a reactive model focused primarily on acute survival into a highly specialized, evidence-based discipline that emphasizes rapid intervention, physiological stabilization, neurological preservation, and long-term functional recovery.

One of the most significant findings emerging from this review is the continued importance of hemorrhage control as the primary determinant of survival following severe combat injury. Despite major technological and organizational advances in military healthcare, uncontrolled bleeding remains the leading cause of preventable death on the battlefield. However, the widespread implementation of Tactical Combat Casualty Care principles has substantially altered this reality. The introduction of combat tourniquets, junctional hemorrhage control devices, advanced hemostatic dressings, and modern transfusion strategies has resulted in measurable reductions in battlefield mortality. These observations are consistent with previous studies demonstrating that rapid hemorrhage control during the prehospital phase significantly improves survival and reduces the incidence of irreversible shock and organ failure (Kragh et al., 2009; Kragh et al., 2011).

The findings also support the growing recognition that successful trauma management requires intervention during the earliest stages of injury. Historically, many battlefield deaths occurred before casualties reached definitive surgical care. Contemporary tactical medicine seeks to address this challenge by delivering life-saving interventions at the point of injury. The reviewed evidence suggests that this shift toward immediate battlefield treatment has been one of the most influential developments in modern military medicine. The effectiveness of Tactical Combat Casualty Care protocols demonstrates the value of standardized evidence-based approaches capable of guiding medical decision-making under highly stressful and resource-constrained conditions (Deaton et al., 2024).

Traumatic brain injury emerged as another central theme throughout the literature. Modern conflicts have increased exposure to blast mechanisms, high-energy projectiles, and complex injury patterns that frequently involve the central nervous system. The reviewed studies indicate that advances in neurocritical care have improved both survival and neurological outcomes among patients with severe traumatic brain injury. Continuous intracranial pressure monitoring, individualized cerebral perfusion management, decompressive surgical techniques, and multimodal neuromonitoring have collectively contributed to reductions in secondary brain injury and improved functional recovery (Carney et al., 2017; Hawryluk et al., 2020).

Importantly, the review highlights the changing conceptualization of traumatic brain injury. Rather than viewing TBI as a singular event, contemporary research increasingly recognizes it as a dynamic pathophysiological process involving inflammation, metabolic dysfunction, vascular compromise, oxidative stress, and progressive neurological deterioration. This understanding has encouraged the development of personalized treatment strategies that address the specific physiological needs of individual patients. Such approaches represent a significant departure from traditional uniform treatment models and may contribute to further improvements in neurological outcomes in future military and civilian trauma populations (Maas et al., 2022).

Radiological innovation represents another major area of advancement identified during this review. Modern combat injuries frequently involve multiple organ systems, making rapid diagnosis essential for effective management. Whole-body computed tomography has become a cornerstone of trauma assessment due to its ability to rapidly identify life-threatening injuries and facilitate prompt surgical decision-making. Likewise, advanced magnetic resonance imaging techniques have improved the detection of subtle neurological abnormalities, including diffuse axonal injury and microstructural brain damage that may not be apparent through conventional imaging methods (Wintermark et al., 2015; Riedy et al., 2016).

The emergence of artificial intelligence-assisted diagnostic systems deserves particular attention. Although many applications remain under development, the literature suggests that machine learning technologies may substantially enhance diagnostic efficiency, reduce interpretation errors, and support clinical decision-making in future military healthcare systems. Such innovations may be especially valuable during mass casualty incidents, where rapid evaluation of large numbers of patients is essential. Nevertheless, further research is required to determine the reliability, ethical implications, and operational feasibility of artificial intelligence in combat environments.

Another important observation concerns the role of damage control surgery and damage control resuscitation. The reviewed evidence consistently demonstrates that prioritizing physiological stabilization before definitive surgical reconstruction improves outcomes among critically injured patients. This strategy addresses the lethal triad of hypothermia, acidosis, and coagulopathy, which remains a major contributor to mortality in severe trauma. By focusing initially on hemorrhage control and stabilization, damage control approaches provide a foundation for subsequent definitive treatment while minimizing the risk of physiological collapse (Galbraith et al., 2023; Lammers et al., 2023).

The findings further emphasize the importance of multidisciplinary trauma systems. Successful management of severe combat injuries increasingly depends on coordinated collaboration among emergency physicians, trauma surgeons, neurosurgeons, radiologists, anesthesiologists, intensivists, rehabilitation specialists, psychologists, and nursing personnel. This integrated model reflects a broader transformation within healthcare that recognizes the complexity of trauma and the necessity of coordinated care throughout the continuum of treatment. Evidence suggests that multidisciplinary systems contribute not only to improved survival but also to enhanced long-term recovery, reduced disability, and improved quality of life among survivors (Meyfroidt et al., 2022).

An especially noteworthy finding is the expanding role of rehabilitation within modern military medicine. Advances in acute trauma care have increased survival rates among patients with injuries that were previously fatal. Consequently, healthcare systems are now confronted with growing numbers of survivors who require long-term physical, neurological, cognitive, and psychological support. The literature indicates that early rehabilitation interventions improve mobility, cognitive performance, emotional well-being, and social reintegration. These findings reinforce the concept that successful trauma care should be evaluated not only according to survival metrics but also according to functional outcomes and quality-of-life measures (Maas et al., 2022).

The review additionally demonstrates the significant influence of military medicine on civilian healthcare systems. Many innovations originally developed for battlefield applications have been successfully integrated into civilian trauma centers, emergency medical services, disaster response programs, and critical care units. Tourniquet utilization, massive transfusion protocols, point-of-care ultrasound, damage control surgery, and trauma system organization are examples of military-derived practices that have improved civilian trauma outcomes worldwide. This transfer of knowledge highlights the reciprocal relationship between military and civilian medicine and underscores the broader societal value of advances generated through combat casualty research (Rossaint et al., 2023).

Within the Latin American context, the findings suggest important opportunities for healthcare development. Countries such as Mexico, Colombia, and Ecuador continue to strengthen trauma systems, emergency preparedness programs, and multidisciplinary healthcare networks. Lessons learned from military trauma care may contribute to improving the management of civilian trauma, natural disasters, mass casualty incidents, and public health emergencies throughout the region. The establishment of trauma registries, specialized trauma centers, and coordinated emergency response systems may further enhance patient outcomes and healthcare resilience (Ordoñez et al., 2016; Rojas et al., 2023).

Despite the considerable progress documented throughout the literature, several challenges remain unresolved. Blast-induced neurological injury continues to present diagnostic and therapeutic difficulties. Long-term neuropsychological outcomes remain incompletely understood, particularly among individuals exposed to repetitive blast exposure. Furthermore, disparities in access to advanced technologies may limit implementation of innovative diagnostic and therapeutic approaches in resource-constrained settings. Addressing these challenges will require sustained investment in research, education, infrastructure development, and international collaboration.

This review has several limitations. As a narrative review, it incorporates studies with varying methodologies, populations, and outcome measures, which may limit direct comparison across investigations. Additionally, the rapidly evolving nature of military medicine means that new technologies and clinical evidence continue to emerge, potentially influencing future interpretations of current findings. Nevertheless, the consistency of the evidence across multiple sources strengthens confidence in the principal conclusions derived from this review.

CONCLUSIÓN

War trauma and tactical medicine have undergone profound transformation during the past two decades, driven by continuous scientific advancement, technological innovation, and the adoption of evidence-based clinical practices. The findings of this review demonstrate that contemporary combat casualty care has evolved into a highly specialized multidisciplinary field focused not only on survival but also on neurological preservation, functional recovery, and long-term quality of life.

One of the most important conclusions derived from the reviewed literature is that effective hemorrhage control remains the cornerstone of battlefield survival. The widespread implementation of Tactical Combat Casualty Care principles, combined with the use of combat tourniquets, hemostatic dressings, junctional hemorrhage control devices, and modern resuscitation strategies, has significantly reduced preventable mortality associated with severe bleeding. These interventions represent some of the most successful innovations in modern military medicine and continue to influence trauma systems worldwide.

The review also confirms that traumatic brain injury remains one of the most complex challenges in contemporary warfare. Advances in neurocritical care, multimodal monitoring, decompressive surgical techniques, and personalized management strategies have improved the diagnosis and treatment of combat-related neurological injuries. Furthermore, the integration of advanced imaging technologies has enhanced the ability of clinicians to identify both overt and subtle forms of brain injury, facilitating earlier intervention and more accurate prognostic assessment.

Radiological innovation emerged as a fundamental component of modern trauma management. Whole-body computed tomography, advanced magnetic resonance imaging, diffusion tensor imaging, portable ultrasound systems, and

emerging artificial intelligence-assisted diagnostic tools have transformed clinical decision-making by improving diagnostic speed, accuracy, and efficiency. These technologies have become essential for managing complex multisystem trauma and are expected to play an increasingly important role in future military and civilian healthcare systems.

Another major conclusion is that damage control surgery and damage control resuscitation have fundamentally changed the management of critically injured patients. By prioritizing physiological stabilization before definitive reconstruction, these approaches have improved survival among patients experiencing severe hemorrhage, coagulopathy, and multisystem trauma. Their success illustrates the importance of adapting surgical strategies to the physiological condition of the patient rather than focusing exclusively on anatomical repair.

The review further highlights the critical role of multidisciplinary trauma systems in achieving optimal outcomes. Effective combat casualty care requires coordinated collaboration among tactical medical personnel, trauma surgeons, neurosurgeons, radiologists, intensivists, rehabilitation specialists, psychologists, and nursing professionals. Such integrated systems ensure continuity of care across all stages of treatment, from point-of-injury management to long-term rehabilitation and social reintegration.

An important observation is the growing influence of military medical innovations on civilian healthcare. Numerous strategies originally developed for battlefield medicine have been successfully incorporated into civilian trauma centers, emergency medical services, disaster response programs, and critical care environments. This transfer of knowledge has strengthened healthcare preparedness and expanded the capacity of healthcare systems to respond effectively to severe trauma and mass casualty incidents.

The findings additionally suggest that countries seeking to strengthen trauma care systems, including those within Latin America such as Mexico, Colombia, and Ecuador, may benefit from the adoption of evidence-based principles derived from modern military medicine. Improvements in trauma organization, emergency preparedness, specialized training, and multidisciplinary coordination have the potential to enhance outcomes in both military and civilian populations.

Despite the substantial progress documented throughout the literature, important challenges remain. Future research should continue to investigate blast-induced neurological injury, advanced neuroprotective therapies, long-term rehabilitation outcomes, artificial intelligence applications, and strategies for implementing innovative technologies in resource-limited environments. Addressing these issues will be essential for further improving survival, reducing disability, and optimizing recovery among patients affected by severe traumatic injuries.

In conclusion, modern war trauma management represents one of the most dynamic and rapidly evolving areas of contemporary medicine. Through advances in tactical care, hemorrhage control, neurotrauma management, diagnostic imaging, damage control strategies, and multidisciplinary rehabilitation, substantial improvements have been achieved in both survival and long-term outcomes. Continued scientific innovation, international collaboration, and commitment to evidence-based practice will remain fundamental to shaping the future of trauma care and enhancing the lives of individuals affected by complex combat-related injuries worldwide.

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