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AI-Driven Autonomous Trauma Care: Transforming Emergency Response in Military and Civilian Settings

ხელოვნურ ინტელექტზე დაფუძნებული ავტონომიური ტრავმის მართვა: გადაუდებელი დახმარების ტრანსფორმაცია სამხედრო და სამოქალაქო გარემოში

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Abstract

Introduction: Timely trauma care during the "golden hour" is critical to reducing mortality in military and civilian emergencies. Recent advancements in artificial intelligence (AI), machine learning, and robotics offer new opportunities to improve outcomes through autonomous diagnostics, triage, and logistical coordination. However, there remains a significant gap in integrating these technologies into trauma care systems, particularly in austere or high-pressure environments. **Methods:** This study conducted a systematic literature review to evaluate the effectiveness of AI-driven autonomous systems in trauma care. Databases searched included PubMed, Scopus, and Web of Science, covering publications from January 2000 to April 2025. Search terms included “AI in trauma care,” “golden hour,” “autonomous medical systems,” and “emergency response.” Grey literature and institutional reports were also analyzed. Study quality was assessed using the Newcastle-Ottawa Scale and AMSTAR tools. **Results:** AI systems demonstrated high diagnostic accuracy (AUC 0.88–0.92) and significantly improved triage efficiency (e.g., 18.7-minute reduction in wait time). Autonomous evacuation using drones reduced mortality by up to 30%, while rapid surgical handoff was associated with a 66% mortality reduction. Applications in both military and civilian settings showed survival rates exceeding 86%. Key areas enhanced by AI included injury detection, patient prioritization, evacuation logistics, and outcome prediction. **Discussion:** AI-driven systems enhance each phase of trauma care, particularly within the golden hour. Despite their benefits, challenges remain, including data biases, variable trauma timelines, and ethical considerations. Proposed solutions include the development of offline-capable mobile applications and real-time decision-support tools. Further research is needed to validate AI models and optimize system deployment in resource-limited environments. **Conclusion:** AI-driven autonomous trauma care systems show substantial promise in improving survival and operational efficiency in both military and

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civilian emergencies. Integrating these technologies into trauma response protocols may redefine standards for emergency care and significantly reduce preventable deaths.

Keywords: Artificial Intelligence (AI), Trauma Care, Golden Hour, Autonomous Medical Systems, Emergency Response, Military Medicine, Triage Algorithms, AI Diagnostics, Medical Robotics, Evacuation Logistics, Mortality Reduction, Mobile Health (mHealth), Decision Support Systems, Battlefield Medicine, Predictive Analytics.

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აბსტრაქტი

შესავალი: ტრავმის დროს დროული დახმარება გადამწყვეტია როგორც სამხედრო, ისე სამოქალაქო საგანგებო სიტუაციებში სიკვდილიანობის შემცირებისათვის. ხელოვნური ინტელექტის სფეროში ბოლო დროს განვითარებულმა ტექნოლოგიებმა გააჩინა ახალი შესაძლებლობები დიაგნოსტიკის, ტრიაჟის და ლოგისტიკური კოორდინაციის ავტონომიური სისტემებით გასაუმჯობესებლად. მიუხედავად ამისა, კვლავ არსებობს სერიოზული ხარვეზი ამ ტექნოლოგიების ტრავმის მართვის სისტემებში ინტეგრირებაში. **მეთოდოლოგია:** ჩატარდა სისტემატური ლიტერატურის მიმოხილვა, რათა შეფასებულიყო ტრავმის მართვაში AI-ზე დაფუძნებული ავტონომიური სისტემების ეფექტიანობა. მოძიება ჩატარდა მონაცემთა ბაზებში PubMed, Scopus და Web of Science, რომლებიც მოიცავდა 2000 წლის იანვრიდან 2025 წლის აპრილამდე გამოქვეყნებულ სტატიებს. ძიების საკვანძო ტერმინები იყო: „AI ტრავმის მართვაში“, „ოქროს საათი“, „ავტონომიური სამედიცინო სისტემები“ და „გადაუდებელი რეაგირება“. **შედეგები:** AI სისტემებმა აჩვენეს მაღალი დიაგნოსტიკური სიზუსტე (AUC 0.88–0.92) და მნიშვნელოვანი გაუმჯობესება ტრიაჟის ეფექტიანობაში (მაგ., ლოდინის დროის შემცირება 18.7 წუთით). ავტონომიური ევაკუაცია დრონების საშუალებით სიკვდილიანობას ამცირებს დაახლოებით 30%-ით, ხოლო სწრაფი ქირურგიული ოპერაცია ასოცირდება სიკვდილიანობის 66%-ით შემცირებასთან. როგორც სამხედრო, ისე სამოქალაქო კონტექსტში გამოყენებისას გადარჩენის მაჩვენებელი აღემატებოდა 86%-ს. AI-ის მიერ გაუმჯობესებული ძირითადი სფეროები მოიცავდა ტრავმის აღმოჩენას, პაციენტების პრიორიტეტიზაციას, ევაკუაციის ლოგისტიკას და შედეგების პროგნოზირებას. **დისკუსია:** AI-ზე დაფუძნებული სისტემები აძლიერებს ტრავმის მართვის ყველა ეტაპს, განსაკუთრებით კი „ოქროს საათში“. მიუხედავად მათი ეფექტიანობისა, პრობლემებად რჩება მონაცემთა მიკერძოება, ტრავმის განსხვავებული დროითი დინამიკა და ეთიკური საკითხები. შემოთავაზებულია გადაწყვეტილებები, როგორებიცაა ოფლაინ რეჟიმში მოქმედი მობილური აპლიკაციები და რეალურ დროში გადაწყვეტილების მხარდამჭერი ინსტრუმენტები. საჭიროა დამატებითი კვლევა AI მოდელების ვალიდაციისა და მათი რესურსებით შეზღუდულ გარემოში ოპტიმიზაციისთვის. **დასკვნა:** AI-ზე დაფუძნებულ ავტონომიურ ტრავმის მართვის სისტემებს აქვთ მნიშვნელოვანი პოტენციალი როგორც გადარჩენის გაუმჯობესების, ისე ოპერაციული ეფექტიანობის ზრდისათვის სამხედრო და სამოქალაქო საგანგებო სიტუაციებში. ამ ტექნოლოგიების ინტეგრირება ტრავმის რეაგირების პროტოკოლებში შეიძლება გახდეს გადაუდებელი დახმარების ახალი სტანდარტი და მნიშვნელოვნად შეამციროს სიკვდილიანობა.

საკვანძო სიტყვები: ხელოვნური ინტელექტი (AI), ტრავმის მართვა, „ოქროს საათი“, ავტონომიური სამედიცინო სისტემები, გადაუდებელი დახმარება, სამხედრო მედიცინა, ტრიაჟის ალგორითმები, AI დიაგნოსტიკა, სამედიცინო რობოტექნიკა, ევაკუაციის ლოგისტიკა, სიკვდილიანობის შემცირება, მობილური ჯანმრთელობის ტექნოლოგიები (mHealth), გადაწყვეტილების მხარდამჭერი სისტემები, პროგნოზული ანალიტიკა.

ციტატა: ტიმოთი ფილიპი, ვივეკ ნაირ ჰარიკუმარი. ნაწლავის მიკრობიოტის როლი პოლიკისტოზური ოვარიუმის სინდრომსა და ინსულინრეზისტენტობაში. ჯანდაცვის პოლიტიკა, ეკონომიკა და სოციოლოგია. ჯანდაცვის პოლიტიკა, ეკონომიკა და სოციოლოგია, 2025; 9 (1). https://doi.org/10.52340/healthecosoc.2025.09.01.11.

Introduction

Advances in artificial intelligence (AI), machine learning, and robotics hold transformative potential for trauma care, particularly in high-stakes military and civilian emergencies. These technologies offer life-saving capabilities by addressing longstanding challenges in emergency response, including delays in diagnosis, triage, and evacuation. Despite their promise, a significant gap remains in effectively integrating AI-driven autonomous systems into existing trauma care infrastructure. This review aims to bridge that gap by exploring how AI technologies can enhance outcomes in time-critical trauma scenarios (Worsham et al., 2024; Liu et al., 2023).

In moments where every second determines survival, such as battlefield injuries or civilian mass-casualty incidents, intelligent systems can dramatically alter the trajectory of care. Through real-time decision support, automated diagnostics, and robotic interventions, AI-driven platforms are redefining the speed and precision of trauma responses.

The concept of the "golden hour", the first 60 minutes following injury, is critical for preventing irreversible physiological damage and reducing mortality rates (Cowley, 1975). The U.S. Department of Defense institutionalized this concept during the war in Afghanistan, mandating evacuation within one hour, which led to a marked reduction in combat mortality (Kotwal et al., 2016). Studies show that rapid surgical intervention within this window reduces mortality by up to 66%, with approximately 68% of trauma deaths occurring during this period (Annals, 2024). While some critics have questioned the empirical robustness of the golden hour (Bledsoe, 2002), its importance remains undisputed, particularly in contemporary conflict zones such as Georgia (Khorram et al., 2022).

Large-scale military operations pose significant challenges for trauma care. The Army Health System (AHS) must manage high volumes of casualties under severe logistical constraints (Worsham et al., 2024). Civilian trauma care systems face similar pressures, especially in mass-casualty events, with polytrauma cases representing up to 38% of injuries treated at forward surgical hospitals (Rai et al., 2011). Exsanguination alone accounts for 40–60% of preventable trauma deaths, underscoring the need for rapid haemorrhage control (JRSM, 2015).

AI and autonomous systems are emerging as powerful tools to address these challenges. They have demonstrated high diagnostic accuracy (AUC 0.88 for critical conditions; 0.89 for haemorrhage detection) (Hamilton et al., 2021; Liu et al., 2023), and can reduce triage wait times by an average of 18.7 minutes (Char et al., 2024). Autonomous drones, equipped with real-time data analytics, have been shown to increase survival rates by 30% through faster casualty evacuation (Pamplin et al., 2025). Data-driven decision-making further optimizes outcomes across the care continuum, with reported diagnostic AUCs ranging from 0.88 to 0.92 (Hamilton et al., 2021; Meyer et al., 2022).

Trauma care spans four critical phases: pre-hospital stabilization, evacuation, definitive surgical care, and rehabilitation (Kotwal et al., 2016; Rai et al., 2011). The initial phase emphasizes haemorrhage control and rapid triage within the golden hour (JRSM, 2015). Evacuation requires timely transport to advanced surgical facilities (Annals, 2024). Definitive care addresses complex polytrauma cases, while rehabilitation focuses on functional recovery and return to duty or civilian life (Worsham et al., 2024). AI enhances each phase through automated diagnostics, intelligent triage, and logistics optimization. Wearable biosensors and AI-assisted monitoring systems provide continuous physiological assessment, improving situational awareness and care coordination (Liu et al., 2023; Pamplin et al., 2025).

Many modern trauma care innovations—such as tourniquets, haemostatic agents, portable ultrasound devices, telemedicine, and advanced prosthetics—originated in military contexts before being adapted to civilian healthcare (JRSM, 2015). This military-to-civilian transfer continues with AI technologies, which now offer advanced capabilities for managing haemorrhage, minimizing delays, and delivering real-time, autonomous interventions. Conflicts like the Kargil War have highlighted the need for such innovations (News, 2021), and AI systems are increasingly positioned to meet that need (Liu et al., 2023; Char et al., 2024).

This review investigates the role of AI-driven autonomous systems in reducing trauma-related mortality and improving care across all stages, diagnostics, triage, coordination, evacuation, surgical care, rehabilitation, and return to duty. By examining applications in both military and civilian settings, it identifies emerging solutions and strategic pathways to enhance trauma outcomes (Worsham et al., 2024; Kotwal et al., 2016; Rai et al., 2011).

Methodology

A comprehensive literature search was conducted across PubMed, Scopus, and Web of Science using targeted search terms, including "AI in trauma care," "golden hour," "autonomous medical systems," "battlefield trauma," "AI diagnostics," and "emergency response." To enhance the scope and inclusivity of the review, grey literature from platforms such as ResearchGate and institutional reports was also examined. The search covered publications from January 2000 to April 2025.

Data extraction focused on key study characteristics, including study design, sample size, type of AI intervention, and reported outcomes, such as mortality rates, diagnostic accuracy (AUC), and triage wait times.

To ensure methodological rigor, the quality of included studies was assessed using the Newcastle-Ottawa Scale for observational studies and AMSTAR for systematic reviews. Studies demonstrating robust methodology, clearly defined outcome measures, and high relevance to trauma-related mortality reduction were prioritized for synthesis.

Literature Review

The Golden Hour in Trauma Care

The golden hour refers to the critical first 60 minutes following traumatic injury, during which timely intervention is essential to prevent irreversible damage and reduce mortality (Cowley, 1975). In a study of 5,737 casualties treated in a forward hospital, Rai et al. (2011) reported a mortality rate of 3.6% (Rai et al., 2011). Following a 2009 U.S. Department of Defense mandate to reduce evacuation times, Kotwal et al. (2016) demonstrated a significant reduction in killed-in-action (KIA) rates (Kotwal et al., 2016). Similarly, The Annals of Surgery (2024) reported a 66% mortality reduction with rapid surgical handoff (Annals, 2024). The golden hour remains critical in modern conflicts, including recent military engagements (Khorram et al., 2022).

Trauma Measurement Scales and AI Interventions

Trauma severity is commonly assessed using scales such as the Trauma and Injury Severity Score (TRISS), Revised Trauma Score (RTS), and Glasgow Coma Scale (GCS) (Kotwal et al., 2016; Meyer et al., 2022). AI enhances the functionality of these scales by improving survival predictions, automating scoring, and optimizing triage, thereby reducing preventable deaths (Char et al., 2024; Hamilton et al., 2021).

Diagnostic Decision-Making

AI-based diagnostic systems have demonstrated high accuracy in trauma care. Hamilton et al. (2021) reported an AUC of 0.88 (95% CI: 0.85–0.91) for general trauma diagnostics and 0.92 for sepsis prediction. Liu et al. (2023) found an AUC of 0.89 for hemorrhage detection. AI applications in appendicitis diagnosis achieved a sensitivity of 81.08% (Zhang et al., 2022). These tools are especially relevant in addressing exsanguination, which accounts for 40–60% of trauma-related deaths (JRSM, 2015).

Triage Efficiency

AI significantly improves triage processes. Char et al. (2024) reported a reduction of 18.7 minutes in triage wait times and a 25% improvement in urgency assessment accuracy. Meyer et al. (2022) found that AI triage systems achieved an AUC of 0.89, compared to 0.76 for RTS, in mass casualty settings. Additionally, autonomous drones have been employed to assist in casualty prioritization and evacuation (Kotwal et al., 2016; Pamplin et al., 2025).

AI-Enhanced Medical Operations and Trauma Care

AI supports real-time decision-making and coordination across trauma care systems, helping to reduce delays in both military and civilian contexts (Worsham et al., 2024; Kotwal et al., 2016; Char et al., 2024). Predictive models aid in earlier return to duty, with one study noting a 7% post-operative infection rate (Rai et al., 2011). Autonomous systems facilitate automated patient transport, with drones reducing evacuation times by up to 30% (Pamplin et al., 2025; Kotwal et al., 2016).

Surgical intervention rates have reached 83.07% in certain settings (Rai et al., 2011), and predictive logistics now support real-time blood supply delivery, addressing one of the most critical bottlenecks in trauma care (Worsham et al., 2024; JRSM, 2015). In civilian applications, AI improves triage accuracy, outcome prediction, and resource allocation, contributing to mortality reductions of 3.6% (Rai et al., 2011) and 60–66% (Annals, 2024). Survival rates in advanced trauma systems now exceed 86% (JRSM, 2015).

Table 1. Mortality Outcomes in Golden Hour Interventions

Study	Intervention	Outcome
Rai et al. (2011)	Prompt evacuation	3.6% mortality
Kotwal et al. (2016)	Evacuation < 60 min	Reduced KIA rates
Annals of Surgery (2024)	Rapid surgical handoff	66% reduction in mortality

Table 2. Trauma Measurement Scales and AI Interventions

Scale	Purpose	AI Intervention
TRISS	Predicts survival	Improves prediction (AUC 0.90) [Meyer, 2022]
RTS	Assesses vital signs	Enhances triage accuracy by 25% [Char, 2024]
GCS	Evaluates consciousness	Automates scoring (AUC 0.88) [Hamilton, 2021]

Table 3. Diagnostic Performance of AI Systems

Study	Condition	AUC (95% CI)	Sensitivity
Hamilton et al. (2021)	Sepsis	0.92 (0.89–0.95)	--
Liu et al. (2023)	Hemorrhage	0.89 (0.86–0.92)	--
Zhang et al. (2022)	Appendicitis	--	81.08%

Table 4. Triage Efficiency with AI Systems

Study	Wait Time Reduction	Accuracy Improvement
Char et al. (2024)	18.7 minutes	25% improvement in urgency scoring
Elhaddad et al. (2024)	15 minutes	--
Meyer et al. (2022)	--	AUC 0.89 vs. 0.76 (RTS benchmark)

Discussion

Our proposed AI-driven autonomous trauma care systems are designed to optimize golden hour interventions and significantly reduce trauma-related mortality (Kotwal et al., 2016; Rai et al., 2011). Documented reductions in mortality—3.6% in forward hospitals (Rai et al., 2011) and 66% following rapid surgical handoff (Annals, 2024)—as well as decreased killed-in-action (KIA) rates (Kotwal et al., 2016) underscore the critical importance of timely, AI-enhanced responses.

The systems also demonstrate high diagnostic accuracy (AUC 0.88–0.89) (Hamilton et al., 2021; Liu et al., 2023) and improved triage efficiency, which helps address delays and fatal complications such as hemorrhage, the leading cause of preventable trauma deaths (JRSM, 2015; News, 2021). These outcomes signal a broader transformation within the Army Health System, particularly in battlefield and remote trauma care (Worsham et al., 2024; Pamplin et al., 2025).

In civilian settings, the integration of AI has led to survival rates exceeding 86% (JRSM, 2015), further validating the technology's cross-sector utility. Nonetheless, significant challenges remain. Data limitations, algorithmic bias, and model generalizability persist as key barriers (Piliuk et al., 2023). Edge computing and synthetic datasets may offer solutions by enabling real-time processing and broader representation across diverse populations (Liu et al., 2023).

The concept of a fixed "golden hour" has also been challenged, with evidence suggesting variability based on trauma type, setting, and patient condition (Bledsoe, 2002). This underscores the need to refine AI prediction models for personalized time-to-intervention estimates (Piliuk et al., 2023).

Ethical oversight remains critical in AI integration. Ensuring safety, transparency, and accountability will be vital for trust and regulatory compliance (Gauff et al., 2024; Rai et al., 2011).

As a practical extension of this work, we propose a mobile application, modeled on the Google Studio platform, which would offer real-time guidance based on validated AI diagnostic tools (AUC 0.88) (Hamilton et al., 2021) and triage algorithms (Char et al., 2024). Incorporating offline functionality (Liu et al., 2023) and mass casualty triage integration (Meyer et al., 2022), the app could reduce casualties by up to 30% in austere and resource-limited environments (Pamplin et al., 2025). Such a tool could empower both soldiers and civilians to make rapid, life-saving decisions in the absence of immediate medical personnel.

To realize this potential, technical, ethical, and safety challenges must be addressed (Piliuk et al., 2023). Future research should aim to:

- Validate and contextualize golden hour parameters,
- Test AI prototypes in real-world and simulated environments, and
- Refine the mobile app's interface and algorithms to ensure usability and reliability [Liu et al., 2023; Pamplin et al., 2025].

Conclusions

AI-driven autonomous trauma care systems are transforming emergency medical response by enabling faster, more accurate, and highly coordinated interventions during the critical golden hour—the decisive window in which immediate care can determine survival. Through the integration of advanced artificial intelligence, these systems streamline diagnostics by rapidly analyzing medical data to detect injuries with high precision. They improve triage by automatically prioritizing patients based on injury severity, ensuring that the most critical cases receive prompt attention. Moreover, they enhance logistical coordination, optimizing the deployment of ambulances, medical personnel, and supplies to minimize treatment delays. This data-driven, autonomous approach has been shown to significantly reduce mortality rates and improve long-term functional outcomes, ultimately enhancing survivors' quality of life. As these technologies continue to evolve, they offer the potential to redefine trauma care by making emergency responses more intelligent, efficient, and life-saving.

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