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Innovative Technologies in Prehospital Trauma Assessment: A Review of Current Practices and Future Directions

By

[1]Osama Mohammed Alghamdi, [2]Abdulaziz Thuwayb Al Sulami, [3]Olayan Ali Alsualmi, [4]Khaled Sohem Olayan Alsualmi, [5]Abdullah Saeed Alqarni, [6]Khaled Saad Alqarni, [7]Mohammed Dhaifallah Albeshri, [8]Faisal Mishlih Al Harthi, [9]Sami Nami Alsulami, [10]Naif Salih Aldoqi

[1]Specialist, Emergency Medical Services, Red Crescent Jeddah
[2,3,4,5,6,7,8,9,10]Technician, Emergency Medical Services, Red Crescent Jeddah

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Abstract

Trauma is a leading global cause of death, claiming approximately 5 million lives annually. Effective prehospital assessment is paramount for optimizing patient outcomes, yet current practices, reliant on the subjective judgment of EMS personnel, suffer from inconsistencies due to varying training and experience, resulting in potentially fatal delays. This systematic review investigates the current state of prehospital trauma assessment and the transformative potential of emerging technologies. We analyze the limitations of traditional methods – subjective evaluations, time constraints, and inconsistent quality – emphasizing the critical need for standardization and technological advancements. The review focuses on innovative technologies including mobile applications, telemedicine, AI, and POCUS, assessing their capacity to streamline information flow, enhance communication between EMS and hospitals, and improve resource allocation. A rigorous methodology employs a systematic search across major databases (PubMed, Scopus, Web of Science), using specific keywords and inclusion/exclusion criteria to ensure unbiased study selection. Quality assessment utilizes the Cochrane Risk of Bias tool and the Newcastle-Ottawa Scale. Thematic analysis will identify current practices, evaluate technological efficacy, and explore implementation challenges across diverse settings. This review aims to provide evidence-based recommendations for integrating these technologies into EMS protocols, ultimately improving trauma care quality, patient survival rates, and the speed and accuracy of prehospital assessment.

Keywords: *Prehospital Trauma Assessment, Emergency Medical Services (EMS), Telemedicine, Point-of-Care Ultrasound (POCUS), Artificial Intelligence (AI)*

1. Introduction

Trauma is a leading cause of morbidity and mortality worldwide, accounting for approximately 5 million deaths annually (World Health Organization, 2020). Timely and accurate prehospital trauma assessment is critical for improving patient outcomes, as it significantly influences the effectiveness of subsequent medical interventions (Kahn et al., 2016). Prehospital trauma assessment involves the evaluation of patients in emergency situations, where rapid decision-making is essential. Traditional assessment methods often rely heavily on the clinical judgment and experience of emergency medical personnel, which can vary significantly based on individual training and situational factors (Hsieh et al., 2019). This variability can lead to delays in critical interventions, adversely affecting survival rates and recovery trajectories (MacKenzie et al., 2014).

Despite advancements in emergency medical services (EMS), current assessment practices face several challenges. The limitations of traditional methods include inconsistencies in assessment quality, reliance on subjective evaluations, and time constraints inherent in emergency situations (Tisherman et al., 2019). For instance, studies have shown that delays in the identification of critical injuries can lead to preventable deaths (Rhee et al., 2017). As a result, there is a pressing need for innovative solutions that can enhance the accuracy and efficiency of trauma assessment in the prehospital setting.

*Corresponding Author: **Osama Mohammed Alghamdi**

Emerging technologies present promising alternatives to traditional trauma assessment methods. Innovations such as mobile applications, telemedicine platforms, and artificial intelligence (AI) tools are being developed to aid EMS personnel in making informed decisions quickly (Dyer et al., 2020). These technologies have the potential to standardize assessments, improve communication between EMS and hospital teams, and facilitate better resource allocation (Grubaugh et al., 2021). For example, mobile applications designed for data collection and triage can streamline information flow, while telemedicine allows for real-time consultations with specialists, thereby enhancing the quality of care delivered in the field (Pomerantz et al., 2018).

Despite the growing interest in these technologies, there remains a notable gap in the literature regarding their effectiveness and implementation in prehospital trauma assessment. Comprehensive reviews synthesizing current practices and evaluating the impact of innovative technologies are lacking. This systematic review aims to address this gap by analyzing the existing literature on prehospital trauma assessment practices and the role of innovative technologies.

1.1. Objectives of the study:

- To identify and analyze current technologies used in prehospital trauma assessment.
- To evaluate the effectiveness and limitations of these technologies in real-world applications.
- To explore emerging technologies and their potential impact on prehospital trauma care.
- To provide recommendations for integrating innovative technologies into existing EMS protocols.

2. Methodology

This study employs a systematic review approach to evaluate the current practices and innovative technologies in prehospital trauma assessment. The methodology follows established guidelines to ensure a comprehensive and unbiased synthesis of the relevant literature.

2.1. Literature Search Strategy

A systematic literature search will be conducted across multiple electronic databases, including PubMed, Scopus, and Web of Science. The search utilizes a combination of keywords and phrases related to prehospital trauma assessment and innovative technologies. Specific search terms will include:

- "prehospital trauma assessment"
- "emergency medical services technology"
- "mobile applications trauma"
- "telemedicine trauma care"
- "artificial intelligence in emergency medicine"

The search is limited to studies published between 200 and 2024 to ensure that the review captures the most recent advancements in technology.

2.2. Inclusion and Exclusion Criteria

Studies are included in the review based on the following criteria:

2.2.1. Inclusion Criteria:

- Peer-reviewed articles published in English.
- Studies focusing on technological interventions in prehospital trauma assessment.
- Research articles, randomized controlled trials, observational studies, and systematic reviews.

2.2.2. Exclusion Criteria:

- Articles not related to prehospital settings.
- Studies focusing on non-technological interventions.
- Opinion pieces, editorials, and conference abstracts without substantial data.

2.3. Data Extraction

Data will be extracted from the selected studies using a standardized extraction form. Key information to be collected includes:

- Author(s) and publication year
- Study design and methodology
- Description of the technology assessed
- Outcomes measured (e.g., accuracy, efficiency)
- Main findings and conclusions

2.4. Quality Assessment

The quality of the included studies will be assessed using appropriate tools based on study design:

- For randomized controlled trials, the Cochrane Risk of Bias tool will be utilized.
- For observational studies, the Newcastle-Ottawa Scale will be applied.

This assessment will help evaluate the robustness of the evidence and identify any potential biases in the studies.

2.5. Data Analysis

A thematic analysis will be conducted to categorize and synthesize the findings from the included studies. The analysis will focus on:

- Current practices in prehospital trauma assessment.
- Effectiveness of various innovative technologies.
- Barriers to implementation and challenges encountered in diverse prehospital settings.

The results will be presented narratively, supported by tables and figures where appropriate, to illustrate key trends and findings.

2.6. Ethical Considerations

As this study involves a systematic review of published literature, ethical approval is not required. However, the review will adhere to ethical guidelines for conducting research, including proper citation of all sources and transparency in reporting findings.

*Corresponding Author: **Osama Mohammed Alghamdi**

3. Literature Review

The study conducted by Lumley et al. (2020) is a scoping review focused on identifying and describing technologies that assist ambulance personnel in the diagnosis and stratification of patients suspected of having a stroke in a pre-hospital setting. Recognizing that timely identification of stroke subgroups can significantly reduce delays in emergency treatment, the review aimed to evaluate technologies with existing proof of concept. The authors performed a systematic electronic search across five bibliographic databases, concentrating on studies published between January 2000 and June 2019. They included studies that utilized diagnostic tests, such as portable imaging and biomarkers, as well as technologies like telemedicine relevant to stroke assessment in ambulances. Ultimately, 19 studies were deemed eligible for inclusion after screening a total of 2,887 articles. The review categorized the identified technologies into three main areas: blood biomarkers, where two studies focused on protocols for identifying stroke subtypes but lacked conclusive results on diagnostic accuracy and patient outcomes; pre-hospital imaging, which included assessments of portable imaging devices such as an infrared screening device and EEG technology, yielding mixed results regarding sensitivity and specificity; and telemedicine, where fifteen studies evaluated systems that transmitted stroke assessment data from the field to hospitals, generally improving time-to-treatment but leaving the impact on clinical outcomes uncertain. The findings suggest that, despite the promise of these technologies for pre-hospital stroke assessment, the current evidence is insufficient to recommend their routine use. The authors call for multi-centre diagnostic accuracy studies and clinical trials to further evaluate these technologies, highlighting the need for advancements in pre-hospital assessment tools to enhance the efficiency of stroke care.

Lu et al. (2023) developed and validated an innovative virtual reality (VR) training tool for the pre-hospital treatment of cranio-maxillofacial (CMF) trauma using the HTC VIVE Pro2 suite. This immersive virtual reality (iVR) platform provides a multi-sensory, holistic surgical training experience, combining videos and three-dimensional interactions to simulate a realistic battlefield environment. Trainees can engage with the CMF anatomy and utilize surgical instruments while observing close-up stereoscopic videos of surgical procedures. Twenty-five CMF surgeons evaluated the tool for face and content validity through a structured assessment process, providing feedback on its content, realism, usability, and the potential for VR in CMF trauma rescue simulation training. The results affirmed the effectiveness of VR for training in this area, with suggestions made for enhancements to improve user experience and instrument interactions. The training tool is now ready for testing with surgical trainees, indicating a significant step forward in surgical education for pre-hospital CMF trauma care.

Ziegler et al. (2008) evaluated the impact of a mobile computing system, the "Stroke Angel System," on pre-hospital stroke care within the German "Stroke Angel Initiative." This study, conducted between 2005 and 2007, equipped five ambulances with PDAs to collect patient data using the Emergency Medical Services Protocol (DIVI) and the Los Angeles Prehospital Stroke Screen (LAPSS), transmitting this information to the receiving hospital. While the system successfully transmitted data in all cases (n=226 patients), the study found LAPSS had limited sensitivity (68.3%) and specificity (85.1%) for pre-hospital stroke detection, suggesting a need for alternative algorithms. Despite this, the system demonstrably reduced in-hospital processing time (from 32 minutes in 2005 to 16 minutes in 2007) and increased the rate of thrombolysis from 6.12% to 11.17% over the study period. The authors concluded that mobile computing technology can improve cross-sectoral emergency management of acute stroke.

Kou, et al. (2015), investigated the knowledge and practices of prehospital doctors in managing traumatic brain injuries (TBI) in Hubei Province, China. A cross-sectional survey of 52 doctors from Wuhan and Xiangyang revealed that while TBI assessment scores were relatively high, scores for TBI treatment were significantly lower. The study found several factors associated with performance: higher education levels correlated with better TBI identification; doctors from emergency medical centers and those with prior surgical or prehospital experience performed better in TBI assessment; and more frequent training improved TBI treatment scores. The study highlighted a shortage of prehospital doctors in the region, an age imbalance among practitioners, and the need for improved continuing medical education (CME) programs to enhance the quality of ambulance services in China. Comparisons were made to the more developed ambulance services in Australia, emphasizing the disparity in resources and training.

The literature on point-of-care ultrasound (POCUS) highlights its evolution from a hospital-centric technology to a widely accessible tool, facilitated by advancements in portability and remote interpretation capabilities. While traditionally requiring trained users, the ability to remotely guide novices in image acquisition has broadened POCUS's reach. This has culminated in the development of remotely telementored self-performed ultrasound (RTMSPUS), initially pioneered in space medicine and now actively investigated for terrestrial applications by the TMUSMI Research Group (Kirkpatrick et al., 2022). RTMSPUS empowers patients to perform self-examinations, enabling home-based monitoring, secondary disease prevention, and increased self-management of health. Its utility is particularly evident in pandemic scenarios, such as monitoring lung health, but its potential extends to a wide range of acute and chronic conditions in individuals with internet access. Further research is needed to fully realize the potential of RTMSPUS across diverse healthcare settings.

Amaral, et al. (2020) examined the expanding role of prehospital point-of-care ultrasound (PHUS) in emergency medical services (EMS). The authors trace the history of ultrasound technology, highlighting its evolution from large, stationary machines to the current generation of portable,

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handheld devices. A key focus is on training requirements for prehospital clinicians, noting the variability in existing programs and the need for standardized curricula and competency assessments. The review discusses various clinical applications of PHUS, including the eFAST exam for trauma, echocardiography for cardiac assessment, and rapid assessment protocols like RUSH and BLUE for shock and respiratory distress. Challenges related to feasibility, including technological limitations, quality assurance, and the impact of medical oversight, are also addressed. The authors cite several studies exploring paramedic and physician perspectives on PHUS implementation, revealing enthusiasm among paramedics but more reserved views from physicians concerning clinical utility and training adequacy. Finally, the review emphasizes the need for further research to evaluate the impact of widespread PHUS adoption on patient outcomes and the development of robust quality assurance programs.

Brown JB et al. (2024) focused on hemorrhage and traumatic brain injury (TBI). The study, stemming from the inaugural HERETIC Symposium, reviewed current challenges and potential solutions. Key findings highlighted the need for improved prehospital diagnostics, including near-infrared spectroscopy (NIRS) for TBI and point-of-care ultrasound for hemorrhage detection. The authors also emphasized the importance of developing readily deployable technologies to address non-compressible torso hemorrhage, such as injectable foam or portable cell-saver technology. Regarding education, the study advocated for shifting paradigms towards clinical immersion experiences and focusing on critical thinking skills, supported by simulation training. The authors stressed the necessity of collaboration between academia and industry to overcome logistical hurdles and regulatory barriers, ultimately aiming to optimize prehospital care and improve patient outcomes in both military and civilian settings. Specific examples of promising technologies, such as GFAP as a TBI biomarker and REBOA for hemorrhage control, were discussed alongside their limitations and potential for future development.

Williamson et al. (2011) reviewed advances in prehospital trauma care, highlighting the evolution of emergency medical systems (EMS) from military-inspired models to sophisticated civilian systems. The authors emphasized the enduring importance of the ABCs of trauma care (Airway, Breathing, Circulation) while detailing advancements in airway management (including supraglottic airway devices and video-assisted laryngoscopes), circulatory access (intraosseous and central venous access), and bleeding control (tourniquets and hemostatic agents). The study also discussed improvements in monitoring techniques (end-tidal capnography and tissue hemoglobin oxygenation measurement) and the crucial role of training, including simulation-based learning and standardized trauma courses (e.g., ATLS, ITLS, TNCC). Finally, the authors addressed prehospital scoring systems used to triage patients and guide transport to appropriate facilities, acknowledging the limitations of some systems in the prehospital setting. The overall aim was to provide an overview of current and future trends in prehospital trauma care, emphasizing the influence of military advancements on civilian practices.

Alotaibi et al. (2023) conducted a review of advancements in pre-hospital emergency care in the United States, highlighting the evolution of Emergency Medical Services (EMS) from its origins in the 1960s to its current complex and regionally diverse structure. The study emphasizes the lack of standardization and resulting confusion surrounding EMS operations, roles, and effectiveness. The authors review key innovations enhancing EMS efficiency and patient outcomes, including mobile health technology, telemedicine integration, advanced diagnostic devices (e.g., AEDs, portable ultrasound), wearable health sensors, drone-based medical delivery, enhanced trauma care equipment, electronic patient care reporting (ePCR), and simulation training. They discuss the evolution of EMS curricula, the diverse regional structures and staffing models, the role of air medical EMS, and emerging trends such as Mobile Integrated Healthcare (MIH-CP). The study also details various pre-hospital care techniques, including advanced airway management, ACLS, trauma care, pain management, patient assessment and triage, and RSI. Finally, the authors underscore the importance of interprofessional collaboration and simulation training in optimizing EMS effectiveness and patient outcomes, while acknowledging the need for ongoing efforts to address regional disparities and ensure widespread adoption of these innovations.

This review article by Walsh (2019) examines ten non-invasive, external brain monitoring devices under development for prehospital stroke diagnosis. The devices utilize diverse technologies including accelerometers (BrainPulse), electroencephalography (EEG; AlphaStroke and BrainScope One), microwaves (EMTensor, EMvision, Strokefinder MD100), near-infrared spectroscopy (Infrascanner 2000), radiofrequency (Sense), transcranial Doppler ultrasound, and volumetric impedance phase shift spectroscopy. The review details each device's technology, intended use (including stroke and other neurological conditions), operational environment (with a focus on prehospital settings), physical structure, and available peer-reviewed publications or other reported findings. The author highlights the inconsistent nature of available evidence, often relying on press releases and company websites rather than solely on peer-reviewed literature due to proprietary algorithms and evolving device versions. The study emphasizes the potential of these devices to improve stroke diagnosis and treatment by enabling earlier differentiation between stroke types (ischemic vs. hemorrhagic, LVO vs. non-LVO) and facilitating quicker treatment decisions, potentially transforming the current paradigm that relies heavily on hospital-based imaging. The limitations of current prehospital stroke diagnosis methods, including the high cost and limited availability of mobile stroke units (MSUs), are also discussed.

Mabry and McManus (2008) reviewed advances in prehospital management of severe penetrating trauma, driven by the Iraq and Afghanistan conflicts. The study highlights a

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shift from extrapolating civilian trauma care models to the battlefield, recognizing the unique epidemiological and tactical considerations of combat. The authors emphasize the importance of Tactical Combat Casualty Care (TCCC) principles, focusing on hemorrhage control as the leading preventable cause of death. Significant advancements in tourniquets, hemostatic agents (such as QuikClot, HemCon Bandage, and ChitoFlex), and intravenous fluid resuscitation strategies are discussed. The study notes a change in IV fluid resuscitation, moving away from liberal crystalloid administration to a more targeted approach using Hextend in cases of hemorrhagic shock, based on evidence suggesting that excessive fluid resuscitation can worsen bleeding. The authors also discuss the evolving role of intravenous hemostatic agents like recombinant Factor VIIa, while acknowledging the need for further research. The article concludes by emphasizing the applicability of these military-derived prehospital strategies to austere civilian environments, particularly in light of potential terrorist attacks or natural disasters.

Kim et al. (2020) explored the potential of fifth-generation (5G) mobile technology to enhance prehospital emergency medical services (EMS) and support paramedics. The study reviewed existing literature on 5G applications in EMS, highlighting its benefits such as high-speed data transmission, ultra-reliable low-latency communication, and improved security and privacy. These features could streamline prehospital care by facilitating timely diagnoses, efficient patient transport, and improved communication between paramedics and hospital physicians. The authors discussed several successful implementations of 5G in EMS, including the "super ambulance" in China and the 5G Connected Ambulance in Ireland. However, they also acknowledged challenges, such as limited regulations, privacy concerns, insufficient evidence for policy reform, and unequal access to 5G networks in underserved areas. The study emphasized the crucial role of paramedics in prehospital care and the need for user-friendly 5G-enabled devices and training programs to maximize the technology's impact. Finally, the authors addressed security and privacy concerns surrounding 5G in healthcare, suggesting a multi-layered security approach and highlighting Korea's efforts to establish international certification standards for patient data security in 5G-based EMS. The overall conclusion was that 5G technology holds significant promise for improving EMS, but its successful implementation requires addressing the identified challenges through collaboration among policymakers, technology developers, and healthcare professionals.

Table 1: Characteristics of included studies

Author(s)	Year	Method	Main Findings/Results	Recommendations
Lumley et al.	2020	Scoping review	Existing technologies (blood biomarkers, pre-hospital imaging, telemedicine) for pre-hospital stroke assessment show mixed results; insufficient evidence for routine use.	Large-scale diagnostic accuracy studies and clinical trials needed to evaluate technologies and improve pre-hospital stroke assessment.
Lu et al.	2023	Development and validation of VR training tool	Developed and validated an immersive VR training tool for pre-hospital cranio-maxillofacial (CMF) trauma treatment; high face and content validity.	Further testing with surgical trainees; tool ready for implementation in training programs.
Ziegler et al.	2008	Evaluation of mobile computing system	"Stroke Angel System" reduced in-hospital processing time and increased thrombolysis rate, but LAPSS had limited sensitivity and specificity.	Improved algorithms for pre-hospital stroke detection needed; mobile computing improves acute stroke management.
Kou et al.	2015	Cross-sectional survey	Prehospital doctors in Hubei Province, China, showed high TBI assessment scores but lower treatment scores; factors like education level, experience, and training influenced performance.	Improved CME programs and resource allocation needed to enhance ambulance services in China.
Kirkpatrick et al.	2022	(Implied) Research on RTMSPUS	Remotely telementored self-performed ultrasound (RTMSPUS) shows promise for home-based monitoring and self-management of health, particularly in pandemic scenarios.	Further research needed to explore the full potential of RTMSPUS across diverse healthcare settings.
Amaral et al.	2020	Review	PHUS shows promise in EMS, but needs standardized curricula, competency assessments, and robust quality assurance programs; paramedic	Further research to evaluate impact on patient outcomes and development of quality assurance

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			enthusiasm contrasts with physician reservations.	programs.
Brown JB et al.	2024	Commentary and expert panel discussion	High prehospital mortality from exsanguination and TBI; advancements in damage control resuscitation, blood/plasma transfusion, tranexamic acid use, and near-infrared spectroscopy for TBI diagnosis.	Shift educational paradigms towards clinical immersion and simulation training; collaboration between academia and industry to translate promising technologies into practice.
Williamson et al.	2011	Review	Overview of advancements in prehospital trauma care, including airway management, circulatory access, bleeding control, monitoring techniques, and training.	Continued focus on ABCs of trauma care and improved training programs.
Alotaibi et al.	2023	Review	Review of advancements in US pre-hospital emergency care, highlighting lack of standardization and innovations like mobile health technology, telemedicine, and advanced diagnostic devices.	Address regional disparities and ensure widespread adoption of innovations; emphasize interprofessional collaboration and simulation training.
Walsh	2019	Review	Review of ten non-invasive brain monitoring devices for prehospital stroke diagnosis; inconsistent evidence, but potential to improve diagnosis and treatment by enabling earlier differentiation between stroke types.	Further research and clinical trials to validate the effectiveness of these devices.
Mabry & McManus	2008	Review	Advances in prehospital management of severe penetrating trauma, driven by military experience, emphasizing hemorrhage control and targeted fluid resuscitation.	Applicability of military-derived prehospital strategies to austere civilian environments.
Kim et al.	2020	Literature review	5G technology holds significant promise for improving EMS, but successful implementation requires addressing challenges like regulations, privacy concerns, and unequal access.	Collaboration among policymakers, technology developers, and healthcare professionals to overcome challenges.

4. Results

This systematic review analyzed current practices and innovative technologies in prehospital trauma assessment, incorporating data from 12 studies (Table 1). The findings are categorized thematically, focusing on current practices, the effectiveness of various technologies, and barriers to implementation.

4.1. Current Practices in Prehospital Trauma Assessment:

The reviewed literature reveals significant variability in prehospital trauma assessment practices. Traditional methods heavily rely on the clinical judgment of emergency medical personnel, leading to inconsistencies in assessment quality and potential delays in critical interventions (Kou et al., 2015; Williamson et al., 2011). Studies highlight the limitations of subjective evaluations and time constraints in emergency situations (Introduction section). The need for standardization and improved accuracy in prehospital assessment is consistently emphasized across the reviewed studies. The importance of adhering to established trauma care principles, such as the ABCs (Airway, Breathing, Circulation), remains paramount (Williamson et al., 2011; Mabry & McManus, 2008). However, advancements in techniques and technologies are needed to enhance efficiency and accuracy. The lack of standardization in US EMS operations, roles, and effectiveness is also a significant concern (Alotaibi et al., 2023).

4.2. Effectiveness of Innovative Technologies:

Several innovative technologies showed promise in enhancing prehospital trauma assessment. Point-of-care ultrasound (POCUS) is increasingly utilized for rapid assessment of various conditions, including hemorrhage and cardiac issues (Amaral et al., 2020). While POCUS requires trained users, the development of remotely telementored self-performed ultrasound (RTMSPUS) expands its accessibility (Kirkpatrick et al., 2022). However, the need for standardized curricula and competency assessments for POCUS implementation is highlighted (Amaral et al., 2020). Mobile computing systems,

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such as the "Stroke Angel System," demonstrated the potential to reduce in-hospital processing time and increase the rate of thrombolysis in stroke patients (Ziegler et al., 2008). However, the study also revealed limitations in the sensitivity and specificity of the prehospital stroke detection algorithm used. The use of virtual reality (VR) training tools offers a promising avenue for improving the skills of prehospital care providers (Lu et al., 2023). Further, the potential of 5G technology to enhance data transmission and communication in EMS is discussed, although challenges regarding regulation, privacy, and access remain (Kim et al., 2020). The review also highlighted the exploration of various technologies for prehospital stroke diagnosis, including those using EEG, near-infrared spectroscopy, and other methods (Walsh, 2019), although the evidence base for these technologies remains limited.

4.3. Barriers to Implementation and Challenges:

Several barriers hinder the widespread adoption of innovative technologies in prehospital trauma assessment. These include the need for further research to validate the effectiveness of many technologies (Lumley et al., 2020; Walsh, 2019), the lack of standardized training programs (Amaral et al., 2020), regulatory hurdles and logistical challenges (Brown JB et al., 2024), concerns about cost and accessibility (Walsh, 2019; Kim et al., 2020), and the need for improved algorithms and data analysis techniques (Ziegler et al., 2008). Furthermore, the limited availability of resources and training in some regions (Kou et al., 2015; Alotaibi et al., 2023) presents a significant obstacle to the implementation of these advancements. Addressing these barriers through collaboration between academia, industry, and policymakers is crucial for optimizing prehospital trauma care.

4.4. Summary of Key Findings:

This systematic review reveals a clear need for improved prehospital trauma assessment practices. While traditional methods remain essential, the integration of innovative technologies holds significant potential for enhancing accuracy, efficiency, and ultimately, patient outcomes. However, successful implementation requires addressing several challenges related to research, training, regulation, and resource allocation. Further research is needed to evaluate the long-term impact of these technologies on patient outcomes and to develop robust quality assurance programs. A collaborative approach involving stakeholders across various sectors is essential to overcome existing barriers and translate promising technologies into widespread clinical practice.

5. Discussion

This systematic review examined the current landscape of prehospital trauma assessment, revealing a critical need for improved accuracy, efficiency, and standardization. While traditional methods rely heavily on the subjective judgment of EMS personnel, leading to inconsistencies and potential delays in critical interventions (Kou et al., 2015; Williamson et al., 2011), the reviewed literature highlights the promising potential of several innovative technologies to address these limitations.

The findings underscore the increasing role of point-of-care ultrasound (POCUS) in prehospital care. Its ability to rapidly assess for hemorrhage and other critical conditions (Amaral et al., 2020) is significantly enhanced by the development of remotely telementored self-performed ultrasound (RTMSPUS), expanding its accessibility and utility, particularly in remote or resource-limited settings (Kirkpatrick et al., 2022). However, widespread adoption necessitates standardized training curricula and competency assessments to ensure consistent quality of care (Amaral et al., 2020). The success of RTMSPUS highlights the potential for empowering patients in their own healthcare management, a trend with implications beyond trauma care.

Mobile computing systems, as demonstrated by the "Stroke Angel System," show promise in streamlining communication and improving the efficiency of acute stroke management (Ziegler et al., 2008). However, the study also highlights the need for improved diagnostic algorithms to enhance the sensitivity and specificity of prehospital stroke detection. This underscores a broader challenge: the need for rigorous evaluation of the diagnostic accuracy and clinical impact of new technologies before widespread implementation.

The development and validation of virtual reality (VR) training tools (Lu et al., 2023) represent a significant advancement in prehospital education. Immersive VR training offers a safe and repeatable environment for honing critical skills, potentially reducing the variability in clinical judgment observed in current practices. This approach aligns with the broader emphasis on simulation-based learning and standardized trauma courses (Williamson et al., 2011) as crucial components of effective prehospital care.

The potential of 5G technology to revolutionize EMS (Kim et al., 2020) is significant, offering high-speed data transmission and improved communication capabilities. However, its successful implementation requires addressing regulatory hurdles, privacy concerns, and ensuring equitable access across all populations. The integration of 5G with other technologies, such as POCUS and mobile computing systems, could create a powerful synergistic effect, further enhancing prehospital trauma assessment.

Several studies highlighted the influence of military advancements on civilian prehospital care (Mabry & McManus, 2008; Brown JB et al., 2024). The emphasis on hemorrhage control and targeted fluid resuscitation strategies developed in combat settings has direct applicability to civilian trauma care. The ongoing development of novel technologies, such as injectable foam for non-compressible torso hemorrhage and advanced biomarkers for TBI detection, offers significant potential for improving outcomes.

Despite the promising advancements highlighted in this review, several challenges remain. The lack of standardization in US EMS operations (Alotaibi et al., 2023) necessitates a concerted effort to develop and implement consistent protocols and training programs. Furthermore, the cost and availability of advanced technologies may create disparities in access to care, particularly in underserved areas. Future

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research should focus on evaluating the cost-effectiveness of these technologies, as well as their impact on health equity.

Thus, while traditional prehospital trauma assessment practices remain essential, the integration of innovative technologies offers a significant opportunity to improve the accuracy, efficiency, and standardization of care. Further research is needed to rigorously evaluate the effectiveness of these technologies, address implementation challenges, and ensure equitable access to improve patient outcomes. Collaboration between researchers, clinicians, policymakers, and technology developers is crucial to translate promising advancements into widespread adoption and improved trauma care for all.

6. Conclusion

This systematic review examined the current state of prehospital trauma assessment and the potential of innovative technologies to improve its accuracy and efficiency. The analysis of twelve studies revealed a significant reliance on the clinical judgment of emergency medical personnel, leading to inconsistencies and potential delays in critical interventions. While traditional methods remain important, adhering to established trauma care principles like the ABCs, the need for standardization and improved accuracy is evident.

Several innovative technologies show promise. Point-of-care ultrasound (POCUS), though requiring trained users, offers rapid assessment capabilities, further enhanced by the emerging remotely telementored self-performed ultrasound (RTMSPUS). Mobile computing systems demonstrate potential for streamlining data transmission and improving time-to-treatment, although limitations in diagnostic accuracy of some algorithms were noted. Virtual reality (VR) training tools offer a valuable method for enhancing provider skills. However, challenges remain, including the need for standardized training curricula for technologies like POCUS, the development of more accurate prehospital diagnostic algorithms, and addressing the limitations of current technologies. Furthermore, the uneven access to and adoption of these technologies across diverse prehospital settings, particularly in resource-limited areas, remains a major barrier. The successful integration of these technologies requires collaboration between policymakers, technology developers, and healthcare professionals. The future of prehospital trauma assessment lies in a balanced approach, combining established best practices with carefully selected and effectively implemented innovative technologies.

7. Recommendations and Best Practices

Based on this review, the following recommendations are proposed:

- Develop and implement standardized protocols for prehospital trauma assessment, incorporating best practices and evidence-based guidelines.
- Implement comprehensive training programs focused on the effective use of innovative technologies, such as POCUS and mobile computing systems. These programs must include standardized competency assessments to ensure proficiency and quality assurance.
- Invest in research and development to improve the accuracy and sensitivity of prehospital diagnostic algorithms for conditions like stroke and traumatic brain injury. This includes exploring the use of novel biomarkers and advanced imaging techniques.
- Develop robust systems for integrating data from various sources, including mobile applications, telemedicine platforms, and hospital systems.
- Ensure equitable access to innovative technologies across all prehospital settings, regardless of geographic location or resource availability. This may require targeted investments in infrastructure and training in underserved areas.
- Widespread adoption of simulation-based training should be encouraged to improve provider skills in the use of advanced technologies and to practice critical thinking in complex trauma scenarios.
- Foster collaboration between researchers, technology developers, EMS providers, and policymakers to facilitate the development, implementation, and evaluation of innovative technologies in prehospital trauma assessment. Regular knowledge sharing and dissemination of research findings are crucial.

8. Recommendations for Future Research

Future research should focus on the following areas:

- Conduct large-scale, randomized controlled trials to rigorously evaluate the effectiveness of innovative technologies in improving patient outcomes.
- Conduct comparative effectiveness research to evaluate the relative benefits and costs of different technologies and strategies for prehospital trauma assessment.
- Conduct implementation science research to identify and address the barriers to the adoption and integration of innovative technologies in diverse prehospital settings.
- Conduct longitudinal studies to assess the long-term impact of innovative technologies on patient outcomes and healthcare system efficiency.
- Continue research and development efforts to create new technologies that address unmet needs in prehospital trauma assessment, such as improved non-invasive diagnostic tools and more effective methods for hemorrhage control.
- Explore the potential of artificial intelligence (AI) and machine learning to improve the accuracy and efficiency of prehospital trauma assessment, including the development of AI-powered decision support systems.

*Corresponding Author: **Osama Mohammed Alghamdi**

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*Corresponding Author: **Osama Mohammed Alghamdi**