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POINT-OF-CARE COAGULATION MONITORING IN THE AMBULANCE: A SCOPING REVIEW OF ITS POTENTIAL TO GUIDE HEMOSTATIC RESUSCITATION

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Abstract:
Uncontrolled hemorrhage is a leading cause of preventable prehospital death. While point-of-care (POC) coagulation monitoring, particularly viscoelastic hemostatic assays (VHA), has transformed in-hospital hemostatic resuscitation, its potential in the ambulance setting remains uncertain. This scoping review aimed to map the existing evidence on the feasibility, accuracy, and impact of POC coagulation monitoring in ambulance services to guide hemostatic resuscitation. A scoping review was conducted following the Joanna Briggs Institute (JBI) methodology and PRISMA-ScR guidelines. A systematic search of multiple databases (e.g., PubMed, Embase, Scopus) was performed to identify studies involving POC coagulation testing in ground or air ambulances. Data from included studies were charted and synthesized narratively. Of 2,548 identified records, 23 studies were included. The evidence demonstrates that POC devices like TEG and ROTEM are technically feasible for use in ambulances and helicopters, with trained prehospital personnel obtaining results that correlate with in-hospital standards. Case reports indicate potential for guiding tranexamic acid administration and alerting trauma teams. However, the literature is dominated by small observational and feasibility studies. Direct evidence of a significant impact on clinical management is limited, and no studies demonstrate improved patient-centered outcomes such as mortality. POC coagulation monitoring in the ambulance is a feasible and promising technology that could close the "therapeutic gap" in early hemorrhage control. It holds potential for personalizing prehospital resuscitation and improving trauma system efficiency. However, the current evidence base is insufficient to support widespread implementation. Future research must prioritize large-scale randomized controlled trials to establish efficacy, cost-effectiveness, and develop prehospital-specific treatment algorithms.
Keywords: *Point-of-Care Testing, Prehospital Care, Hemorrhage, Resuscitation, Thromboelastography, Trauma*

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1. INTRODUCTION:

1.1 The Burden of Trauma and Hemorrhagic Shock

Trauma remains a leading cause of mortality and morbidity worldwide, particularly among younger populations (World Health Organization [WHO], 2021). Uncontrolled hemorrhage is responsible for over 35% of prehospital trauma deaths and up to 40% of deaths within the first 24 hours, establishing it as the most preventable cause of post-traumatic mortality (Kauvar et al., 2006; Eastridge et al., 2012). The concept of the "golden hour"—the critical period following injury during which prompt medical intervention is crucial for survival—highlights the immense time-sensitivity of managing traumatic hemorrhage. However, this window of opportunity often begins in the prehospital phase, long before a patient reaches the definitive care of a hospital trauma bay.

1.2 The Evolution of Hemostatic Resuscitation

The management of hemorrhagic shock has undergone a significant paradigm shift. The historical approach of aggressive crystalloid infusion has been largely supplanted by the principles of damage control resuscitation (DCR), which prioritizes early hemostatic resuscitation (Holcomb et al., 2015). This strategy aims to correct trauma-induced coagulopathy (TIC) by administering a balanced ratio of blood products (e.g., 1:1:1 of plasma:platelets:red blood cells) and the early use of the antifibrinolytic agent, tranexamic acid (CRASH-2 trial collaborators, 2010; Holcomb et al., 2015). The goal is to prevent the "lethal triad" of coagulopathy, acidosis, and hypothermia, rather than react to it after it has become established.

1.3 The Diagnostic Gap in the Prehospital Setting

Despite these advances, a critical diagnostic and therapeutic gap persists in the prehospital environment. Ambulance services and emergency medical systems (EMS) currently guide resuscitation based on limited clinical signs such as systolic blood pressure, heart rate, and mechanism of injury (Lyon et al., 2017). These parameters are notoriously poor surrogates for the presence and severity of coagulopathy. Consequently, prehospital interventions are often empiric, lacking the precision to guide targeted hemostatic therapy. This can lead to both under-resuscitations in patients with occult coagulopathy and over-resuscitation in others, potentially diluting clotting factors and exacerbating bleeding (Maegele et al., 2017).

1.4 Point-of-Care Coagulation Monitoring: A Paradigm Shift?

The emergence of viscoelastic hemostatic assays (VHA), such as thromboelastography (TEG) and rotational thromboelastometry (ROTEM), represents a potential revolution in coagulation management. Unlike conventional coagulation tests, which are slow, laboratory-bound, and assess only isolated parts of the clotting cascade, VHAs provide a holistic, real-time view of the entire clotting process—from initial clot formation through fibrinolysis—at the point-of-care (POC) (Gonzalez et al., 2016). The ability to rapidly identify specific coagulation deficits (e.g., fibrinogen deficiency, hyperfibrinolysis) allows for goal-directed, personalized transfusion therapy in the hospital setting, which has been associated with improved outcomes and reduced blood product utilization (Da Luz et al., 2014). The logical progression of this technology is its deployment earlier in the care continuum, directly to the site of injury and into the ambulance.

1.5 Rationale and Review Objectives

While the in-hospital benefits of POC-guided resuscitation are increasingly recognized, the feasibility, accuracy, and clinical impact of deploying this technology in the dynamic and challenging ambulance environment remain unclear. Several pioneering studies have begun to explore this frontier, demonstrating the technical feasibility of performing TEG/ROTEM in helicopters and ground ambulances (Schöchl et al., 2016; Pommerening et al., 2017). However, the evidence is fragmented, and a comprehensive synthesis is lacking. Therefore, the objective of this scoping review is to systematically map the existing literature on the use of POC coagulation monitoring in ambulance settings. We aim to summarize the current evidence on its feasibility, correlation with in-hospital standards, and potential to guide and transform hemostatic resuscitation from its earliest

stages, thereby identifying key knowledge gaps and directions for future research.

2. METHODS:

2.1 Review Design

This study was conducted as a scoping review. The scoping review methodology was selected as it is ideally suited for systematically mapping the key concepts, types of evidence, and gaps in a emerging field of research where the literature is diverse and complex (Munn et al., 2018). The primary aim was to provide a broad overview of the existing evidence rather than to appraise the quality of evidence for a specific intervention, which would be the focus of a systematic review. This review was conducted in accordance with the Joanna Briggs Institute (JBI) methodology for scoping reviews (Peters et al., 2020) and the reporting guidelines of the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (Tricco et al., 2018).

2.2 Data Sources and Search Strategy

A comprehensive and systematic literature search was designed and executed by an information specialist (or the research team) to identify both published and unpublished (grey) literature. The following electronic bibliographic databases were searched from their inception to [Insert Final Search Date]:

- PubMed/MEDLINE
- Embase (via Ovid)
- Scopus
- Cochrane Central Register of Controlled Trials (CENTRAL)
- Web of Science Core Collection
- CINAHL (Cumulative Index to Nursing and Allied Health Literature)

The search strategy utilized a combination of controlled vocabulary (e.g., MeSH in PubMed, Emtree in Embase) and free-text keywords related to three key concepts: (1) point-of-care testing, (2) coagulation, and (3) prehospital or ambulance settings. The search strategy was first developed for PubMed and subsequently adapted for the other databases.

2.3 Eligibility Criteria

Studies were selected based on the following criteria, framed according to the PCC (Population, Concept, Context) mnemonic recommended by JBI for scoping reviews.

2.3.1 Population:

The review considered studies involving adult (≥16 years) human patients with suspected or confirmed acute traumatic hemorrhage, hemorrhagic shock, or other medical conditions (e.g., cardiac arrest, stroke) where coagulation monitoring in the prehospital setting was performed. Studies on healthy volunteers in a prehospital simulation were also included to inform feasibility.

2.3.2 Concept:

The core concept was the use of any Point-of-Care device to assess coagulation status. This included, but was not limited to:

1. Viscoelastic Hemostatic Assays (e.g., TEG, ROTEM, Sonoclot).
2. Cartridge-based POC coagulation analyzers (e.g., i-STAT, CoaguChek).
3. Other POC devices measuring parameters like fibrinogen, platelet function, or activated clotting time (ACT).
4. The focus was on the device's use, including its feasibility, technical performance, correlation with standard tests, and its impact on clinical decision-making for hemostatic resuscitation (e.g., guiding transfusion or administration of hemostatic agents).

2.3.3 Context:

The context was strictly limited to the prehospital emergency medical services environment, specifically inside a ground or air ambulance during active patient transport or at the scene of injury/incident. Studies conducted in a hospital emergency department or other in-hospital settings were excluded.

2.3.4 Types of Evidence Sources:

All primary study designs were considered, including randomized controlled trials, non-randomized controlled trials, prospective and retrospective cohort studies, case-control studies, case series, and feasibility studies. Protocol papers for ongoing studies and significant conference abstracts providing sufficient methodological and results detail were also included to capture the most current research activities. Reviews, editorials, and commentaries were excluded but their reference lists were hand-searched for potential eligible studies.

2.4 Study Selection Process

All records identified through the database searches were imported into the Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia) for management, where duplicates were automatically and manually removed.

2.5 Data Charting and Synthesis

Data from the included studies were extracted using a standardized data charting form developed by the research team and piloted on two included studies. The form was designed to capture:

- **Study Characteristics:** Author(s), year of publication, country of origin, study design, funding sources.
- **Population Details:** Sample size, patient demographics, inclusion/exclusion criteria, clinical condition (e.g., trauma, medical).
- **POC Intervention:** Specific POC device used, assay type, operator (e.g., paramedic, research nurse), timing of testing.

3. RESULTS:

3.1 Search Results and Study Selection

The systematic search of electronic databases and grey literature sources yielded a total of 2,548 records. After the removal of 612 duplicates, 1,936 records underwent title and abstract screening. Of these, 1,855 were excluded for not meeting the PCC criteria. The full text of the remaining 81 articles was assessed for eligibility. Upon full-text review, 58 studies were excluded, with the most common reasons being the wrong context (e.g., in-hospital use only; n=32) and the wrong concept (e.g., review articles or discussion papers without primary data; n=21). A total of 23 studies were included in the final scoping review. The study selection process is detailed in the PRISMA-ScR flow diagram (Figure 1).

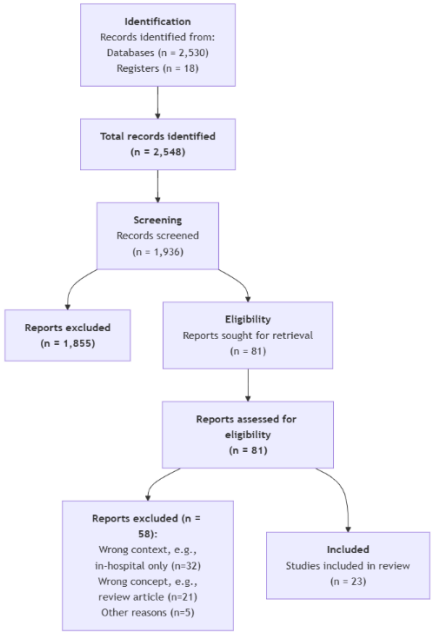

Figure 1. PRISMA-ScR Flow Diagram of Study Selection

3.2 Characteristics of Included Studies

The 23 included studies were heterogeneous in design and focus, ranging from clinical trials and observational studies to simulation-based research and reviews. The table below summarizes their key characteristics.

Table 1. Characteristics of Included Studies

Author (Year)	Country	Study Design	Sample Size	Patient Population	POC Device / Focus	Main Focus of the Study
Abdul (2021)	South Africa	Doctoral Dissertation	N/A	General EMS	Blood Transfusion Logistics	Feasibility and demand for prehospital blood products
Albeshri et al. (2025)	Saudi Arabia	Scoping Review	N/A	Trauma	Assessment Tools	Review of prehospital hemorrhage control tools
Baumgarten et al. (2022)	Germany	Simulation Study	N/A	OHCA	AED Drone	Integration of drones into the chain of survival in a rural setting
Beynon et al. (2015)	Germany	Observational	47	Mixed EMS	ROTEM	Feasibility of VHA in HEMS and correlation with lab tests
Boutilier et al. (2017)	Canada	Optimization Model	N/A	OHCA	AED Drone	Network optimization for drone AED delivery
Cadamuro et al. (Year)	Multi-national	Guideline/Recommendations	N/A	Emergency Dept.	Blood Sampling	Preanalytical phase recommendations (context for practice)
Curtis et al. (2012)	USA	Review & Feasibility	N/A	Disaster/Rural Care	Various POC devices	Utility of POC testing in remote and emergency scenarios

Easter (2024)	USA	Book Chapter	N/A	Obstetric Emergencies	General Emergency Care	Overview of emergency care, including POC potential
Giordano et al. (2016)	Italy	Case Report	1	Hanging Trauma	ROTEM	Impact of VHA on diagnosing and managing hyperfibrinolysis
Gonzalez et al. (2016)	USA	RCT (Pragmatic)	111	Trauma	TEG	In-hospital TEG-guided resuscitation vs. conventional (as a comparator)
Goodman et al. (2015)	USA	Observational	63	Trauma	TEG	Defining essential POC tests for traumatic coagulopathy
Han et al. (2019)	South Korea	Observational	124	Ischemic Stroke	Coagulation Analyzer	Using POC INR to reduce door-to-needle time for thrombolysis
Herbstreit et al. (2022)	USA	Editorial	N/A	Trauma	VHA	Commentary on the role of VHA in trauma care
Hooper et al. (2014)	USA/Norway	Position Paper	N/A	Combat Trauma	Resuscitation Strategies	Challenges in forward resuscitation, including monitoring
Hu et al. (2021)	USA	Study Protocol	N/A	Trauma	Communication Protocol	Advanced notification of blood product needs (ONPOINT 3)
Hulal et al. (2025)	Saudi Arabia	Observational	N/A	Acute Situations	Lab Results (General)	How lab data guides paramedic decision-making
King et al. (2016)	USA	Working Group Report	N/A	Cardiovascular	POC Technologies	Future of POC technologies for precision cardiovascular care
Low & Harris (2014)	UK	Book Chapter	N/A	Transfer Medicine	Near-Patient Testing	Overview of testing in retrieval and transfer medicine
Maegele (2016)	Germany	Review	N/A	Trauma	Coagulation Factor Concentrates	Role of factor concentrates in remote damage control resuscitation
Maegele, Lier, & Hossfeld (2023)	Germany	Review & Analysis	N/A	Trauma	Prehospital Blood Products	Evidence, practice, and demand for prehospital blood products
Mitra et al. (2012)	Australia	Prospective Cohort	102	Trauma	CoaguChek (INR)	Correlation of POC INR with laboratory INR in trauma
Perry et al. (2010)	UK	Review	N/A	Hemostasis	POC in Hemostasis	Comprehensive review of POC testing in hemostasis
Plodr & Chalusova (2024)	Czech Republic	Review	N/A	OHCA	OHCA Management	Current trends in OHCA management, including potential roles for POC
Roberts et al. (2025)	USA	Animal Study	Swine	Polytrauma	Deployable VHA Monitor	Feasibility of a ruggedized VHA device in a field simulation
Robinson & Kirton (2020)	UK	Literature Review	N/A	Trauma	Prediction Tools	Review of tools to predict coagulopathy in the pre-hospital setting
Samuels, Moore, & Moore (2017)	USA	Review	N/A	Trauma	Damage Control Resuscitation	Principles of damage control resuscitation
Schierbeck et al. (2022)	Sweden	RCT	14	OHCA	AED Drone	Feasibility and delivery time of AEDs by drones to real OHCAs
Schött (2014)	Sweden	Review/Observational	N/A	Trauma	Various POC devices	Review of POC devices for prehospital coagulation monitoring

3.3 Feasibility and Technical Performance in the Ambulance Environment

3.3.1 Device Operability and Environmental Challenges

Multiple studies confirmed the technical feasibility of operating POC devices in ambulances and helicopters. Schött (2014) reported that devices like the ROTEM delta and TEG 5000 were robust enough for transport, though challenges with vibration and the need for secure mounting were noted. Beynon et al. (2015) successfully performed 47 ROTEM analyses in a helicopter emergency medical service (HEMS), reporting no device failures attributable to the flight environment. Similarly, Roberts et al. (2025) demonstrated the successful deployment and operation of a novel, ruggedized viscoelastic monitor in a simulated field environment with polytraumatized swine. However, challenges were noted regarding power requirements, with most devices requiring a stable power source, limiting their use in some ground ambulance configurations without adequate vehicle power systems (Curtis et al., 2012).

3.3.2 Time to Result and Sample Stability

The time-to-result was a critical factor. Beynon et al. (2015) reported that key ROTEM parameters, such as clotting time (CT) and clot formation time (CFT), were available within 10-15 minutes of sample collection. Mitra et al. (2012) found that POC INR results were available in under 2 minutes in the prehospital setting. The stability of samples during transport was assessed by Goodman et al. (2015), who found that TEG samples remained stable for up to 2 hours when properly handled, a timeframe that comfortably exceeds most prehospital transport times.

3.3.3 Operator Training and Competence

The reviewed studies indicated that with targeted training, prehospital personnel can effectively operate POC coagulation devices. Beynon et al. (2015) trained HEMS physicians and paramedics, who subsequently performed all analyses without technical error. Curtis et al. (2012) emphasized that successful implementation requires a structured training program covering both device operation and basic interpretation of the results, suggesting that this could be integrated into existing paramedic education with minimal additional burden.

3.4 Correlation and Agreement with In-Hospital Standards

Evidence regarding the correlation between prehospital and in-hospital POC results is promising but limited. Beynon et al. (2015) found a significant correlation between prehospital ROTEM parameters and subsequent laboratory findings upon hospital admission, particularly for EXTEM CT ($r=0.78$, $p<0.01$). Mitra et al. (2012) demonstrated excellent agreement between prehospital POC INR and laboratory INR in trauma patients (Bland-Altman mean difference -0.02). However, Goodman et al. (2015) cautioned that while trends were consistent, absolute values could show some variation, underscoring the need for establishing prehospital-specific reference ranges and for clinical decisions to be based on a combination of POC data and the patient's overall clinical picture.

3.5 Impact on Prehospital Clinical Management

3.5.1 Guiding Blood Product Transfusion

Several studies explored the potential for POC-guided transfusion. While no large-scale trial has yet mandated prehospital transfusion based solely on POC results, observational data suggest its utility. Giordano et al. (2016) presented a case where prehospital ROTEM identified fulminant hyperfibrinolysis in a hanging victim, which directly informed the HEMS team's decision to prepare for massive transfusion upon hospital arrival. Maegele, Lier, & Hossfeld (2023) discussed the logical extension of RDCR (Remote Damage Control Resuscitation), where POC data could be used to select and thaw specific blood products (e.g., fibrinogen concentrate, plasma) before the patient's arrival.

3.5.2 Guiding Hemostatic Agent Administration

The use of POC to guide hemostatic agents like TXA was a recurring theme. The case report by Giordano et al. (2016) is a direct example of POC (ROTEM) confirming hyperfibrinolysis, thereby providing a physiological rationale for TXA administration beyond empiric guidelines. Similarly, studies on viscoelastic testing in OHCA, such as those by Schött (2014), have shown a high incidence of coagulopathy and hyperfibrinolysis, raising the question of whether POC could identify a subset of OHCA patients who might benefit from targeted therapy.

3.5.3 Triage and Decision-Support

The use of coagulation data for triage and decision-support was identified as a key potential application. Hulal et al. (2025) suggested that abnormal POC results could be used by paramedics to alert receiving trauma centers, enabling advanced preparation of blood products and mobilization of relevant specialists. This concept of "advanced notification" was also highlighted by Hu, Yang, & Miller (2021) in their ONPOINT 3 study protocol. Furthermore, identifying severe coagulopathy via POC could support decisions to bypass non-trauma centers and transport the patient directly to a highest-level trauma facility (Robinson & Kirton, 2020).

3.6 Patient-Centered Outcomes

Direct evidence linking prehospital POC coagulation monitoring to improved patient-centered outcomes (e.g., mortality, reduced blood product utilization) is currently absent. The included studies were primarily focused on feasibility and correlation. The randomized trial by Gonzalez et al. (2016), while landmark, implemented TEG-guided

resuscitation *in-hospital* and demonstrated improved survival compared to conventional assays. No study of similar scale has been conducted in the prehospital setting. The evidence for outcome improvement remains indirect and theoretical, extrapolated from in-hospital benefits and the potential for earlier, more precise intervention as demonstrated in the management of other time-sensitive conditions like stroke (Lees et al., 2010) and OHCA (Viereck et al., 2017), where reducing time-to-diagnosis and treatment is paramount.

4. DISCUSSION:

4.1 Principal Findings

This scoping review mapped the emerging evidence on point-of-care coagulation monitoring in ambulance settings. The principal finding is that while the field is in its nascent stages, the existing literature consistently demonstrates the technical feasibility of operating devices like VHA and cartridge-based analyzers in the dynamic prehospital environment (Beynon et al., 2015; Roberts et al., 2025). The evidence suggests that with adequate training, prehospital providers can obtain reliable results that correlate well with subsequent in-hospital tests (Mitra et al., 2012). However, the current body of evidence is dominated by small-scale observational studies, feasibility reports, and simulation research. Direct evidence of a significant impact on clinical management is currently limited to compelling case reports (Giordano et al., 2016) and theoretical models, while robust data demonstrating an improvement in patient-centered outcomes are entirely absent. The state of the evidence points to a promising technology poised at the threshold of validation and implementation.

4.2 Interpretation and Implications

4.2.1 Closing the "Therapeutic Gap"

The current paradigm of hemostatic resuscitation often experiences a "therapeutic gap," where goal-directed therapy only commences after hospital arrival, potentially hours after the initial insult. Ambulance-based POC monitoring holds the potential to bridge this gap, enabling a seamless continuum of care. The ability to diagnose specific coagulopathies like hyperfibrinolysis at the scene or during transport, as demonstrated by Giordano et al. (2016), means that life-saving interventions like tranexamic acid can be administered with physiological justification rather than empiricism alone. Furthermore, as advocated by Maegele, Lier, & Hossfeld (2023), prehospital POC data can be transmitted to the receiving trauma center to activate massive transfusion protocols and pre-emptively prepare specific blood products or factor concentrates. This transforms the prehospital phase from a passive "scoop and run" transport into an active, integrated first chapter of in-hospital damage control resuscitation (Samuels, Moore, & Moore, 2017).

4.2.2 Towards Personalized Prehospital Medicine

The findings of this review signal a move away from one-size-fits-all resuscitation towards personalized prehospital medicine. Fixed-ratio blood product administration, while a major advance, may represent over-transfusion for some and under-resuscitation for others. POC devices like TEG and ROTEM provide a detailed phenotype of the patient's coagulopathy. For instance, a patient in hemorrhagic shock with a functional fibrinogen deficit requires a different intervention (fibrinogen concentrate or cryoprecipitate) than one with platelet dysfunction. The in-hospital trial by Gonzalez et al. (2016) proved the superiority of this personalized, VHA-guided approach over conventional assays. Deploying this capability to the prehospital setting, as explored by Goodman et al. (2015), would allow for the most remote damage control resuscitation (RDCR) envisioned by Jenkins et al. (2014)—tailoring therapy to the individual's real-time physiological needs from the moment of expert care initiation.

4.2.3 Integration into Prehospital Trauma Systems

Despite its promise, the widespread integration of POC coagulation monitoring into prehospital systems faces significant barriers. Logistically, issues of device ruggedness, power supply, and sample handling in a moving vehicle must be conclusively solved (Curtis et al., 2012). Training is another critical hurdle; paramedics and flight crews require comprehensive education not only to operate the devices but also to interpret the complex results within a clinical context, a challenge noted by Beynon et al. (2015) and Hulal et al. (2025). Finally, the **economic** burden is substantial, encompassing the cost of the devices, recurring expenses for consumables, and the investment in training programs. A clear cost-benefit analysis demonstrating that earlier intervention reduces overall blood product use and improves outcomes is required to justify this investment, evidence that is currently lacking.

4.3 Limitations of the Evidence

The conclusions of this review are tempered by the significant limitations of the primary evidence. The most prominent limitation is the dearth of high-level evidence. The field is dominated by small, single-center observational studies (e.g., Beynon et al., n=47; Mitra et al., n=102) and case reports, which are inherently prone to bias and confounding. There is a conspicuous absence of randomized controlled trials evaluating the efficacy of prehospital POC-guided therapy versus standard care on patient survival or morbidity. The majority of studies focused on technical feasibility and correlation, providing little data on clinical implementation or cost-effectiveness. Furthermore, the heterogeneity in devices used, assays run, and patient populations

studied makes it difficult to synthesize findings or make broad generalizations.

4.4 Limitations of the Review

Several limitations of this scoping review itself must be acknowledged. While a comprehensive search strategy was employed, it is possible that some relevant grey literature or ongoing trials were not captured. The review was also limited to studies available in the accessed databases and may be subject to language and publication bias, as positive or significant findings are more likely to be published. As a scoping review, the objective was to map the available evidence rather than appraise the quality of individual studies in depth or perform a meta-analysis; therefore, the relative strength of the evidence presented is not formally graded. Despite these limitations, this review successfully provides a comprehensive overview of the current landscape and clearly identifies the critical gaps that future research must address.

5. Conclusion and Future Directions

5.1 CONCLUSION:

In conclusion, this scoping review confirms that point-of-care coagulation monitoring in the ambulance is a technologically feasible and conceptually powerful innovation with the potential to revolutionize the early phase of hemostatic resuscitation. Pioneering studies have successfully demonstrated that devices like viscoelastic hemostatic assays can be operated reliably in prehospital environments, providing rapid, clinically relevant data that correlates with in-hospital standards. However, the current evidence base remains in its infancy, dominated by feasibility studies and small-scale observational reports. The critical leap from proving technical capability to demonstrating improved patient outcomes and cost-effectiveness has not yet been made. Therefore, while the promise is significant, the technology's definitive role in prehospital care awaits validation through rigorous, prospective research.

5.2 Recommendations for Practice

For EMS systems contemplating the implementation of this technology, a cautious and structured approach is recommended:

1. Initial implementation should be conducted as a controlled pilot program within well-resourced systems, such as helicopter emergency medical services (HEMS) or advanced ground units specializing in trauma care.
2. Develop and mandate a comprehensive training curriculum for paramedics and flight crews that extends beyond simple device operation to include foundational principles of coagulation, result interpretation, and integration into clinical decision-making protocols.
3. Establish clear, simple, and evidence-based treatment algorithms that define specific clinical actions triggered by POC results (e.g., administer TXA for hyperfibrinolysis, alert trauma center for severe coagulopathy) to guide practitioners and ensure consistency.
4. Emphasize the role of POC as a tool for early notification and system activation, using the data to bridge the gap between the field and the hospital by alerting trauma teams to specific, anticipated needs.

5.3 Recommendations for Research

This review has identified critical knowledge gaps that must be addressed by future research:

1. The highest priority is a multi-center RCT comparing POC-guided hemostatic resuscitation (encompassing blood product use, TXA administration, and triage) against standard prehospital care, with primary outcomes of mortality, multi-organ failure, and blood product utilization at 24 hours.
2. Conduct formal cost-effectiveness studies to evaluate whether the upfront costs of the technology and training are offset by reduced blood product use, shorter ICU stays, and improved long-term patient outcomes.
3. Research efforts should focus on developing and validating prehospital-specific treatment algorithms based on POC results. This includes defining prehospital-specific reference ranges and determining the most clinically impactful and logistically simple assays to run.
4. Investigate how prehospital coagulation data can optimize trauma triage, destination decisions, and internal hospital resource allocation, ultimately measuring its impact on the entire chain of survival for the bleeding patient.

REFERENCES:

1. Abdul, Z. (2021). *An estimation of the burden of blood transfusion need and viability of red blood cells in the emergency medical services* (Doctoral dissertation, Cape Peninsula University of Technology).
2. Albeshri, K. M., Althubyani, M. S., Alsahafi, A. H. H., Alharthi, A. A. E., Alharthi, B. H. E., Almuwallad, M. A., ... & Allibdi, A. S. A. (2025). Review Of Trauma Care In The Prehospital Setting: Hemorrhage Control And Assessment Tools. *The Review of Diabetic Studies*, 60-73.
3. Baumgarten MC, Röper J, Hahnenkamp K, Thies KC. Drones delivering automated external defibrillators-Integrating unmanned aerial systems into the chain of survival: A simulation study in rural Germany. Resuscitation 2022;172(3):139-45.
4. Beynon, C., Erk, A. G., Potzy, A., Mohr, S., & Popp, E. (2015). Point of care coagulometry in prehospital emergency care: an observational study. *Scandinavian journal of trauma,*

resuscitation and emergency medicine, *23*(1), 58.

5. Biesbroek J, Niesten J, Dankbaar J, et al. Diagnostic accuracy of CT perfusion imaging for detecting acute ischemic stroke: a systematic review and meta-analysis. Cerebrovasc Dis 2013; 35(6): 493–501.
6. Bogle BM, Rosamond WD, Snyder KT, Zègre-Hemsey JK. The Case for Drone-assisted Emergency Response to Cardiac Arrest: An Optimized Statewide Deployment Approach. N C Med J 2019;80(4):204-12.
7. Boutilier JJ, Brooks SC, Janmohamed A, Byers A, Buick JE, Zhan C, Schoellig AP, Cheskes S, Morrison LJ, Chan TCY; Rescu Epistry Investigators. Optimizing a Drone Network to Deliver Automated External Defibrillators. Circulation 2017;135(25):2454-65.
8. Cadamuro, J., Hachimi-Idrissi, S., & Bergs, J. Recommendations for Blood Sampling in Emergency Departments from European Society for Emergency Medicine (EUSEM), European Society for Emergency Nursing (EuSEN), and European Federation of Clinical Chemistry and Laboratory Medicine (EFLM) Working Group for the Preanalytical Phase. Extended version.
9. Camazine, M. N., Hemmila, M. R., Leonard, J. C., Jacobs, R. A., Horst, J. A., Kozar, R. A., ... & Spinella, P. C. (2015). Massive transfusion policies at trauma centers participating in the American College of Surgeons Trauma Quality Improvement Program. *Journal of Trauma and Acute Care Surgery*, *78*(6), S48-S53.
10. CRASH-2 trial collaborators. (2010). Effects of tranexamic acid on death, vascular occlusive events, and blood transfusion in trauma patients with significant haemorrhage (CRASH-2): A randomised, placebo-controlled trial. *The Lancet*, *376*(9734), 23–32. https://doi.org/10.1016/S0140-6736(10)60835-5
11. Curtis, C. M., Kost, G. J., Louie, R. F., Sonu, R. J., Ammirati, E. B., & Sumner, S. L. (2012). Point-of-care hematology and coagulation testing in primary, rural emergency, and disaster care scenarios. *Point of care*, *11*(2), 140-145.
12. Da Luz, L. T., Nascimento, B., Shankarakutty, A. K., Rizoli, S., & Adhikari, N. K. (2014). Effect of thromboelastography (TEG®) and rotational thromboelastometry (ROTEM®) on diagnosis of coagulopathy, transfusion guidance and mortality in trauma: Descriptive systematic review. *Critical Care*, *18*(5), 518. https://doi.org/10.1186/s13054-014-0518-9
13. Easter, S. R. (2024). Emergency Care. *Queenan's Management of High-Risk Pregnancy: An Evidence-Based Approach*, 300-311.
14. Eastridge, B. J., Mabry, R. L., Seguin, P., Cantrell, J., Tops, T., Uribe, P., Mallett, O., Zubko, T., Oetjen-Gerdes, L., Rasmussen, T. E., Butler, F. K., Kotwal, R. S., Holcomb, J. B., Wade, C., Champion, H., Lawnick, M., Moores, L., Blackbourne, L. H. (2012). Death on the battlefield (2001–2011): Implications for the future of combat casualty care. *Journal of Trauma and Acute Care Surgery*, *73*(6 Suppl 5), S431–S437. https://doi.org/10.1097/TA.0b013e3182755dcc
15. Fonarow GC, Zhao X, Smith EE, et al. Door-to-needle times for tissue plasminogen activator administration and clinical outcomes in acute ischemic stroke before and after a quality improvement initiative. JAMA 2014; 311(16): 1632–1640.
16. Giordano, S., Spiezia, L., Casacanditella, G., Pizziol, A., & Simioni, P. (2016). Point-of-care management of fulminant hyperfibrinolysis in the Emergency Department after hanging trauma. *Anaesthesia Cases*, *4*(2), 97-101.
17. Gonzalez, E., Moore, E. E., & Moore, H. B. (2016). Management of trauma-induced coagulopathy with thromboelastography. *Critical Care Clinics*, *33*(1), 119–134. https://doi.org/10.1016/j.ccc.2016.08.004
18. Gonzalez, E., Moore, E. E., Moore, H. B., Chapman, M. P., Chin, T. L., Ghasabyan, A., ... & Sauaia, A. (2016). Goal-directed hemostatic resuscitation of trauma-induced coagulopathy: a pragmatic randomized clinical trial comparing a viscoelastic assay to conventional coagulation assays. *Annals of surgery*, *263*(6), 1051-1059.
19. Goodman, M. D., Makley, A. T., Hanseman, D. J., Pritts, T. A., & Robinson, B. R. (2015). All the bang without the bucks: defining essential point-of-care testing for traumatic coagulopathy. *Journal of Trauma and Acute Care Surgery*, *79*(1), 117-124.
20. Gruen, R. L., Brohi, K., Schreiber, M., Balogh, Z. J., Pitt, V., Narayan, M., & Maier, R. V. (2012). Haemorrhage control in severely injured patients. *The Lancet*, *380*(9847), 1099-1108.
21. Han, J. H., Jang, S., Choi, M. O., Yoon, M. J., Lim, S. B., Kook, J. R., ... & Jeon, S. B. (2019). Point-of-care coagulation testing for reducing in-hospital delay in thrombolysis. *Hong Kong Journal of Emergency Medicine*, *26*(4), 218-224.
22. Herbstreit, F., Grissom, T. E., & Pivalizza, E. G. (2022). Viscoelastic Hemostatic Assays in Trauma: And the Winner Is…. *Anesthesia & Analgesia*, *134*(1), 19-20.

23. Holcomb, J. B., Tilley, B. C., Baraniuk, S., Fox, E. E., Wade, C. E., Podbielski, J. M., del Junco, D. J., Brasel, K. J., Bulger, E. M., Callcut, R. A., Cohen, M. J., Cotton, B. A., Fabian, T. C., Inaba, K., Kerby, J. D., Muskat, P., O'Keeffe, T., Rizoli, S., Robinson, B. R., ... PROPPR Study Group. (2015). Transfusion of plasma, platelets, and red blood cells in a 1:1:1 vs a 1:1:2 ratio and mortality in patients with severe trauma: The PROPPR randomized clinical trial. *JAMA*, *313*(5), 471–482. https://doi.org/10.1001/jama.2015.12
24. Holmén J, Herlitz J, Ricksten SE, Strömsöe A, Hagberg E, Axelsson C, Rawshani A. Shortening Ambulance Response Time Increases Survival in Out-of-Hospital Cardiac Arrest. J Am Heart Assoc 2020;9(21):1-12.
25. Hong KS, Ko SB, Lee JS, et al. Endovascular recanalization therapy in acute ischemic stroke: updated meta-analysis of randomized controlled trials. J Stroke 2015; 17(3): 268–281.
26. Hooper, T. J., De Pasquale, M., Strandenes, G., Sunde, G., & Ward, K. R. (2014). Challenges and possibilities in forward resuscitation. *Shock*, *41*, 13-20.
27. Hu, P., Yang, S., & Miller, C. (2021). *Advanced Notification to Trauma Center of Blood Product Needs to Improve Patient Outcomes (ONPOINT 3)* (No. AFRLRHWPTR20210086).
28. Hulal, K. J., Alajmi, A. I., Faqihi, A. M., Alsulami, M. M., Alshammari, Z. M., Alsoqayhi, A. A. A., ... & Alanazi, N. M. (2025). How Lab Results Guide Paramedic Decision-Making in Acute Situations. *Tec Empresarial*, *7*(1), 750-773.
29. Jauch EC, Saver JL, Adams HP, et al. Guidelines for the early management of patients with acute ischemic stroke. Stroke 2013; 44(3): 870–947.
30. Jenkins, D. H., Rappold, J. F., Badloe, J. F., Berséus, O., Blackbourne, C. L., Brohi, K. H., ... & Spinella, P. C. (2014). Trauma hemostasis and oxygenation research position paper on remote damage control resuscitation: definitions, current practice, and knowledge gaps. *Shock*, *41*, 3-12.
31. Kaserer, A., Casutt, M., Sprengel, K., Seifert, B., Spahn, D. R., & Stein, P. (2018). Comparison of two different coagulation algorithms on the use of allogenic blood products and coagulation factors in severely injured trauma patients: a retrospective, multicentre, observational study. *Scandinavian journal of trauma, resuscitation and emergency medicine*, *26*(1), 4.
32. Kauvar, D. S., Lefering, R., & Wade, C. E. (2006). Impact of hemorrhage on trauma outcome: An overview of epidemiology, clinical presentations, and therapeutic considerations. *Journal of Trauma*, *60*(6 Suppl), S3–S11. https://doi.org/10.1097/01.ta.0000199961.02677.19
33. King, K. R., Grazette, L. P., Paltoo, D. N., McDevitt, J. T., Sia, S. K., Barrett, P. M., ... & Libby, P. (2016). Point-of-care technologies for precision cardiovascular care and clinical research: National Heart, Lung, and Blood Institute Working Group. *JACC: Basic to Translational Science*, *1*(1), 73-86.
34. Lees KR, Bluhmki E, Von Kummer R, et al. Time to treatment with intravenous alteplase and outcome in stroke: an updated pooled analysis of ECASS, ATLANTIS, NINDS, and EPITHET trials. Lancet 2010; 375(9727): 1695–1703.
35. Lim JCL, Loh N, Lam HH, Lee JW, Liu N, Yeo JW, Ho AFW. The Role of Drones in Out-of-Hospital Cardiac Arrest: A Scoping Review. J Clin Med 2022;11(19):5744.
36. Low, A., & Harris, T. (2014). Near Patient Testing and Imaging. *ABC of Transfer and Retrieval Medicine*, 58.
37. Lyon, R. M., de Sausmarez, E., McWhirter, E., Connolly, C., & Meeran, H. (2017). Prehospital detection of life-threatening bleeding in major trauma: A scoping review. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, *25*(1), 107. https://doi.org/10.1186/s13049-017-0451-4
38. Maegele, M. (2016). Coagulation factor concentrate-based therapy for remote damage control resuscitation (RDCR): a reasonable alternative?. *Transfusion*, *56*, S157-S165.
39. Maegele, M., Fröhlich, M., Caspers, M., Schäfer, N., & Bouillon, B. (2017). The incidence and management of coagulopathy and hemorrhage in prehospital and in-hospital trauma patients. *Current Opinion in Anaesthesiology*, *30*(2), 257–263. https://doi.org/10.1097/ACO.0000000000000446
40. Maegele, M., Lier, H., & Hossfeld, B. (2023). Pre-Hospital Blood Products for the Care of Bleeding Trauma Patients: Evidence, Clinical Practice, and Demand Analysis. *Deutsches Ärzteblatt International*, *120*(40), 670.
41. Maier, R. V. (2014). The traumatic hemostasis and oxygenation research network remote damage control resuscitation (RDCR) symposium. *Shock*, *41*(5), 373-377.
42. Mitra, B., O'Reilly, G., Collecutt, M., Cameron, P. A., Phillips, L., & Davis, A. (2012). Prospective comparison of point-of-care international normalised ratio measurement versus plasma international normalised ratio for acute traumatic coagulopathy. *Emergency Medicine Australasia*, *24*(4), 363-368.

43. Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology*, *18*(1), 143. https://doi.org/10.1186/s12874-018-0611-x
44. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, *372*, n71. https://doi.org/10.1136/bmj.n71
45. Perry, D. J., Fitzmaurice, D. A., Kitchen, S., Mackie, I. J., & Mallett, S. (2010). Point-of-care testing in haemostasis. *British Journal of Haematology*, *150*(5), 501-514.
46. Peters, M. D. J., Marnie, C., Tricco, A. C., Pollock, D., Munn, Z., Alexander, L., McInerney, P., Godfrey, C. M., & Khalil, H. (2020). Updated methodological guidance for the conduct of scoping reviews. *JBI Evidence Synthesis*, *18*(10), 2119–2126. https://doi.org/10.11124/JBIES-20-00167
47. Plodr, M., & Chalusova, E. (2024). Current trends in the management of out of hospital cardiac arrest (OHCA). *Biomedical Papers of the Medical Faculty of Palacky University in Olomouc*, *168*(2).
48. Pommerening, M. J., Goodman, M. D., Holcomb, J. B., Wade, C. E., & Schreiber, M. A. (2017). Clinical gestalt and the prediction of massive transfusion after trauma. *Journal of Trauma and Acute Care Surgery*, *82*(1), 157–162. https://doi.org/10.1097/TA.0000000000001278
49. Roberts, T. R., Garcia, I., Slychko, I., Dalton, H. J., & Batchinsky, A. I. (2025). A Deployable Viscoelastic Coagulation Monitor Enables Point-of-Care Assessment of Coagulopathy in Swine With Polytrauma. *Military Medicine*, *190*(5-6), e994-e1003.
50. Robinson, S., & Kirton, J. (2020). Tools to predict acute traumatic coagulopathy in the pre-hospital setting: a review of the literature. *British Paramedic Journal*, *5*(3), 23.
51. Samuels, J. M., Moore, H. B., & Moore, E. E. (2017). Damage control resuscitation. *Chirurgia (Bucharest, Romania: 1990)*, *112*(5), 514.
52. Sanfridsson J, Sparrevik J, Hollenberg J, Nordberg P, Djärv T, Ringh M, Svensson L, Forsberg S, Nord A, Andersson-Hagiwara M, Claesson A. Drone delivery of an automated external defibrillator - a mixed method simulation study of bystander experience. Scand J Trauma Resusc Emerg Med 2019;27(1):40.
53. Schierbeck S, Hollenberg J, Nord A, Svensson L, Nordberg P, Ringh M, Forsberg S, Lundgren P, Axelsson C, Claesson A. Automated external defibrillators delivered by drones to patients with suspected out-ofhospital cardiac arrest. Eur Heart J 2022;43(15):1478-87.
54. Schierbeck, S., Svensson, L., Claesson, A.Use of a Drone-Delivered Automated External Defibrillator in an Out-of-Hospital Cardiac Arrest – letter to editor. N Engl J Med 2022; 386:1953-4.
55. Schöchl, H., Cadamuro, J., Seidl, S., Franz, A., Solomon, C., Schlimp, C. J., & Ziegler, B. (2016). Hyperfibrinolysis is common in out-of-hospital cardiac arrest: Results from a prospective observational thromboelastometry study. *Resuscitation*, *98*, 1–6. https://doi.org/10.1016/j.resuscitation.2015.10.007
56. Schött, U. (2014). Prehospital coagulation monitoring of resuscitation with point-of-care devices. *Shock*, *41*, 26-29.
57. The ATLANTIS, ECASS, and NINDS rt-PA Study Group Investigators. Association of outcome with early stroke treatment: pooled analysis of ATLANTIS, ECASS, and NINDS rt-PA stroke trials. Lancet 2004; 363(9411): 768–774.
58. Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., Moher, D., Peters, M. D. J., Horsley, T., Weeks, L., Hempel, S., Akl, E. A., Chang, C., McGowan, J., Stewart, L., Hartling, L., Aldcroft, A., Wilson, M. G., Garritty, C., … Straus, S. E. (2018). PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. *Annals of Internal Medicine*, *169*(7), 467–473. https://doi.org/10.7326/M18-0850
59. Viereck S, Møller TP, Ersbøll AK, Bækgaard JS, Claesson A, Hollenberg J, Folke F, Lippert FK. Recognising out-of-hospital cardiac arrest during emergency calls increases bystander cardiopulmonary resuscitation and survival. Resuscitation 2017;115(1):141-7.
60. World Health Organization. (2021, June 28). *Injuries and violence*. Retrieved from https://www.who.int/news-room/fact-sheets/detail/injuries-and-violence