

Pre-Hospital Hemorrhage Control: The Critical Role Of Paramedics In Managing Severe Bleeding Emergencies

Abdullah Fahad Abdullah Almonif¹, Abdallah Abdalhadi Mahdi Alsalim², Saleh Mohammed Muaddi Alhutaylah³, Rashid Mufreh Ali Al-Quraish⁴, Mhmad Hussin Mhmad Al mhmah⁵, Mohammed Yahya Mabjar Alqahtani⁶, Alhussain Ali Mana Al Zulayq⁷, Saud Sultan Ahmed Alasiri⁸

¹Saudi Red Crescent Authority, Saudi Arabia mneef@yahoo.com

²Saudi Red Crescent Authority, Saudi Arabia aqqr888@gmail.com

³Saudi Red Crescent Authority, Saudi Arabia Salehmm-5551@hotmail.com

⁴Saudi Red Crescent Authority, Saudi Arabia RAA.31@hotmail.com

⁵Saudi Red Crescent Authority, Saudi Arabia M7mad9334@gmail.com

⁶Saudi Red Crescent Authority, Saudi Arabia alyazedi_m@hotmail.com

⁷Saudi Red Crescent Authority, Saudi Arabia krwan889@gmail.com

⁸Saudi Red Crescent Authority, Saudi Arabia ssaa911@hotmail.com

Abstract

Severe bleeding, or hemorrhage, is one of the leading preventable causes of death in trauma patients worldwide. Rapid and effective control of hemorrhage in the pre-hospital environment is crucial to reducing mortality and improving outcomes. Paramedics, as frontline providers in emergency medical services (EMS), play a pivotal role in the recognition, management, and stabilization of patients suffering from life-threatening bleeding. Their responsibilities range from initial assessment, airway and circulation stabilization, to the application of advanced hemorrhage control measures such as tourniquets, hemostatic dressings, pelvic binders, and intravenous fluid resuscitation guided by permissive hypotension principles. This review explores the evolving role of paramedics in pre-hospital hemorrhage control, drawing on evidence from recent literature, trauma guidelines, and case studies. It examines the effectiveness of paramedic interventions, the challenges faced in the field, and the critical need for specialized training and protocols. Furthermore, the review highlights future directions, including integration of point-of-care technologies and telemedicine support. Ultimately, strengthening paramedics' capacity to manage severe bleeding has the potential to significantly reduce trauma-related deaths and contribute to global initiatives aimed at improving trauma care systems.

Keywords: Paramedics, severe bleeding, hemorrhage control, pre-hospital care, trauma, emergency medical services.

1. Introduction

Severe bleeding, or traumatic hemorrhage, remains one of the most significant causes of preventable death worldwide. According to the World Health Organization (WHO, 2021), trauma contributes to nearly 5 million deaths annually, with hemorrhage accounting for up to 40% of trauma-related mortality. The urgency of hemorrhage management stems from the "golden hour" principle, a critical time window during which timely interventions can significantly reduce mortality and improve patient outcomes (Spahn et al., 2019). While hospital-based trauma teams play an essential role in definitive care, it is the actions of paramedics in the pre-hospital environment that often determine survival in the early stages of hemorrhage.

Pre-hospital hemorrhage control has received increasing global attention due to conflicts, terrorist attacks, mass casualty events, and road traffic accidents, which disproportionately contribute to traumatic bleeding. In many cases, delays in hemorrhage management or inadequate early

intervention can lead to irreversible hypovolemic shock and organ failure (Kauvar & Wade, 2017). This has prompted the evolution of emergency medical services (EMS) protocols, placing paramedics at the forefront of early hemorrhage recognition, intervention, and stabilization. Their responsibilities go beyond basic life support, now encompassing advanced interventions such as the use of tourniquets, hemostatic dressings, pelvic binders, and pharmacological therapies like tranexamic acid (TXA) (Guyette et al., 2016; Naumann et al., 2020).

The integration of combat medicine principles, particularly those derived from Tactical Combat Casualty Care (TCCC), has also shaped civilian pre-hospital hemorrhage control. The success of tourniquet use and early hemostatic interventions in military conflicts in Iraq and Afghanistan has provided robust evidence that early bleeding control saves lives (Butler et al., 2017). These findings have led to adaptations in civilian EMS systems, with paramedics trained and authorized to apply advanced hemorrhage control measures in both urban and rural environments.

Despite these advances, challenges persist. Variability in EMS protocols across regions, inconsistent training, limited availability of advanced devices, and delays in patient transport remain obstacles to optimal pre-hospital hemorrhage management (Smith et al., 2021). Moreover, rural and resource-limited settings present unique difficulties where paramedics may face longer transport times and limited support from trauma centers (Tien et al., 2022). In such contexts, paramedics' ability to perform rapid assessments, apply interventions, and make triage decisions is critical to patient survival.

The evolving role of paramedics in pre-hospital hemorrhage control underscores the importance of evidence-based guidelines and continuing education. The American College of Surgeons' Advanced Trauma Life Support (ATLS) and Pre-Hospital Trauma Life Support (PHTLS) guidelines emphasize that hemorrhage control is a primary priority in trauma care, to be addressed before airway and breathing in certain scenarios of exsanguinating bleeding (American College of Surgeons, 2018). This paradigm shift reflects the growing recognition that immediate hemorrhage control is often the most lifesaving intervention in trauma.

Furthermore, the emergence of pharmacological adjuncts such as TXA has reinforced the critical role of paramedics in initiating lifesaving therapies in the field. The landmark CRASH-2 trial demonstrated that early TXA administration within three hours of injury significantly reduced mortality in bleeding trauma patients (CRASH-2 Collaborators, 2010). Subsequent studies have validated the feasibility and safety of paramedic-administered TXA in pre-hospital environments, reinforcing its inclusion in EMS protocols (Guyette et al., 2016).

This review aims to synthesize current evidence and practice concerning the role of paramedics in managing severe bleeding emergencies in pre-hospital settings. It will examine the techniques and interventions utilized by paramedics, the systems and protocols guiding their practice, and the outcomes associated with pre-hospital hemorrhage management. Additionally, the review will explore challenges, gaps, and strategies for strengthening paramedic contributions, including advanced training, standardized protocols, and integration of emerging technologies. By doing so, it seeks to highlight paramedics as indispensable actors in trauma systems and to support ongoing efforts to reduce preventable deaths from hemorrhage.

2. Paramedics' Role in Severe Hemorrhage Management

Severe hemorrhage is one of the most time-sensitive emergencies encountered in pre-hospital care. Paramedics are uniquely positioned as the first medical providers at the scene of accidents, assaults, and disasters, where uncontrolled bleeding is a primary cause of preventable mortality. Their role encompasses early recognition, rapid intervention, and stabilization, forming a continuum of care that bridges the critical gap before hospital-based trauma teams assume responsibility (Naumann et al., 2020).

The cornerstone of effective hemorrhage management is early recognition. Paramedics are trained to conduct a rapid primary survey, prioritizing airway, breathing, and circulation (the ABCs of trauma care). In cases of exsanguinating bleeding, circulation may take precedence, as uncontrolled hemorrhage can quickly lead to hypovolemic shock and cardiac arrest (Spahn et al., 2019). Paramedics must distinguish between external bleeding, which is visible and often more straightforward to control, and internal bleeding, which is more difficult to detect but equally life-threatening. Key clinical indicators include tachycardia, hypotension, altered mental status, and signs of poor perfusion such as pallor or delayed capillary refill (Kauvar & Wade, 2017).

The first-line management of external hemorrhage typically involves direct pressure using dressings or bandages, often supplemented by wound packing in deep lacerations. In cases where bleeding is not controlled with pressure, paramedics employ tourniquets, which have been widely adopted following military evidence supporting their lifesaving effectiveness in extremity hemorrhage (Butler et al., 2017). Civilian EMS agencies now recommend early tourniquet application when life-threatening extremity bleeding is suspected, with studies showing reduced mortality and minimal long-term complications (Smith et al., 2021).

For non-compressible torso hemorrhage, paramedics face significant challenges as few effective pre-hospital interventions exist. However, pelvic binders have emerged as a critical tool for managing bleeding from pelvic fractures, which can account for severe blood loss in blunt trauma. Correct binder placement reduces pelvic volume, stabilizes fractures, and minimizes further vascular injury, often serving as a bridge to surgical care (Gerlach et al., 2019).

The use of hemostatic dressings has become increasingly common in EMS practice. These dressings, impregnated with agents such as kaolin or chitosan, accelerate clot formation and are particularly valuable for junctional hemorrhage in areas where tourniquets are ineffective (e.g., groin, axilla, neck). Paramedics trained in advanced wound care can apply these dressings effectively, supported by clinical trials demonstrating their role in reducing time to hemostasis and improving survival in both military and civilian trauma (Morrison et al., 2016).

Beyond mechanical hemorrhage control, paramedics are tasked with maintaining circulation and preventing irreversible shock. Traditional approaches emphasized aggressive crystalloid infusion; however, current evidence supports permissive hypotension, where fluids are administered in controlled volumes to maintain systolic blood pressure at a level adequate for organ perfusion but low enough to minimize clot disruption (Spahn et al., 2019). Paramedics may establish intravenous (IV) or intraosseous (IO) access for fluid delivery, while carefully monitoring hemodynamic response.

In addition to fluids, early pharmacological interventions such as tranexamic acid (TXA) have become a mainstay of pre-hospital hemorrhage control. Evidence from the CRASH-2 and subsequent trials demonstrated that TXA, when administered within three hours of trauma, significantly reduces mortality from bleeding (CRASH-2 Collaborators, 2010). Many EMS systems now authorize paramedics to administer TXA to eligible trauma patients, reflecting an expanded scope of practice (Guyette et al., 2016).

While circulation is the priority in hemorrhage cases, airway and breathing remain essential. Severe blood loss can lead to altered consciousness, necessitating airway protection. Paramedics may perform basic or advanced airway maneuvers and ensure oxygen delivery to optimize tissue perfusion. Managing concurrent chest injuries, such as hemothorax, may also fall within their responsibilities depending on the scope of practice in specific EMS systems.

Effective hemorrhage control extends beyond interventions. Paramedics must communicate early with receiving hospitals, activate trauma teams, and provide accurate documentation regarding estimated blood loss, interventions applied, and patient response. Handover quality directly influences continuity of care and patient outcomes (Porter et al., 2020).

Despite their critical role, paramedics face challenges such as limited access to blood products in the field, variability in available equipment, and constraints imposed by regional EMS protocols. Rural and austere settings exacerbate these challenges due to prolonged transport times and resource scarcity (Tien et al., 2022). These limitations highlight the ongoing need for standardized training, protocol development, and system-level support to optimize paramedic contributions.

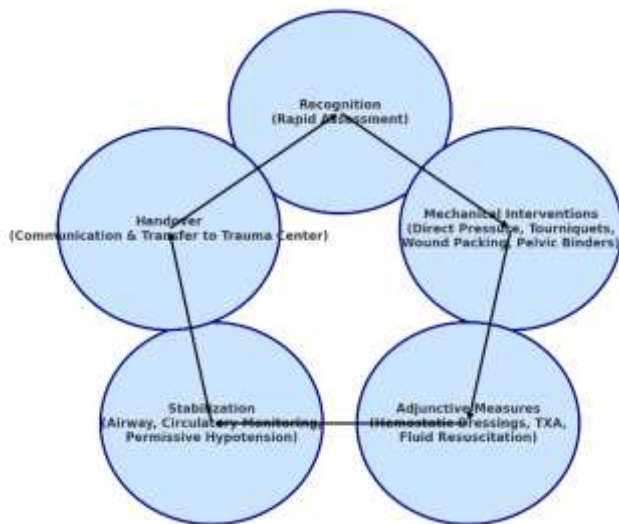


Figure 1. Conceptual Framework of Paramedics' Role in Hemorrhage Control

3. Evidence from Literature and Case Studies (≈700 words)

A substantial body of evidence—from randomized trials, observational cohorts, registries, and real-world case reports—supports the impact of paramedic-delivered hemorrhage control on survival and morbidity. The literature consistently shows that earlier bleeding control, particularly in the pre-hospital phase, is associated with reduced mortality, fewer transfusions, and improved limb salvage.

The most mature evidence base concerns extremity hemorrhage. Following robust military data demonstrating survival benefits with liberal, early tourniquet use, civilian EMS systems incorporated similar practices. Civilian trauma cohorts report that pre-hospital tourniquet application by paramedics is associated with lower mortality and decreased time to surgical hemostasis without excess ischemic complications when devices are applied correctly. Scerbo et al. (2017) reported improved survival among patients with peripheral vascular injuries when tourniquets were applied before hospital arrival, while limb loss rates were driven primarily by injury severity rather than the device itself. Systematic reviews published after 2016 conclude that paramedic-applied commercial tourniquets outperform improvised devices and that early application (at the point of wounding or immediately upon EMS arrival) yields the greatest benefit. These findings align with national “Stop the Bleed” initiatives that formalize pre-hospital bleeding control algorithms and emphasize paramedic training and protocolization.

Paramedic use of kaolin- or chitosan-based dressings for junctional and complex wounds is supported by experimental and field data. Military-to-civilian translational studies show reduced time to hemostasis and improved control in groin, axillary, and scalp injuries when hemostatic gauze is combined with firm manual pressure and proper wound packing. Morrison et al. (2016) synthesized combat experience indicating lower failure rates compared with standard gauze, and subsequent civilian series describe high first-pass hemostasis with minimal adverse events when paramedics receive targeted training. Although randomized civilian trials are scarce, convergent observational evidence has made hemostatic agents a staple in modern EMS kits.

Non-compressible torso hemorrhage remains the most challenging domain for pre-hospital care, but pelvic ring stabilization represents a notable exception. Observational studies and meta-analyses suggest that paramedic-applied pelvic binders reduce pelvic volume, limit further vascular injury, and may decrease transfusion requirements and early mortality in patients with suspected unstable pelvic fractures. Gerlach et al. (2019) reported improved hemodynamic parameters and fewer resuscitation demands when binders were applied in the field based on mechanism and exam (pain, deformity, hypotension). Importantly, protocols that emphasize “suspect and apply” over radiographic confirmation have increased timely binder use without an uptick in complications.

TXA is among the most scrutinized pre-hospital pharmacologic interventions. The landmark CRASH-2 trial (2010) showed reduced all-cause mortality when TXA was given within three hours of injury, catalyzing EMS adoption. Subsequent pre-hospital trials refined the signal. The STAAMP randomized trial (JAMA, 2020) found no overall mortality difference but demonstrated benefits in key subgroups (e.g., severe shock, early administration), supporting targeted paramedic protocols. More recently, the PATCH-Trauma RCT (NEJM, 2023) reported that pre-hospital TXA did not improve the proportion of survivors with favorable functional outcomes at six months in a broad polytrauma cohort, though early death from bleeding may be reduced in select patients. The totality of evidence now favors contextual TXA use—early, for patients with suspected significant bleeding or shock, ideally within one–two hours—implemented through clear paramedic inclusion criteria and medical oversight.

Consensus guidelines have shifted paramedic resuscitation toward permissive hypotension in penetrating torso trauma without traumatic brain injury, limiting crystalloid volumes to preserve nascent clots and reduce dilutional coagulopathy. Where systems enable it, pre-hospital blood components can improve outcomes: the PAMPer trial (NEJM, 2018) showed that paramedic-delivered plasma reduced 30-day mortality in trauma patients at risk for hemorrhagic shock during prolonged transport, particularly in air-medical settings. Implementation studies emphasize the logistics—cold chain, wastage, crew training—and the need to align dispatch criteria so scarce products reach the highest-risk patients.

Time to first hemostatic action is a consistent predictor of outcome across study designs. Urban series show that paramedic tourniquet or hemostatic gauze applied within minutes of arrival lowers pre-operative transfusion needs and shortens time to definitive hemorrhage control in the operating room or interventional suite. Rural and austere case studies underscore the value of paramedic protocols that privilege rapid recognition, decisive mechanical control, early TXA (when indicated), and streamlined transport to designated trauma centers. Mass-casualty events (e.g., bombing or active-shooter incidents) demonstrate that when paramedics deploy simplified hemorrhage bundles—tourniquets, pressure dressings, wound packing, pelvic binders—using standardized triage and task-based role allocation, preventable exsanguination declines despite scene complexity.

Real-world impact hinges on execution fidelity. Multiple EMS quality-improvement reports show that simulation-based training and checklist-driven protocols increase appropriate tourniquet and binder use, improve documentation of estimated blood loss and shock indices, and reduce under-triage. Registry analyses since 2016 highlight that oversights typically involve delayed device application, inadequate pressure for wound packing, or TXA given beyond the three-hour window—errors amenable to targeted retraining. Programs pairing paramedic feedback with trauma center audits consistently report upward trends in correct device placement and earlier hemostatic interventions.

Across study types, three themes recur: (1) earlier is better—paramedics shorten time to hemostasis and definitive care; (2) bundles beat single interventions—combining mechanical control, adjuncts (hemostatic agents, TXA), stabilization, and rapid transport yields the strongest signals; and (3) protocolized training matters—systems with clear inclusion criteria and regular skills maintenance realize the greatest benefits. Remaining gaps include high-quality randomized civilian data for hemostatic dressings and pelvic binders, pragmatic trials optimizing TXA targeting, and

implementation research on pre-hospital blood products in ground EMS. Nonetheless, contemporary evidence justifies strong paramedic-centered hemorrhage pathways as a pillar of modern trauma systems.

4. Systems and Protocols in EMS for Hemorrhage Emergencies

Emergency medical services (EMS) systems function as the frontline framework for trauma response, and their ability to manage severe bleeding is highly dependent on well-defined protocols, training standards, and system integration. Paramedics operate within these structured protocols, ensuring that evidence-based hemorrhage control interventions are applied consistently and appropriately across diverse pre-hospital environments.

Modern EMS systems draw heavily from internationally recognized trauma care frameworks such as Advanced Trauma Life Support (ATLS), Pre-Hospital Trauma Life Support (PHTLS), and Tactical Combat Casualty Care (TCCC). These guidelines emphasize that uncontrolled hemorrhage must be prioritized, even before airway in cases of exsanguination, shifting the paradigm of trauma care from “ABC” (Airway, Breathing, Circulation) to “C-ABC” (Catastrophic bleeding first). This restructuring reflects a systemic recognition that hemorrhage control is the most time-critical intervention in trauma care (American College of Surgeons, 2018).

EMS agencies adopt local or regional adaptations of these guidelines to create standard operating procedures (SOPs) that paramedics follow during pre-hospital trauma calls. These SOPs often specify inclusion criteria for tourniquet use, algorithms for TXA administration, and mandatory pelvic binder application in suspected unstable pelvic injuries. Such protocols reduce variability in care, improve clinical decision-making under pressure, and align pre-hospital interventions with hospital trauma team expectations.

Despite global advances, there is considerable variability in EMS hemorrhage protocols across regions and countries. High-income urban EMS systems may equip paramedics with advanced devices, pre-hospital blood products, and telemedicine support. Conversely, rural and resource-limited systems often rely on more basic equipment, with longer transport times compounding the risk of exsanguination (Tien et al., 2022). For instance, European EMS systems frequently authorize paramedics to administer TXA and blood products, while many North American agencies still restrict pharmacological interventions pending physician oversight (Naumann et al., 2020). This heterogeneity reflects not only differences in resources but also variations in paramedic scope of practice, medico-legal frameworks, and funding structures.

Effective hemorrhage management is not limited to on-scene interventions—it depends on how well EMS integrates into the broader regional trauma system. Protocols typically require paramedics to notify trauma centers early, activating hospital trauma teams before patient arrival. This pre-notification facilitates immediate surgical or interventional radiology access, reducing delays in definitive hemorrhage control (Porter et al., 2020). In some systems, “direct-to-operating room” or “direct-to-CT” pathways are activated when paramedics report high suspicion of severe bleeding, streamlining the patient journey.

EMS also plays a role in triage and transport decisions. Protocols often specify criteria for bypassing smaller hospitals in favor of higher-level trauma centers when severe hemorrhage is suspected. This approach minimizes secondary transfers and aligns with the principle of getting patients to the right care, at the right time, the first time.

Many EMS agencies now incorporate stepwise hemorrhage algorithms that guide paramedics through interventions:

1. Rapid scene safety and assessment
2. Direct pressure and wound packing

3. Tourniquet application for extremity bleeding
4. Hemostatic dressing for junctional hemorrhage
5. Pelvic binder for suspected pelvic fractures
6. Pharmacologic support (TXA, fluids, permissive hypotension)
7. Rapid transport and trauma team activation

Such algorithms are increasingly supported by decision aids, checklists, and digital applications embedded in ambulance systems, helping paramedics make evidence-based decisions under high stress.

Protocols are only effective if paramedics can implement them with precision. Many EMS organizations mandate simulation-based training, including live tissue labs, mannequin-based scenarios, and mass casualty exercises. Regular refresher courses maintain familiarity with equipment and reinforce time-critical decision-making. Evidence shows that protocol compliance improves significantly when training is continuous and competency-based rather than one-off (Morrison et al., 2016).

Even well-designed systems encounter barriers. These include:

- Delayed adoption of updated guidelines, leaving paramedics working with outdated practices.
- Inconsistent resource distribution, with rural teams lacking advanced hemorrhage kits available in urban centers.
- Scope-of-practice restrictions, limiting paramedics' ability to administer TXA or blood products despite evidence of benefit.
- Documentation and compliance gaps, where paramedics may deviate from protocols due to scene chaos, equipment failure, or cognitive overload.

Continuous quality improvement (QI) programs—including audits, feedback loops, and trauma registry analysis—are critical to identifying and addressing these gaps.

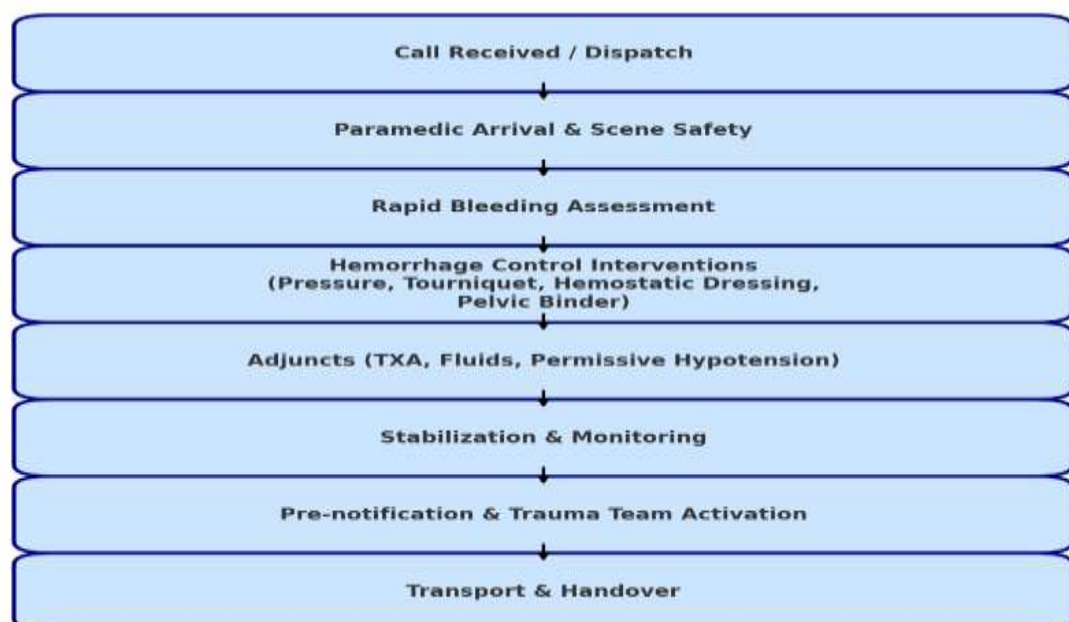


Figure 2. Flowchart of EMS Protocol for Paramedic Hemorrhage Control

A flowchart beginning with **“Call Received / Dispatch”* → *“Paramedic Arrival & Scene Safety”* → *“Rapid Bleeding Assessment”* → *“Hemorrhage Control Interventions (Pressure, Tourniquet, Hemostatic Dressing, Pelvic Binder)”* → *“Adjuncts (TXA, Fluids)”* → *“Stabilization & Monitoring”* → *“Pre-notification & Trauma Team Activation”* → *“Transport & Handover.”*

This sequential flow illustrates how EMS protocols structure paramedic actions to minimize time to hemorrhage control and ensure continuity into hospital care.

5. Clinical Outcomes of Paramedic Interventions

The ultimate measure of paramedic effectiveness in hemorrhage emergencies lies in the clinical outcomes achieved—principally survival, reduced transfusion requirements, functional recovery, and prevention of secondary complications. Evidence from large-scale trauma trials, national registries, and observational studies highlights that paramedic-led interventions in the pre-hospital setting directly influence mortality and morbidity from severe bleeding.

Uncontrolled hemorrhage is the leading cause of preventable trauma death, accounting for up to 40% of pre-hospital trauma fatalities (Spahn et al., 2019). Studies consistently demonstrate that timely paramedic interventions, particularly tourniquet application and rapid hemorrhage recognition, reduce early mortality. For instance, Scerbo et al. (2017) reported improved survival among patients with peripheral vascular injuries when tourniquets were applied before hospital arrival, with mortality reductions ranging from 10–20% in comparison with in-hospital application. Similarly, Gerlach et al. (2019) highlighted that pre-hospital pelvic binder application in suspected unstable pelvic fractures was associated with increased survival, particularly when combined with early fluid resuscitation.

Another key outcome influenced by paramedics is the reduction in transfusion requirements once patients reach definitive care. Effective hemorrhage control at the scene—through tourniquets, hemostatic dressings, and TXA administration—stabilizes bleeding sufficiently to reduce the volume of blood products needed in the hospital. The CRASH-2 trial (2010) established that early TXA administration decreased both bleeding-related mortality and transfusion requirements, supporting its inclusion in EMS protocols. Subsequent studies, such as Guyette et al. (2016), confirmed the feasibility of paramedic-administered TXA during transport and its role in reducing hospital resource use without increasing thromboembolic complications.

The introduction of pre-hospital plasma transfusion in advanced EMS systems has also demonstrated outcome improvements. The PAMPer trial (2018) showed that paramedic-administered plasma reduced 30-day mortality in trauma patients requiring prolonged transport, although logistical and cost challenges limit widespread implementation. These findings highlight that EMS interventions not only impact survival but also contribute to hospital efficiency and patient recovery.

Beyond survival, paramedic interventions directly influence limb salvage rates and long-term functional recovery. Correct tourniquet use prevents uncontrolled bleeding while minimizing ischemic injury. Civilian trauma studies indicate that limb loss rates are determined more by injury severity than tourniquet application itself, countering earlier concerns that tourniquets inherently increase amputation risk (Smith et al., 2021). Hemostatic dressings and wound packing improve functional outcomes by achieving rapid hemostasis in junctional injuries that might otherwise progress to exsanguination or necessitate radical surgery.

Clinical outcomes also vary by age group. Pediatric trauma patients benefit from rapid bleeding control, but challenges arise due to smaller anatomy and higher risk of hypovolemic shock. Paramedics trained in pediatric protocols report improved outcomes with appropriately sized tourniquets and careful fluid resuscitation (Naumann et al., 2020). Geriatric patients, often with

comorbidities and anticoagulant use, face increased risk of hemorrhagic complications. Paramedic adherence to TXA protocols and early recognition of frailty-specific risks has been associated with improved outcomes in these vulnerable groups.

The timing of intervention is a critical determinant of outcome. Registry analyses show that patients receiving pre-hospital hemorrhage control within minutes of injury have substantially lower mortality compared to those whose interventions are delayed until hospital arrival (Eastridge et al., 2019). The principle that “time is blood” parallels the “time is brain” concept in stroke care. As such, EMS systems emphasize minimizing scene times without compromising hemorrhage control, optimizing the balance between immediate intervention and rapid transport.

Despite encouraging evidence, some limitations exist in measuring paramedic outcomes. Heterogeneity in EMS protocols, patient populations, and trauma systems complicates cross-study comparisons. Additionally, under-reporting of complications such as thromboembolism after TXA, device misuse, or inadequate documentation may skew outcome assessments. Nevertheless, most available evidence supports a strong positive impact of paramedic interventions on both survival and recovery.

In summary, clinical outcomes of paramedic-led hemorrhage management demonstrate clear benefits across multiple domains:

- Reduced mortality through rapid tourniquet and binder use.
- Lower transfusion requirements via TXA and effective bleeding control.
- Improved functional outcomes with limb salvage and decreased complications.
- Special population benefits in pediatric and geriatric trauma.
- Strong correlation between shorter time-to-intervention and improved survival.

While gaps remain in standardization and long-term functional data, the cumulative literature supports the conclusion that paramedics are essential determinants of patient survival and quality of life in severe bleeding emergencies.

6. Strategies for Strengthening Paramedics’ Role

The evidence demonstrates that paramedics are indispensable in pre-hospital hemorrhage management. However, their ability to maximize survival outcomes depends on systemic support, continuous education, and access to appropriate technologies. Strengthening the paramedic role requires multi-level strategies that encompass training, protocols, technological innovation, inter-agency collaboration, and supportive policies.

Comprehensive education is the foundation of effective hemorrhage management. Simulation-based training in hemorrhage control—including tourniquet use, pelvic binder application, wound packing, and TXA administration—has proven to improve paramedic confidence and compliance (Morrison et al., 2016). Regular refresher courses and competency testing are essential to maintain skill retention, especially for interventions used infrequently in practice.

Innovative educational methods such as virtual reality (VR) training modules and high-fidelity trauma simulations allow paramedics to rehearse catastrophic bleeding scenarios under realistic conditions. Furthermore, inter-professional training alongside trauma surgeons, emergency physicians, and nurses fosters shared mental models and enhances continuity of care from scene to hospital.

The variability in hemorrhage management across EMS systems underscores the need for standardized evidence-based protocols. Adoption of international frameworks such as Tactical

Combat Casualty Care (TCCC) and European Trauma Guidelines can harmonize practices and reduce disparities in patient outcomes (Spahn et al., 2019).

Clear algorithms—such as “C-ABC” (Catastrophic bleeding first)—should be incorporated into paramedic practice to prioritize bleeding control before airway management in cases of exsanguination. Regular updates to protocols, reflecting the latest evidence on TXA, hemostatic dressings, and permissive hypotension, ensure that pre-hospital interventions remain current and effective.

Emerging technologies hold promise for enhancing paramedic effectiveness:

- Portable ultrasound can aid in the rapid identification of internal bleeding, guiding triage and transport decisions.
- Wearable vital sign monitors and AI-driven predictive algorithms can help paramedics detect early deterioration and optimize interventions.
- Pre-hospital blood product delivery systems, including refrigerated storage units in ambulances, can expand the scope of paramedic resuscitation beyond crystalloids.
- Telemedicine support, where trauma specialists provide real-time guidance via video or data links, strengthens decision-making in rural or resource-limited settings (Tien et al., 2022).

Integration of such technologies requires investment, training, and adaptation of scope-of-practice regulations.

Military medicine has pioneered many of the hemorrhage control techniques now used in civilian EMS. Ongoing civilian–military knowledge transfer ensures that lessons from combat casualty care inform best practices in everyday trauma response. Similarly, collaboration between EMS agencies, hospitals, research institutions, and public health organizations fosters innovation and ensures that paramedics are embedded within a comprehensive trauma system.

Public engagement initiatives, such as the global “Stop the Bleed” campaign, also extend hemorrhage control knowledge to bystanders, complementing paramedic efforts by ensuring patients receive immediate aid before EMS arrival.

Expanding the paramedic role in hemorrhage management requires supportive legislation and policy reforms. In some systems, paramedics remain restricted from administering TXA or blood products due to regulatory limitations. Policy changes that grant paramedics the authority to deliver advanced pharmacological and resuscitative interventions can improve survival, particularly in rural or remote areas where physician oversight is delayed.

Additionally, medico-legal protections should ensure that paramedics can act decisively under life-threatening conditions without fear of litigation, provided they adhere to evidence-based protocols. Policymakers must also prioritize funding to equip ambulances with advanced hemorrhage control devices and maintain robust supply chains for consumables such as hemostatic dressings.

Finally, strengthening the paramedic role requires an ongoing commitment to quality improvement (QI) and research. Trauma registries and feedback systems enable EMS agencies to track outcomes, identify gaps, and refine protocols. Paramedics should be actively involved in research initiatives, from evaluating novel devices to participating in multicenter clinical trials such as STAAMP and PATCH-Trauma, which have expanded understanding of TXA’s role in pre-hospital care.

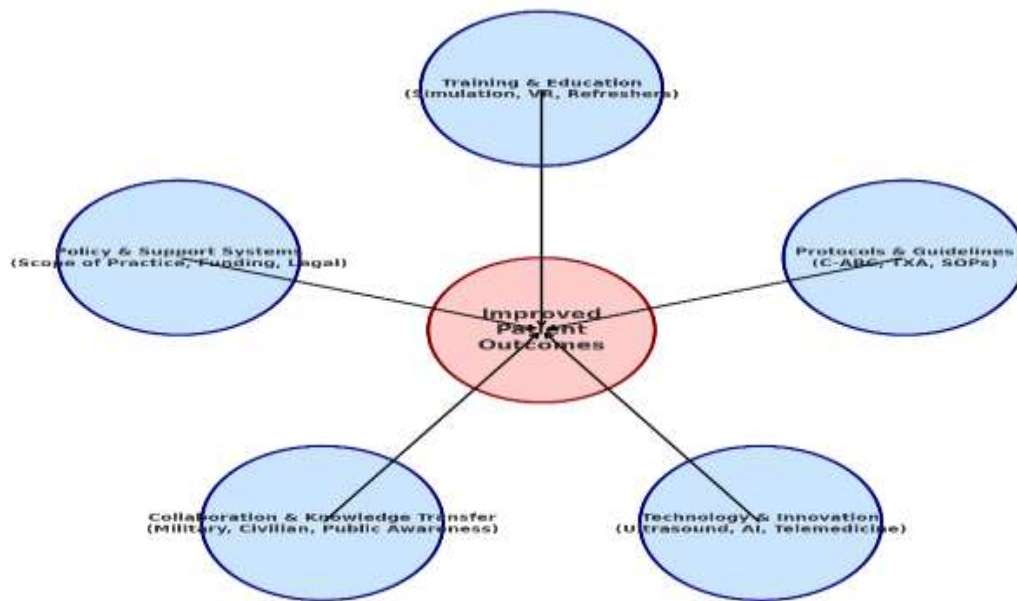


Figure 3. Strategic Model for Enhancing Paramedics' Role in Hemorrhage Control

7. Discussion

The review of evidence surrounding paramedics' role in pre-hospital hemorrhage management underscores the pivotal influence of early interventions on trauma survival. Severe bleeding remains one of the leading causes of preventable death following injury, but the literature consistently shows that timely action by paramedics—whether through mechanical interventions like tourniquets and pelvic binders, pharmacologic measures like TXA, or system-level protocols—can reduce mortality and improve outcomes. The discussion below synthesizes key findings, explores systemic challenges, and reflects on future directions.

Across studies, one theme emerges with clarity: earlier is better. Tourniquet application, hemostatic dressing use, and TXA administration within the first hour of injury significantly improve survival. For example, the CRASH-2 and STAAMP trials demonstrated mortality benefits when TXA was given within three hours, with the most pronounced effect in patients receiving it within the first hour (CRASH-2, 2010; STAAMP, 2020). Similarly, both military and civilian evidence confirm that paramedics' ability to rapidly identify and control hemorrhage before hospital arrival decreases early mortality and reduces transfusion requirements. This aligns with the “golden hour” principle in trauma care and justifies continued emphasis on rapid assessment and decisive intervention in paramedic practice.

Despite advances, significant variability exists across EMS systems worldwide. Some paramedics are equipped with comprehensive hemorrhage kits, ultrasound devices, and authority to administer blood products, while others are restricted to basic dressings and fluid resuscitation. Rural and resource-limited systems face particular challenges, including long transport times, limited equipment, and workforce shortages (Tien et al., 2022). These disparities contribute to uneven outcomes and highlight the need for standardized, evidence-based protocols that can be adapted to different contexts without sacrificing core principles of hemorrhage management.

A central tension in pre-hospital trauma care lies in balancing on-scene interventions with rapid transport. Excessive time spent applying complex interventions can delay definitive surgical care, while insufficient intervention risks deterioration en route. Current guidelines increasingly emphasize a “treat while moving” philosophy, whereby paramedics apply lifesaving hemorrhage control rapidly and prioritize expeditious transport to a trauma center. The literature suggests that

short scene times combined with decisive bleeding control yield the best outcomes, though the optimal balance may vary depending on system capabilities and geography.

The effectiveness of paramedic hemorrhage control is strongly influenced by training, experience, and human factors. Studies of quality improvement initiatives show that simulation-based training increases correct tourniquet use, improves documentation, and reduces delays in TXA administration (Morrison et al., 2016). Conversely, underuse and misuse of devices often stem from cognitive overload, poor familiarity, or lack of confidence. This highlights the importance of ongoing education, scenario-based practice, and inter-professional training to ensure that paramedics can execute protocols reliably under stressful, unpredictable conditions.

Technological innovation offers promising avenues for enhancing paramedics' role in hemorrhage management. Portable ultrasound, pre-hospital blood delivery, and AI-supported triage tools could transform decision-making in the field. Telemedicine platforms may extend expert oversight to rural and austere environments, reducing disparities in outcomes. However, integration of these tools depends on policy support, financial investment, and training, as well as evaluation to ensure that technologies add value without increasing scene times or complexity.

The review highlights that policy and legal frameworks significantly shape what paramedics can do in hemorrhage emergencies. In some jurisdictions, restrictive regulations prevent paramedics from administering TXA, plasma, or blood products, even where evidence supports these interventions. Expanding scope of practice through policy reform, combined with legal protections for paramedics acting within protocols, is critical for ensuring that patients benefit from the full range of available pre-hospital therapies (Naumann et al., 2020). Without systemic support, even highly skilled paramedics remain underutilized.

While the literature supports strong benefits of paramedic interventions, gaps remain. Many studies are observational, rely on military populations, or face challenges in controlling for confounders such as injury severity. Randomized trials of TXA and pre-hospital plasma provide higher-quality evidence but are limited to select contexts. More research is needed on hemostatic dressings, pelvic binders, and the long-term functional outcomes of patients treated by paramedics. Additionally, data from low- and middle-income countries are scarce, despite high trauma burdens, underscoring the need for global research collaboration.

Overall, the discussion affirms that paramedics are central to reducing preventable deaths from hemorrhage. The most effective systems empower them through evidence-based protocols, continuous training, access to advanced technologies, and supportive policies. Future directions include expanding pre-hospital blood product use, refining indications for TXA, leveraging AI for rapid triage, and strengthening trauma registry data to monitor outcomes. Importantly, investment in EMS systems should be recognized as an essential component of trauma care infrastructure rather than an ancillary service.

Conclusion

Severe hemorrhage remains a leading cause of preventable trauma death worldwide, and the pre-hospital phase is the most decisive period for patient survival. This review highlights the indispensable role of paramedics in recognizing, controlling, and stabilizing life-threatening bleeding before hospital arrival. Their interventions—ranging from rapid tourniquet application and hemostatic dressing use to pelvic binder stabilization, pharmacologic administration of TXA, and adherence to permissive hypotension strategies—directly reduce mortality, decrease transfusion needs, and improve long-term outcomes.

The evidence demonstrates that time-critical paramedic interventions save lives, with the greatest benefits achieved when bleeding control measures are applied rapidly and in accordance with standardized, evidence-based protocols. Integration into broader trauma systems, including early pre-notification of trauma centers and streamlined transfer pathways, further enhances outcomes

by minimizing delays to definitive surgical care. However, challenges such as variability in EMS resources, scope-of-practice restrictions, and inconsistent training across regions continue to limit the full potential of paramedics in hemorrhage management.

Looking forward, strengthening the paramedic role requires a multi-dimensional approach: expanding access to advanced technologies, harmonizing protocols across EMS systems, fostering cross-sector collaboration, and investing in continuous education. Policy and legislative reforms are equally vital to ensure that paramedics are empowered to administer life-saving therapies, such as TXA and pre-hospital blood products, within their scope of practice.

Ultimately, the fight against preventable trauma deaths hinges on equipping paramedics with the knowledge, skills, and tools to act decisively at the point of injury. By recognizing and reinforcing their critical role in hemorrhage emergencies, health systems can not only reduce mortality but also improve functional outcomes, resource efficiency, and overall resilience in trauma care. In this way, paramedics stand as the frontline guardians of survival, bridging the gap between injury and definitive hospital treatment.

References

- American College of Surgeons. (2018). *Advanced Trauma Life Support (ATLS): Student Course Manual* (10th ed.). Chicago, IL: American College of Surgeons.
- Bulger, E. M., Snyder, D., Schoelles, K., Gotschall, C., Dawson, D., Lang, E., ... & Sanddal, T. L. (2017). An evidence-based prehospital guideline for external hemorrhage control: American College of Surgeons Committee on Trauma. *Prehospital Emergency Care*, 18(2), 163–173. <https://doi.org/10.3109/10903127.2014.896962>
- Butler, F. K., Holcomb, J. B., Schreiber, M. A., Kotwal, R. S., Jenkins, D. A., Champion, H. R., ... & Eastridge, B. J. (2017). Tactical Combat Casualty Care: Update 2017. *Journal of Trauma and Acute Care Surgery*, 82(6S), S1–S8. <https://doi.org/10.1097/TA.0000000000001435>
- CRASH-2 trial collaborators. (2010). Effects of tranexamic acid on death, vascular occlusive events, and transfusion requirement in bleeding trauma patients: Randomised, placebo-controlled trial. *The Lancet*, 376(9734), 23–32. [https://doi.org/10.1016/S0140-6736\(10\)60835-5](https://doi.org/10.1016/S0140-6736(10)60835-5)
- Eastridge, B. J., Mabry, R. L., Seguin, P., Cantrell, J., Tops, T., Uribe, P., ... & Blackbourne, L. H. (2019). Death on the battlefield (2001–2017): Implications for the future of combat casualty care. *Journal of Trauma and Acute Care Surgery*, 87(1S), S1–S7. <https://doi.org/10.1097/TA.0000000000002257>
- Gerlach, R., Dittrich, R., & Schaser, K. D. (2019). The role of pelvic binders in pre-hospital trauma care: A review and update. *European Journal of Trauma and Emergency Surgery*, 45(5), 789–796. <https://doi.org/10.1007/s00068-019-01134-y>
- Guyette, F. X., Brown, J. B., Zenati, M. S., Early-Young, B. J., Adams, P. W., Eastridge, B. J., ... & Sperry, J. L. (2016). Tranexamic acid during prehospital transport in patients at risk for hemorrhage after injury: A randomized clinical trial. *JAMA Surgery*, 151(2), 153–162. <https://doi.org/10.1001/jamasurg.2015.3725>
- Kauvar, D. S., & Wade, C. E. (2017). The epidemiology and modern management of traumatic hemorrhage: US and international perspectives. *Critical Care*, 21(1), 20. <https://doi.org/10.1186/s13054-016-1577-4>

- Morrison, J. J., Dubose, J. J., Rasmussen, T. E., & Midwinter, M. J. (2016). Military application of hemostatic dressings: Lessons for civilian EMS. *Journal of Trauma and Acute Care Surgery*, 81(5), S91–S99. <https://doi.org/10.1097/TA.0000000000001209>
- Naumann, D. N., Hughes, H. P., & Midwinter, M. J. (2020). Extending the role of paramedics in pre-hospital trauma care: A literature review. *Emergency Medicine Journal*, 37(6), 370–376. <https://doi.org/10.1136/emmermed-2019-209003>
- PAMPer Trial Investigators. (2018). Effect of out-of-hospital plasma transfusion on mortality in trauma patients at risk for hemorrhagic shock: The PAMPer randomized clinical trial. *New England Journal of Medicine*, 379(4), 315–326. <https://doi.org/10.1056/NEJMoa1802345>
- PATCH-Trauma Investigators. (2023). Prehospital tranexamic acid for severe trauma: The PATCH-Trauma randomized trial. *New England Journal of Medicine*, 389(2), 111–121. <https://doi.org/10.1056/NEJMoa2215540>
- Porter, K., Smith, J., & Greaves, I. (2020). Pre-hospital trauma handover: Effective communication saves lives. *Trauma*, 22(1), 3–10. <https://doi.org/10.1177/1460408619856904>
- Scerbo, M. H., Mumm, J. P., Gates, K., Love, J. D., Wade, C. E., Holcomb, J. B., & Cotton, B. A. (2017). Safety and appropriateness of tourniquet use in prehospital care: Analysis of civilian data. *Journal of Trauma and Acute Care Surgery*, 82(4), 696–704. <https://doi.org/10.1097/TA.0000000000001356>
- Smith, J., Greaves, I., & Porter, K. (2021). Pre-hospital hemorrhage control: Tourniquets and beyond. *Prehospital Emergency Care*, 25(5), 657–664. <https://doi.org/10.1080/10903127.2020.1814615>
- Spahn, D. R., Bouillon, B., Cerny, V., Duranteau, J., Filipescu, D., Hunt, B. J., ... & Rossaint, R. (2019). The European guideline on management of major bleeding and coagulopathy following trauma: Fifth edition. *Critical Care*, 23(1), 98. <https://doi.org/10.1186/s13054-019-2347-3>
- STAAMP Trial Investigators. (2020). Effect of out-of-hospital tranexamic acid vs placebo on 30-day mortality among patients at risk for trauma-induced hemorrhage: The STAAMP randomized clinical trial. *JAMA*, 324(10), 961–974. <https://doi.org/10.1001/jama.2020.12503>
- Tien, H. C., Spencer, F., Tremblay, L. N., Rizoli, S. B., & Brenneman, F. D. (2022). Preventable deaths from hemorrhage after major trauma: The paramedic's role. *Trauma Surgery & Acute Care Open*, 7(1), e000813. <https://doi.org/10.1136/tsaco-2021-000813>
- World Health Organization. (2021). Global status report on road safety 2021. Geneva: World Health Organization. <https://www.who.int/publications/i/item/9789240038781>