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The Golden Hour in Trauma Care: Integrating Prehospital Paramedic Assessment, Diagnostic Imaging, Laboratory Testing, Blood Bank Services, and Nursing Management

Lafi Ali s Almutairi[(1)], Abdullah Naif Almutairi[(2)], Saeed Salem Salman Almalki[(3)], Mohammed Ahmed Ageeli[(4)], Ali Mohsen Ahmed Jaafari[(3)], Makki Abdul Raheem Ageeli[(3)], Hussain Abdu Khairy[(5)], Hani Mohammed Farhan Alanazi[(6)]

(1)Wtheilan general hospital, Ministry of health
(2)Thadiq Hospital, Ministry of Health
(3)Sabya General Hospital, Ministry of Health
(4)Jazan, Ministry of Health
(5)Prince Mohammed Bin Nasser Hospital – Jazan, Jazan Health Cluster
(6)Hospital Mental Health, Hafar Albatin

Abstract

Background: The "golden hour" concept remains a cornerstone of trauma care, positing that rapid, coordinated intervention within the first 60 minutes after injury significantly reduces morbidity and mortality. Achieving this requires seamless integration of multiple disciplines across the prehospital and in-hospital continuum. **Aim:** This narrative review synthesizes recent advances and evidence on integrating prehospital paramedic assessment, diagnostic imaging, laboratory testing, blood bank services, and nursing management to optimize trauma resuscitation during the critical golden hour. **Methods:** A comprehensive literature search of PubMed, CINAHL, and Scopus was conducted for English-language articles published between January 2015 and January 2025. Keywords included "golden hour," "trauma resuscitation," "prehospital care," "paramedic assessment," "trauma radiology," "point-of-care laboratory," "massive transfusion protocol," and "trauma nursing." Studies, systematic reviews, clinical guidelines, and meta-analyses were narratively synthesized. **Results:** The review identifies a paradigm shift from siloed, sequential care to a parallel, integrated, and data-driven trauma system. Key advances include prehospital ultrasound and whole blood transfusion by paramedics, immediate computed tomography (CT) scanning upon arrival, point-of-care viscoelastic testing for goal-directed hemostatic resuscitation, and nurse-led massive transfusion protocol activation. The trauma team's non-technical skills and shared mental models are critical to the success of this integration. **Conclusion:** The golden hour is maximized not by any single intervention but by the choreographed integration of prehospital and hospital disciplines into a cohesive, time-sensitive system. Future progress depends on closed-loop communication technologies, artificial intelligence-driven decision support, and continued emphasis on team-based training to transform the resuscitation from a process of steps into a symphony of coordinated, life-saving action.

Keywords: Golden Hour; Trauma Resuscitation; Prehospital Care; Point-of-Care Testing; Massive Transfusion Protocol.

Introduction

Traumatic injury remains a leading cause of death and disability worldwide, accounting for over 4.4 million deaths annually and representing a significant burden on global health systems, particularly among individuals under the age of 45 (Heron et al., 2022; World Health Organization, 2022; Yusoff et al., 2023). The concept of the "golden hour" in trauma care, though debated in its precise temporal rigidity, remains a powerful and clinically useful paradigm. First articulated by R. Adams Cowley, it posits that a patient's outcome following severe injury is heavily dependent on the speed and quality of definitive care delivered within the first 60 minutes after the traumatic event (Rogers et al., 2015). This period encompasses the critical sequence of prehospital response, transport, emergency department (ED) resuscitation, diagnostic workup, and transition to definitive hemorrhage control or operative intervention. Death during this early phase is most often due to catastrophic hemorrhage or severe traumatic brain injury (TBI), both of which demand a time-critical, coordinated, and multi-disciplinary response (Mitura et al., 2021). A failure or delay at any link in this complex chain can result in a preventable death, making the integration of services the single most important determinant of trauma system performance (Huo et al., 2023).

The modern trauma resuscitation is a masterclass in multi-disciplinary choreography; a complex ballet performed under extreme time pressure and physiological duress. It requires the simultaneous and synchronized efforts of paramedics, emergency physicians, trauma surgeons, radiologists and

*Corresponding author mmkzo00011@gmail.com (Lafi Ali s Almutairi).
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radiology technologists, medical laboratory scientists, blood bank specialists, and trauma nurses (Wilson et al., 2020). Each discipline brings a unique and essential dataset to the bedside: the paramedic's prehospital assessment and initial physiological trends; the radiologist's rapid interpretation of ultrasound and CT images to identify the anatomical source of hemorrhage; the laboratory scientist's quantification of metabolic derangement and coagulopathy through point-of-care testing; the blood bank's preparation and delivery of balanced blood products through a massive transfusion protocol (MTP); and the trauma nurse's continuous physiological monitoring, psychosocial support, and meticulous documentation that binds the entire process together (Barleycorn & Lee, 2018). Historically, these domains operated in relative siloes, with sequential handoffs that created dangerous information gaps and delays. The modern paradigm has shifted towards a parallel, horizontal model of care, where these assessments and interventions occur simultaneously, integrated by a shared mental model and a trauma team leader who synthesizes the incoming torrent of data into a cohesive, life-saving strategy (Forde et al., 2016). Figure 1 demonstrates the continuous pathway from prehospital assessment to definitive care through coordinated paramedic, imaging, laboratory, blood bank, and nursing interventions.

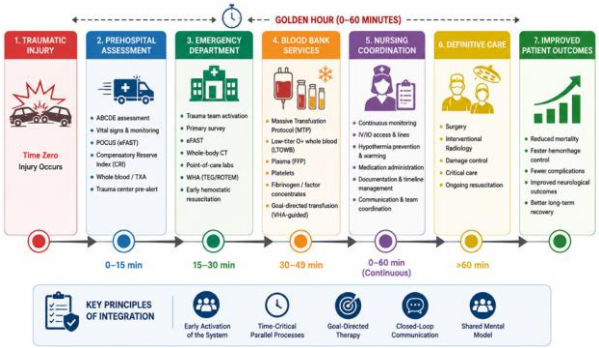

Figure 1. Integrated Golden Hour Trauma Care Pathway.

This narrative review explores the advances made over the last decade (2010-2025) in each of these five critical domains of golden hour care, with a central focus on their integration. It moves beyond a description of individual component interventions to examine the evidence for how their seamless fusion reduces time-to-intervention, minimizes preventable deaths, and improves outcomes for the severely injured patient. The review traces the patient's journey from the point of injury through the ED doors and into the operating room or interventional radiology suite, analyzing the following key questions: How have advances in prehospital paramedic assessment, including the use of portable ultrasound and the initiation of blood products in the field, shortened the time to definitive hemostasis? What is the role of immediate, protocol-driven whole-body CT scanning and point-of-care sonography in accelerating anatomical diagnosis, and how does this integrate with laboratory-based physiological diagnosis? How have point-of-care viscoelastic hemostatic assays (VHA), such as thromboelastography (TEG) and rotational thromboelastometry (ROTEM), transformed the blood bank's capability to provide goal-directed, personalized massive transfusion, moving beyond empiric, fixed-ratio protocols? Finally, what is the indispensable role of expert trauma nursing in orchestrating this complex symphony, acting as the patient's advocate, the team's communication hub, and the guardian of the golden hour timeline? By synthesizing the literature across these fields, this paper provides a comprehensive overview for the entire multi-professional trauma team, highlighting that the true power of the golden hour lies not in isolated technical brilliance but in the integrated, choreographed system of care.

The Prehospital Phase: Extending the Golden Hour into the Field

The golden hour does not begin when the patient arrives at the hospital; it begins at the moment of injury, or as the prehospital maxim states, "the platinum ten minutes" for scene assessment and management. The prehospital phase, delivered by paramedics and emergency medical technicians (EMTs), is tasked with a paradoxical mission: to perform rapid, life-saving interventions and gather critical information for hospital notification while simultaneously minimizing on-scene time. The evolution of prehospital care in the last decade has dramatically expanded the paramedic's diagnostic and therapeutic armamentarium, effectively extending the golden hour's diagnostic window into the field and allowing for a head start on the hospital-based resuscitation.

Advanced Prehospital Assessment and Decision-Making

Traditional prehospital trauma assessment relies on mechanism of injury, basic vital signs, and the structured physical examination of the primary survey. However, the reliance on vital signs alone has proven dangerously insensitive for detecting occult shock (Johnson et al., 2018). A landmark 2015 study demonstrated that up to 25% of severely injured patients with occult hypoperfusion, as defined by an elevated base deficit or lactate, had normal prehospital heart rate and blood pressure (Convertino et al., 2015). This physiological deception, or compensated shock, leads to under-triage and a delayed, less aggressive hospital response upon arrival. To combat this, advanced paramedic assessment now increasingly incorporates non-invasive monitoring of the compensatory reserve, using technologies like the Compensatory Reserve Index (CRI), which analyzes arterial waveform features from a simple pulse oximeter to provide an early, real-time measure of central volume loss long before a drop in systolic blood pressure occurs (van der Ster et al., 2018). A

multi-center trial showed that integrating CRI into prehospital triage improved the sensitivity for identifying patients requiring life-saving interventions by 18% compared to standard triage criteria alone, heralding a new age of physiology-based prehospital triage (Convertino et al., 2021).

Perhaps the most transformative development in prehospital assessment is the deployment of portable ultrasound, or point-of-care ultrasound (POCUS), by paramedics and critical care retrieval teams. The role of prehospital ultrasound is focused and binary: to answer a single, critical question that changes immediate management. The most validated applications are the detection of pneumothorax, cardiac tamponade, and intra-abdominal free fluid as a marker of hemorrhage (Vianen et al., 2023). A 2018 systematic review and meta-analysis of prehospital ultrasound found that it altered patient management in 32-67% of cases, most commonly by prompting a change in destination decision (e.g., direct transport to a Level I trauma center with a cardiothoracic surgeon for a detected cardiac tamponade) or the performance of a specific prehospital intervention like a finger thoracostomy (Bøtker et al., 2018). A field diagnosis of intraperitoneal free fluid in a hypotensive blunt trauma patient by a helicopter emergency medical service (HEMS) paramedic can trigger a hospital pre-alert for an immediate operating room, bypassing the ED entirely—the ultimate time-saving maneuver. This "point-of-injury triage" fundamentally alters the traditional trauma workflow, collapsing the time between diagnosis and definitive surgical control (O'Dochartaigh & Douma, 2015).

Prehospital Interventions and the Dawn of Field Blood Transfusion

Paramedic-delivered interventions during the golden hour have progressed far beyond cervical spine immobilization and splinting. Advanced airway management, including rapid sequence intubation (RSI) and the use of supraglottic devices, is now a core competency of critical care paramedic systems, though its superiority over basic airway management in TBI is a subject of intense and ongoing prospective study, notably the multi-center PART trial (Bernard et al., 2010; Fitzgerald et al., 2019). The most profound paradigm shift, however, is in the management of hemorrhagic shock. The concept of permissive hypotension, where small-volume crystalloid resuscitation is used to maintain a palpable radial pulse without normalizing blood pressure, has been standard for over a decade to avoid dislodging soft clots. However, the recognition of crystalloid's harmful effects—dilutional coagulopathy, acidosis, and acute kidney injury—has driven a paradigm shift towards early, balanced hemostatic resuscitation in the field (Sperry et al., 2018).

This has culminated in the widespread introduction of prehospital blood product administration by HEMS and increasingly by ground-based advanced paramedic services. Initially utilizing thawed plasma and packed red blood cells (pRBCs), a pioneering step demonstrated in the PAMPer trial, which showed a 30-day survival benefit for severely injured patients receiving prehospital plasma compared to standard crystalloid (Sperry et al., 2018). A more disruptive innovation is the use of cold-stored, low-titer group O whole blood (LTOWB) as a single-bag, "complete" resuscitation fluid providing pRBCs, plasma, and platelets in a physiological ratio. A 2022 analysis from the Prehospital Air Medical Plasma (PAMPer) and Study of Tranexamic Acid during Air Medical and Ground Prehospital Transport (STAAMP) trials showed that prehospital LTOWB was independently associated with a 50% reduction in 24-hour mortality and a significant improvement in hemodynamic stability on ED arrival when compared to component therapy or crystalloid (Guyette et al., 2022). The ability of a paramedic to initiate a balanced blood transfusion at the roadside collapses the concept of the golden hour, starting the process of hemostatic resuscitation potentially 30 to 45 minutes before hospital arrival. This powerful integration of a traditional "hospital-only" capability (blood bank services) into the hands of a highly trained paramedic represents the leading edge of the prehospital-hospital continuum. Figure 2 illustrates simultaneous contributions from prehospital care, diagnostic imaging, laboratory medicine, blood bank services, and trauma nursing to support rapid clinical decision-making.

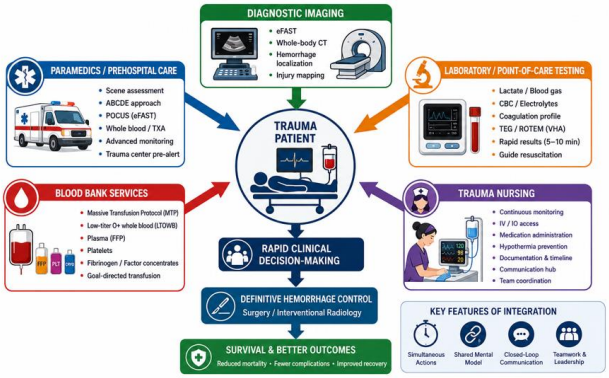

Figure 2. Parallel Multidisciplinary Trauma Team During the Golden Hour

The Emergency Department: The Nexus of Diagnosis and Integration

The patient's arrival in the trauma bay is the moment of maximum convergence. Within minutes, the paramedic hands over a structured clinical picture while multiple teams simultaneously begin their assessment. The ED phase of the golden hour is where the diagnostic power of radiology and laboratory testing must be perfectly integrated with the therapeutic actions of the trauma team to definitively arrest the lethal triad of hypothermia, acidosis, and coagulopathy.

Parallel Workflows in Diagnostic Imaging

Diagnostic imaging is the cornerstone of anatomical injury identification in the unstable patient. The Advanced Trauma Life Support (ATLS) paradigm has been fundamentally updated by the near-universal adoption of the extended Focused Assessment with Sonography for Trauma (eFAST) as a bedside, repeatable, and radiation-free tool to immediately identify pneumothorax, hemothorax, cardiac tamponade, and intra-abdominal free fluid. In the critically unstable patient, a positive eFAST for intraperitoneal fluid is a direct ticket to the operating theater. A prospective study demonstrated that a formalized, dual-sequence workflow—where eFAST is performed by the emergency physician or surgeon during the primary survey, in parallel with the preparation of the CT scanner—reduced the mean time to CT for stable high-mechanism patients by 8 minutes and the time to operative intervention for unstable FAST-positive patients by 15 minutes compared to a sequential, physician-ordered model (Benovoy, 2016).

For the hemodynamically normal patient with a high-risk mechanism, the immediate whole-body CT (WBCT) scan has become the non-negotiable gold standard. The debate over "pan-scanning" versus selective scanning has been largely settled by the weight of evidence showing a significant survival benefit. A landmark 2016 multicenter randomized controlled trial (REACT-2) found that immediate WBCT, compared to a selective CT approach based on conventional radiography and physical examination, did not significantly reduce in-hospital mortality in the overall trauma population, but critical subgroup analyses and subsequent systematic reviews have consistently shown that it accelerates time to final diagnosis and reduces the need for delayed, unplanned interventions, particularly in the polytrauma patient (Treskes et al., 2020). The current consensus is that the immediate WBCT protocol must be deeply integrated into the trauma activation response: the scanner is automatically prepared upon a "Trauma Code" pre-alert, a pre-printed WBCT protocol is activated without a separate radiologist order, and the trauma team leader ensures a seamless and rapid transport of a stabilized patient to and from the scanner, with the team remaining in the CT control room to receive the preliminary radiologist report in real-time (Huber-Wagner et al., 2013). This integration of a pre-planned radiology workflow eliminates the historical bottleneck of waiting for a phone call, an order, and a technologist.

From Empiric to Goal-Directed Hemostasis: The Laboratory-Bedside Interface

The laboratory's role in the golden hour has undergone a transformation no less profound than radiology's. The traditional approach—sending a rainbow of tubes to a centralized lab and waiting 45-60 minutes for conventional coagulation tests (CCTs) like prothrombin time (PT) and activated partial thromboplastin time (aPTT)—has been exposed as dangerously slow and physiologically incomplete. CCTs were designed to monitor anticoagulation, not trauma-induced coagulopathy (TIC), and they provide no information on platelet function, fibrinogen levels, or the stability of the fibrin clot (Holcomb et al., 2015). The new standard of care, now enshrined in multiple European and North American guidelines, is point-of-care (POC) viscoelastic hemostatic assays (VHA) using thromboelastography (TEG) or rotational thromboelastometry (ROTEM) (Spahn et al., 2019).

These tests are performed on a small whole-blood sample in a compact device situated in the trauma bay, with initial results on the clot's initiation, strength, and stability available within 5 to 10 minutes. This speed converts a diagnostic lag into a real-time biological feedback loop (Curry et al., 2023). A 2021 systematic review and meta-analysis of 17 studies involving over 4,500 patients demonstrated that VHA-guided transfusion algorithms, compared to CCT-guided or fixed-ratio MTPs, led to a significant reduction in the use of high-ratio fresh frozen plasma and pRBCs, a lower incidence of multi-organ failure, and a significant 15% improvement in overall survival (Baksaas-Aasen et al., 2021). The translation of this laboratory data into a dynamic therapeutic plan is typically guided by an evidence-based algorithm. For example, a flat tracing with a prolonged clotting time (TEG R-time or ROTEM CT) indicates a need for plasma or factor concentrate; a weak clot amplitude (TEG MA or ROTEM MCF) with a normal clotting time points to a fibrinogen deficit, prompting cryoprecipitate or fibrinogen concentrate; while a weak clot due solely to platelet dysfunction directs the administration of platelets (Dujardin et al., 2022). This precision approach, often nurse-driven at the bedside, represents the epitome of integrated care, where the laboratory result is not a delayed consultation but a direct trigger for a specific, personalized therapeutic action, replacing blind transfusions with a data-driven strategy (Table 1).

Table 1. Integration of Laboratory and Blood Bank Services for Goal-Directed Resuscitation

Phase	Traditional Model (Siloed)	Integrated Model (Goal-Directed)	Clinical Impact
Sample	Citrated plasma sent to central lab	Whole blood to trauma bay POC TEG/ROTEM device	Results available in 5-10 min vs. 45-60 min
Result	PT/INR, aPTT, platelet count, fibrinogen (static,	R-time/CT, K-time/CFT, α-angle, MA/MCF, LY30/ML (dynamic, whole-blood, functional)	Identifies TIC subtype: enzymatic deficiency vs.

	plasma-based, incomplete)		platelet/fibrinogen deficit vs. hyperfibrinolysis
Clinical Trigger	Fixed-ratio MTP (1:1:1) activated by physician gestalt; empiric product administration	VHA-algorithm triggers specific product: plasma for prolonged R-time; fibrinogen for low MA; platelets for low MA with normal fibrinogen	Reduces inappropriate transfusion; lower rates of ARDS, MOF, and overall mortality (Baksaas-Aasen et al., 2021)
Blood Bank Role	Reactive: to order and request. Prepares MTP pack based on phone call	Proactive and predictive: receives early activation, uses VHA data feed to anticipate and prepare next targeted blood product round	Decreases product wastage; ensures timely availability of rare or specific products

Note. POC: point-of-care; TEG: thromboelastography; ROTEM: rotational thromboelastometry; TIC: trauma-induced coagulopathy; MTP: massive transfusion protocol; ARDS: acute respiratory distress syndrome; MOF: multi-organ failure.

Blood Bank Services: The Pivot of Proactive Resuscitation

The hospital blood bank is no longer a passive dispensary located in the basement; it is a critical and proactive member of the golden hour team. The transition from a reactive, request-based system to a pre-emptive, protocol-driven Massive Transfusion Protocol (MTP) has been one of the great successes of modern trauma systems. An MTP is a pre-defined, multi-disciplinary plan for the rapid, sustained delivery of balanced blood products, typically activated by a single, dedicated phone call and a pre-set clinical trigger.

The composition of the MTP has been the subject of intense investigation. The landmark PROPPR trial definitively established that a 1:1:1 ratio of pRBCs, fresh frozen plasma (FFP), and platelets, compared to a 2:1:1 ratio, was associated with a greater proportion of patients achieving anatomical hemostasis and a reduction in early death from exsanguination within the first 24 hours, although no difference in overall mortality was found at 30 days (Holcomb et al., 2015). This has made the 1:1:1 "damage control resuscitation" pack the standard for MTP initiation. However, the future of blood banking in trauma lies beyond the one-size-fits-all model. Building on the VHA diagnostics discussed, the blood bank's role is evolving towards supplying whole blood, as well as purified, pathogen-reduced coagulation factor concentrates (PCCs, fibrinogen concentrate) for a more tailored physiological correction. The integration of LTOWB into the MTP is a major trend, fueled by its logistical simplicity (one bag instead of three), its physiological balance, and its compelling association with improved survival in massive hemorrhage (Shea et al., 2020). A major task for the blood bank and trauma team is the continuous management of cold chain logistics for prehospital and ED-stored blood, a nursing and blood bank responsibility that is a hidden but essential component of system performance (van Turenhout et al., 2020). Nurse-led activation of the MTP, based on a pre-approved protocol triggered by the presence of persistent hypotension and a positive FAST, has also been shown to significantly reduce the time to first unit of blood transfusion by up to 15 minutes, demonstrating the power of nursing integration in streamlining core processes (Bawazeer et al., 2015).

Nursing Management: The Central Integrator of the Trauma Team

The trauma nurse is the central nervous system of the golden hour resuscitation. This role transcends task execution; the nurse is the patient's advocate, the team's communication hub, the guardian of the timeline, and the primary integrator of the multi-disciplinary plan. The quality of trauma nursing leadership and coordination directly impacts every metric of golden hour performance, from time-to-CT to the prevention of hypothermia.

The core of nursing management during this phase is the systematic, protocol-driven primary and secondary survey, but with an emphasis on parallel processing. While the physician performs the hands-on primary survey, the trauma nurse simultaneously initiates the "trauma panel" of interventions: exposing the patient, establishing large-bore intravenous (IV) or intraosseous (IO) access, placing the patient on a cardiac and pulse oximetry monitor, obtaining an automated blood pressure, drawing the pre-set panel of trauma labs (including a sample for VHA and a type and crossmatch), and initiating active rewarming measures. The prevention of the lethal triad begins with aggressive nursing care; the use of pre-warmed IV fluids, forced-air warming blankets, and raising the ambient room temperature are simple, high-impact nursing actions proven to reduce the incidence of admission hypothermia and its associated coagulopathy and acidosis (Perlman et al., 2016). A 2020 quality improvement study demonstrated that a simple "hypothermia prevention bundle" checklist, championed by nursing leadership, reduced the incidence of ED arrival hypothermia from 38% to 12% in severely injured patients (Ralph et al., 2020).

Beyond technical skills, the trauma nurse's non-technical skills are the lifeblood of the integrated team. The nurse is often the de facto "time-keeper," documenting every intervention on a flow sheet, verbally announcing elapsed time during a trauma

code (e.g., "15 minutes since arrival, FAST is positive, MTP round two infusing"), and maintaining the team's shared situational awareness. The concept of a shared mental model, where all team members understand the patient's current state, the immediate plan, and their specific roles, is a key predictor of team performance and is actively cultivated by strong nursing leadership (Johnsen et al., 2017). The nurse is typically the first to detect a change in patient status—a subtle drop in oxygen saturation, a new premature ventricular contraction on the monitor, a change in mental status—and is empowered to vocalize this concern directly to the team leader. The most critical and standardized moment of integration is the formal, structured handoff from the prehospital paramedic to the entire in-hospital team (Durr et al., 2023). This is a nurse-led or nurse-enforced process, often using a mnemonic like ATMIST (Age, Time of injury, Mechanism, Injuries found/suspected, Signs and Symptoms, Treatment given) to ensure a silent, uninterrupted report that forms the foundation for the shared mental model of the entire resuscitation (Cowan et al., 2023). This integration of information, vital signs, and human factors into a single, time-stamped, and communicated narrative is the unique and irreplaceable contribution of trauma nursing to the golden hour (Jamshidi et al., 2019).

Future Perspectives and Challenges in Integration

The quest for the perfect golden hour system faces persistent challenges, but a suite of emerging technologies promises the next leap forward. A major challenge is the "data silo" problem: the paramedic's monitor data is lost at the ED door; the CT scan is viewed on a separate workstation; the TEG results are on a small screen next to the device; and the blood bank's MTP status is communicated by phone. This fragmentation of critical information increases cognitive load and creates opportunities for error. The future lies in the creation of a unified, real-time "digital trauma bay." This would integrate live-streamed prehospital data, the eFAST ultrasound image, the CT preliminary read, the POC lab results, and the MTP status into a single, large-format dashboard visible to the entire team, underpinned by an AI-driven decision support system (Peng et al., 2023). An AI model could be trained to fuse these multi-modal data streams, identify the early, subclinical signatures of decompensation, and provide visual and auditory prompts—for example, flagging a subtle but progressive narrowing of the pulse pressure on the monitor alongside a rising VHA clot time, signaling that the patient is "unpacking" and needs an escalation of hemostatic therapy before the blood pressure drops (Abujaber et al., 2020).

Augmented reality (AR) for trauma nursing and vascular access is another promising integration tool. An AR headset could project the patient's ultrasound-proven vein anatomy directly onto the skin, guiding a difficult IV or IO placement during profound shock, reducing the door-to-access time. Telemedicine, or tele-trauma, is already enabling a senior trauma surgeon to remotely supervise a junior team or a rural clinician performing an eFAST or a resuscitative thoracotomy, breaking down geographical barriers to golden hour expertise. The persistent challenge for all these technologies is to ensure they support, rather than distract from, the fundamental human-to-human interaction and the strong, closed-loop communication that is the hallmark of a high-functioning team. The ultimate frontier is the seamless, "zero-handoff" integration of the entire patient journey, from a paramedic's field diagnosis that directly activates a hybrid operating room, to an AI-powered blood bank that autonomously begins thawing the predicted next round of plasma, all orchestrated by a nurse-leader whose cognitive burden is reduced by technology, allowing a greater focus on the patient (Table 2). Figure 3 shows the proposed future model of integrated trauma care using digital communication, artificial intelligence, point-of-care diagnostics, and multidisciplinary coordination to optimize management during the golden hour.

Table 2. Key Disciplines in the Golden Hour: Evolving Roles and Future Trends

Discipline	Traditional Role (Pre-2015)	Current Integrated Role (2015-2025)	Future Perspective (2025+)
Paramedics	Scoop and run; basic vital signs; crystalloid infusion	Advanced physiology (CRI, lactate); POCUS; prehospital LTOWB/TXA; direct-to-OR transport decision	AI-driven triage; autonomous hemostatic resuscitation; continuous patient data streaming to the trauma bay
Radiology	On-demand, sequential imaging ordered by physician	Protocol-driven, parallel eFAST and immediate WBCT; radiologist as real-time diagnostic team member in the trauma bay	AI-assisted instant image interpretation for hemorrhage detection; augmented reality overlay of injuries on the patient
Medical Laboratory	Batched plasma assays (PT/INR, aPTT) in a	Trauma bay POC VHA (TEG/ROTEM); real-time, goal-	Multi-omics profiling for personalized coagulopathy correction; continuous, non-

	central lab; >45 min turnaround	directed algorithm triggers; 5-10 min turnaround	invasive hemoglobin and coagulopathy monitoring
Blood Bank	Reactive transfusion service; MTP activated by phone call	Proactive MTP activation by multiple team members; delivery of 1:1:1 packs and LTOWB; preparation for VHA-guided precision products	AI-predictive blood product preparation; cell-free hemoglobin substitutes; lyophilized platelets for immediate reconstitution
Nursing	Task-oriented support; manual documentation and vital sign charting	Central integrator and communication hub; leader of parallel processes and hypothermia prevention; guardian of the golden hour timeline	Operator of a unified, AI-integrated digital trauma bay dashboard; AR-guided vascular access; tele-present nursing supervision for rural sites

Note. CRI: Compensatory Reserve Index; POCUS: point-of-care ultrasound; LTOWB: low-titer O-positive whole blood; TXA: tranexamic acid; OR: operating room; eFAST: extended focused assessment with sonography in trauma; WBCT: whole-body computed tomography; VHA: viscoelastic hemostatic assay; MTP: massive transfusion protocol; AI: artificial intelligence.

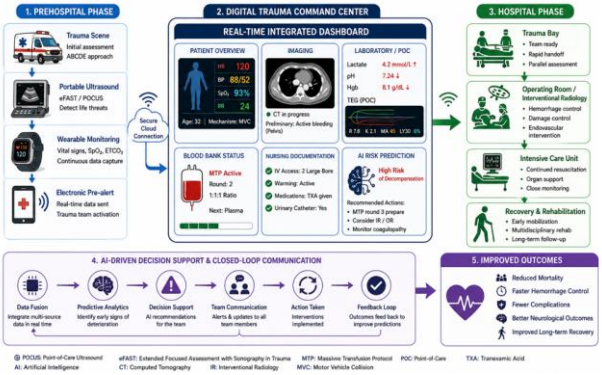

Figure 3. Future Integrated Digital Trauma System

Conclusion

The golden hour in trauma care is not a mystical temporal window but a practical, evidence-based construct that demands a system engineered for speed, precision, and flawless integration. This review demonstrates that the major advances in trauma care over the past decade are not merely the new devices or drugs, but the systematic destruction of the silos that once separated prehospital, radiology, laboratory, blood bank, and nursing disciplines. The paramedic who performs a prehospital ultrasound and initiates whole blood transfusion is no longer a transporter; they are the first node in a continuous chain of hemostatic resuscitation. The point-of-care TEG device in the trauma bay is not just a lab test; it is a direct, real-time command signal for the blood bank to transition from an empiric 1:1:1 massive transfusion to a personalized, goal-directed therapy. The trauma nurse who manages the airway, activates the MTP, and documents the timeline is not just a caregiver; they are the central integrator and communication nexus upon which the team's shared mental model is built.

The future of golden hour integration is a closed-loop system where information flows without friction: the prehospital diagnosis pre-activates the hospital's physical and human resources, the diagnostic imaging is instantly fused with physiological data from the laboratory, and an AI-augmented decision support system presents the team with a dynamic, predictive risk profile, not a static checklist. Yet, as technology becomes more pervasive, the non-technical skills of the human team—leadership, followership, closed-loop communication, and mutual trust—become more, not less, important. The goal is to create a symphony of action where every discipline's unique contribution is not just heard, but perfectly synchronized in time and purpose. The golden hour, therefore, is not found on a clock; it is created by a team that is prepared, pre-emptive, and perfectly integrated. The continued evolution and refinement of this multi-disciplinary choreography, from the roadside to the operating room, remains the single most powerful tool we have to reduce the global burden of death and disability from traumatic injury.

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