A retrospective review of blood component transfusions in prehospital aeromedical care

Abstract

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| **Background: E**arly administration of blood products has become increasingly important in aeromedical transport due to its potential to improve outcomes in critically ill trauma patients by stabilizing hemodynamics and reducing mortality.This study aims to analyze current practices and future perspectives of blood component transfusion in prehospital aeromedical care.  **Study design:** A descriptive, qualitative, and retrospective observational study, utilizing a methodological framework based on a bibliographic review of indexed journal articles.  **Methodology:** A systematic search on PubMed was conducted using the terms “blood components,” “transfusion,” “aeromedical,” and “pre-hospital,” limited to the last 10 years. Thirty-four articles were selected and analyzed according to thematic relevance.  **Results:** Prehospital blood transfusion (PHBT) has been documented as a safe procedure that optimizes care and facilitates effective hemodynamic management in trauma patients, as well as significantly reduces mortality rates and improves shock index stabilization. Studies highlight favorable outcomes associated with PHBT, emphasizing the need for its efficient integration, particularly in aeromedical services. Challenges specific to aeromedical transport include maintaining blood product temperature and viability during flight, managing limited onboard storage capacity, and coping with physiological stressors such as vibration and altitude changes that may affect transfusion safety and efficacy. Despite these challenges, PHBT enhances early hemodynamic management and facilitates timely hemorrhage control.  **Conclusion:** Evidence supports that blood transfusion during prehospital aeromedical transport can improve patient survival and hemodynamic stability. Further research is essential to develop optimized protocols that address the unique logistical and physiological challenges of aeromedical environments to ensure patient safety and maximize clinical benefits. |

*Keywords: blood products, hemostatic resuscitation, trauma care, massive transfusion.*

1. INTRODUCTION

Trauma is the leading cause of death among patients under 45 years old, representing a significant public health challenge worldwide (Beiriger et al., 2023; Plodr et al., 2023; Mitra et al., 2023; Rossaint et al., 2023; Yazer et al., 2023; Lima et al., 2021). Hemorrhage is the primary cause of preventable death, accounting for 33 to 56% of fatalities during pre-hospital care (Plodr et al., 2023; Nascimento et al., 2022; Levin et al., 2022; Lima et al., 2021). Rapid and effective hemorrhage control is essential, as massive bleeding can lead to death within minutes (Certain et al., 2023; Carrol et al., 2020).

Historically, resuscitation protocols emphasized the early and aggressive administration of crystalloids such as saline and lactated Ringer's solution (Certain et al., 2023; Yazer et al., 2023). However, Griggs et al. (2018) demonstrated that this approach is associated with increased immediate mortality (within six hours) due to blood loss, and delayed mortality (within 28 hours) resulting from complications such as multiple organ failure and dilutional coagulopathy when compared to blood transfusions. Patients suffering from acute traumatic coagulopathy have an eightfold increased risk of death within the first 24 hours (Mitra et al., 2023).

Modern pre-hospital trauma resuscitation protocols now emphasize permissive hypotension and restrict crystalloid use (Yazer et al., 2023; Levin et al., 2022). Recent evidence supports the use of blood components in the pre-hospital environment, promoting their adoption in mobile units to improve hemodynamic control and reduce associated complications (Certain et al., 2023; Yazer et al., 2023; Levin et al., 2022). Furthermore, multiple studies have linked prehospital blood product administration to decreased mortality rates (Cornelius et al., 2023; Lammers et al., 2023; Plodr et al., 2023; Nascimento et al., 2022; Levin et al., 2022).

Due to the hemodynamic and metabolic complexities influencing clinical progression, massive transfusion requires a meticulous approach that accounts for circulating blood volume, tissue oxygenation adequacy, coagulation changes, and metabolism (Nascimento et al., 2022; Lima et al., 2021).

In emergency medicine, blood transfusion plays a vital role in optimizing pre-hospital care (Lammers et al., 2023). The careful implementation of blood component transfusion in pre-hospital settings represents a significant advancement in managing critically ill patients, especially during aeromedical transport (Nascimento et al., 2022). Moreover, aeromedical services improve access to blood products, enhancing pre-hospital interventions (Cornelius et al., 2023).

Administering blood products during intensive care aeromedical transport is a complex task due to aircraft weight limits, storage requirements, and the scarcity of universal donor blood products, necessitating innovation and organization (Latimer et al., 2021). There remains a paucity of specific studies addressing blood component transfusion during aeromedical transport, highlighting the need for thorough investigation of clinical effectiveness as well as logistical and operational challenges in emergency settings (Nascimento et al., 2022; Peters et al., 2019).

In this context, this study proposes an analysis of blood component transfusion in pre-hospital care, with special focus on its integration into aeromedical transport. The critical analysis of methods, results, and implications discussed herein aims not only to consolidate existing knowledge but also to stimulate discussion on the effective implementation of blood component transfusion, promoting advances in emergency medicine.

2. metHODOLOGY

An integrative literature review was conducted between March and April 2025, utilizing the databases PubMed, Scopus, and Web of Science. The search terms included: “prehospital blood transfusion,” “aeromedical transport,” “air medical services,” “hemorrhagic shock,” and “emergency medical services.” Inclusion criteria comprised original studies, systematic reviews, and guidelines specifically addressing prehospital transfusion in aeromedical contexts, published between 2013 and 2024, available in full text, and written in English. The selection process consisted of four steps: (1) identification of records; (2) removal of duplicates; (3) screening of titles and abstracts; and (4) full-text review applying eligibility criteria. Case reports and studies published more than five years ago were excluded unless deemed seminal works in the field. Priority was given to studies published in journals with an impact factor above 2.0, to ensure inclusion of research with higher methodological rigor and scientific relevance, thereby enhancing the reliability and validity of the evidence base in this review.

DISCUSSION

Pre-hospital blood transfusion (PHBT) has evolved significantly over the past three decades, establishing itself as a safe and increasingly widespread procedure among trauma patients (Beiriger et al., 2023; Plodr et al., 2023). Drawing from military experience, pre-hospital services worldwide have refined their protocols by incorporating transfusion therapy within mobile units, aiming for more effective hemodynamic control and reduced complication rates (Certain et al., 2023). Nevertheless, despite these advancements, preventable mortality from exsanguinating injuries remains alarmingly high globally (Thies et al., 2020).

The primary goals of damage control resuscitation for severely traumatized patients are to restore intravascular volume and to prevent or reverse the lethal triad of acidosis, hypothermia, and coagulopathy (Chan et al., 2023; Nascimento et al., 2022). These pathological processes are triggered by endothelial activation, potentiated by tissue hypoxia secondary to hypovolemia (Lima et al., 2021). Consequently, contemporary hemostatic resuscitation strategies emphasize maintaining adequate perfusion of vital organs and ensuring tissue oxygenation until definitive hemostasis is achieved (Beiriger et al., 2023).

Among these strategies, massive transfusion is fundamental, often combined with restricted crystalloid use, prompt control of compressible hemorrhages, and prioritization of surgical intervention (Lima et al., 2021). Volume replacement with blood components typically follows a 1:1:1 ratio of packed red blood cells, plasma, and platelets, supplemented by cryoprecipitate or fibrinogen concentrate to optimize fibrinogen levels. However, while this approach aims to approximate whole blood, it cannot perfectly replicate physiological ratios due to inevitable dilution of hematocrit, platelet count, and fibrinogen concentration (Chan et al., 2023).

Blood transfusion is generally indicated when losses exceed 25–30% of total blood volume or in cases of class III or IV hypovolemic shock, which, if not promptly addressed within the first hour, may progress to multiple organ failure and death (Nascimento et al., 2022).

Decision-making regarding transfusion in the pre-hospital environment is particularly challenging due to the limited diagnostic resources available to first responders (Plodr et al., 2023; Brown et al., 2016). Notably, identification criteria for PHBT vary; in European contexts, it is predominantly indicated for patients with severe trauma, shock, or prolonged entrapment while unstable (Thies et al., 2020). Furthermore, Brown et al. (2016) suggest that patients exhibiting significant hypotension (SBP ≤ 80 mmHg) and tachycardia (HR > 110 bpm), even if transient during transport, likely benefit from blood transfusion.

In a systematic review by Shand et al. (2019), comprising 22 studies (16 civilian, 6 military), the most common physiological criteria for PHBT were systolic blood pressure thresholds from <70 to <90 mmHg, tachycardia thresholds >108 to >130 bpm, or absence of radial pulse. Additionally, five studies incorporated injury mechanisms such as penetrating trauma or amputations above the knee/elbow as criteria. Moreover, Plodr et al. (2023) emphasize that shock index and pulse pressure are more reliable parameters, with superior sensitivity and specificity, for predicting the need for PHBT in trauma patients.

The shock index (heart rate divided by systolic blood pressure) is increasingly recognized as a superior trauma outcome predictor compared to vital signs alone (Plodr et al., 2023). In line with this, the European Guideline on severe bleeding and coagulopathy endorses shock index for hypovolemic shock assessment (Plodr et al., 2023). El-Menyar et al. (2018) identified an optimal cutoff of 0.81 predicting massive transfusion with 85% sensitivity and 64% specificity. Pulse pressure (difference between systolic and diastolic pressure) tends to decrease in bleeding due to reduced intravascular volume (Plodr et al., 2023).

Additionally, Certain et al. (2023) evaluated pre- and post-transfusion vital signs and shock index in trauma patients. Mean systolic blood pressure upon arrival was 52.6 mmHg (range 0–110 mmHg), with a mean heart rate of 114 bpm (range 0–160 bpm), resulting in an initial mean shock index of 2.16. Following packed red blood cell transfusion, mean systolic pressure rose to 85.2 mmHg (range 0–120 mmHg) and heart rate decreased to 93.7 bpm (range 0–150 bpm), reducing shock index to 1.1. Thus, a key outcome of PHBT is the significant improvement in shock index, reflecting enhanced hemodynamic stability in critically injured patients.

Similarly, Hanlin et al. (2023) conducted a five-year retrospective analysis of adult trauma patients transported by helicopter aeromedical services, applying the Assessment of Blood Consumption (ABC) score. Pre-hospital use of this score demonstrated a sensitivity of 51% and specificity of 85% for predicting massive transfusion, correctly classifying 83% of cases. In the emergency department, sensitivity increased to 60% with specificity at 84%, maintaining 83% correct classification. Notably, PHBT in aeromedical transport has been associated with reduced early mortality, as Brown et al. (2016) reported higher odds of 24-hour survival among transfused patients. Hence, reduction in mortality and improvement in shock index stand out as key outcomes supporting PHBT.

Although PHBT intuitively improves survival, evidence remains inconsistent. Two recent randomized trials compared pre-hospital blood product administration with standard fluid resuscitation using 0.9% saline. On one hand, Moore et al. (2018) found pre-hospital plasma associated with improved survival. On the other hand, Sperry et al. (2018) reported that thawed plasma administration pre-hospital to patients at risk of hemorrhagic shock was safe and lowered 30-day mortality.

In a randomized, double-blind, parallel-group study, Young et al. (2014) evaluated adult trauma patients requiring blood transfusion, intubation, or surgery within 60 minutes. Participants received either 0.9% saline or Plasma-Lyte A for resuscitation. Resuscitation with Plasma-Lyte A led to better acid-base status and reduced hyperchloremia 24 hours post-injury compared to 0.9% saline.

Moreover, Brown et al. (2016) conducted a retrospective cohort study with helicopter-transported trauma patients. Those receiving packed red blood cell transfusion were matched 1:2 with controls (240 treated vs. 480 controls). Transfusion correlated with higher odds of 24-hour survival, lower incidence of shock, and decreased need for additional transfusions within 24 hours, highlighting PHBT benefits in aeromedical transport.

An important additional consideration is that aeromedical evacuation can exacerbate post-injury morbidity due to hypoxic and hypobaric conditions inherent to flight. In this context, Wallen et al. (2022) conducted an animal study involving 42 pigs, assessing whether resuscitation with blood products could mitigate the adverse physiological effects of post-injury flight. Control groups received either lactated Ringer’s or blood products and were exposed to varying altitudes. The study revealed that cerebral perfusion, tissue oxygenation, and intracranial pressure remained stable across groups. However, crystalloid resuscitation was associated with prolonged lactic acidosis and a pro-inflammatory response, potentially predisposing multiply injured patients to secondary cellular injury. These findings suggest that such physiological insults may be mitigated by resuscitation strategies incorporating blood products.

Additionally, aeromedical-specific challenges, such as limited storage capacity for blood products, variable cabin pressures, and restricted space for complex procedures, further complicate the implementation of PHBT in this environment (Beiriger et al., 2023; Certain et al., 2023). Accordingly, the following table (Table 1) summarizes the critical aspects identified in this review regarding prehospital blood transfusion in aeromedical transport.

Table 1. Critical Aspects of Aeromedical Blood Transfusion.

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| **Aspects** | **Description** |
| Logistical challenges | Limited space, need for proper blood product storage, equipment weight and volume constraints. |
| Physiological challenges | Hypobaric hypoxia, thermal stress, exacerbation of trauma-induced coagulopathy. |
| Recommended protocols | Continuous monitoring, fluid warming, use of cold-stored whole blood or lyophilized plasma, specialized team training. |
| Available evidence | Predominantly observational studies; randomized trials are lacking. |

When transfusion reactions occur, they typically manifest early during the infusion. In such cases, the transfusion must be immediately halted, venous access maintained with 0.9% saline, vital signs assessed, appropriate pharmacological interventions administered, and the blood center notified, with the implicated blood bag forwarded for investigation (Nascimento et al., 2022).

Furthermore, research on pre-hospital transfusion faces significant clinical and logistical challenges, complicating cohort matching and data collection. Isolating the effects of pre-hospital blood transfusion (PHBT) is difficult due to multiple confounding factors influencing outcomes, rendering samples prone to bias (Shand et al., 2019). Therefore, while accurately identifying PHBT candidates is critical, it remains complex given the limited diagnostic tools available in the pre-hospital setting (Plodr et al., 2023).

Additionally, pre-hospital parameters are dynamic and influenced by patient age, complicating the development of universal PHBT algorithms. Nonetheless, simple parameters such as the shock index and pulse pressure may streamline clinical decision-making and reduce unnecessary use of blood products, which are both scarce and costly (Plodr et al., 2023).

Moreover, the Assessment of Blood Consumption (ABC) score, validated for predicting the need for massive transfusion in trauma, considers injury mechanism, systolic blood pressure, heart rate, and Focused Assessment with Sonography for Trauma (FAST) findings (Lima et al., 2021). Hanlin et al. (2023) reported that its implementation reduced mortality by 23%; however, the score was developed and validated in hospital settings, necessitating further studies for its pre-hospital application.

In addition to transfusion strategies, historically, liberal crystalloid use in trauma resuscitation has been associated with inflammatory disturbances, coagulopathy, hemodilution, hypothermia, and hyperchloremic acidosis. In pre-hospital settings, crystalloid use is linked to hyperfibrinolysis and increased mortality, prompting recommendations to limit crystalloid administration and prioritize early transfusion of blood products (Brown et al., 2016). Moreover, red blood cell transfusion provides volume expansion and enhanced oxygen delivery, essential for sustaining metabolism during hypoperfusion. Early modulation of post-injury inflammation has a positive impact on outcomes (Brown et al., 2016).

Furthermore, evidence indicates that prompt activation of massive transfusion protocols can improve trauma survival by up to 25%, with aeromedical services expanding access to blood products (Cornellius et al., 2023). However, aeromedical services face challenges due to prolonged response times to accident scenes in vast geographic areas (Certain et al., 2023). Meyer et al. (2017) found that each minute of delay in blood product administration increases mortality risk by 5%. In regions without pre-hospital transfusion capabilities, blood products are typically administered only after hospital admission, with delays averaging 25 minutes (range: 12–59 minutes), excluding mean on-scene times of 43 minutes and further delays in transfusion initiation. Consequently, reducing the time to hemostasis by 15 minutes significantly decreases 30-day mortality, reinforcing the survival benefit of early transfusion (Certain et al., 2023).

Finally, under current Brazilian legislation, the use of low-titer group O whole blood or thawed plasma for pre-hospital transfusions is not authorized. Certain et al. (2023) highlight that implementing whole blood distribution requires restructuring production and storage logistics, which depend on future policy changes. Increasing operational capacity and storage infrastructure is critical to support this transition (Beiriger et al., 2023).

4. ConclusION

The integration of blood component transfusion into prehospital aeromedical care represents a significant advancement in the management of trauma and critically ill patients. Current evidence demonstrates that prehospital blood transfusion (PHBT) improves hemodynamic stability and enhances survival rates in severely injured individuals, particularly when implemented with appropriate patient selection and continuous monitoring.

Despite these benefits, substantial challenges persist, including logistical difficulties related to blood product storage and transport, elevated costs, and the inherent complexity of accurately identifying suitable candidates for transfusion in prehospital settings. Overcoming these barriers necessitates ongoing research, technological innovation, and the development of standardized protocols to ensure the safe and effective application of transfusion practices.

Importantly, the outdated practice of universally administering group O blood products is no longer considered appropriate. The preferential use of ABO- and Rh-specific blood components is now recommended to minimize the risk of fatal transfusion reactions, thereby enhancing patient safety in the prehospital environment.

Future research should prioritize large-scale, prospective trials aimed at refining transfusion protocols, optimizing transfusion ratios, and evaluating long-term clinical outcomes. The widespread adoption of evidence-based transfusion strategies in aeromedical transport holds substantial potential to further improve survival rates and elevate the quality of care for critically ill patients worldwide.

**Recommendations**

Prehospital aeromedical services should prioritize the implementation of ABO- and Rh-specific transfusions to minimize the risk of adverse transfusion reactions and to enhance patient safety. The establishment of standardized transfusion protocols is imperative and should be guided by large-scale, prospective studies aimed at optimizing transfusion ratios and refining patient selection criteria within the aeromedical context. Moreover, substantial investment in logistical infrastructure and storage solutions is essential, with a focus on incorporating innovative technologies that ensure the maintenance of blood product viability during transport. This includes the adoption of advanced temperature control mechanisms and compact storage systems adapted to the unique operational constraints of aeromedical missions. It is noted that continuous education and specialized training of aeromedical personnel in transfusion indications, techniques, and safety measures are critical to maximizing therapeutic efficacy while minimizing associated risks.

**Limitations**

This study presents several noteworthy limitations. Firstly, the scarcity of randomized controlled trials specifically addressing prehospital blood transfusion in aeromedical environments limits the robustness of the available evidence and precludes the establishment of definitive causal relationships, as most existing studies are observational or retrospective in nature. Additionally, there is significant heterogeneity among transfusion protocols across different aeromedical services and geographic regions, which hinders both the standardization and the generalization of findings. Another limitation arises from the selection criterion that prioritized journal impact factor; although this approach aimed to ensure methodological rigor, it may have inadvertently excluded relevant studies published in emerging or lower-impact journals. Finally, this review did not include a formal risk of bias assessment for the selected studies, a methodological component that could be addressed in future research to further strengthen the quality and reliability of the evidence base.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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