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Transfusion Management in Trauma: What is Current Best Practice?

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Abstract

Purpose of Review In the past few years, transfusion strategies in trauma have changed dramatically. We aim to define current practices, explore the evidence leading to these shifts, and identify areas of contemporary research within this field.

Recent Findings Some major shifts include initiating blood products in the prehospital setting and favoring whole blood rather than individual blood components. Additional improvements include expanding trauma resuscitation to include AB plasma in untyped patients, several adjuncts given as part of massive transfusion protocols, and utilizing thromboelastography for individually tailored resuscitation. These practices remain at the forefront of trauma transfusion research with several trials completed and ongoing to establish their safety and practical value.

Summary The degree of change over just the past few years highlights the opportunity for improvement in the field. Despite being standard of care for over a century, transfusion in trauma is still evolving to optimize patient care.

Keywords Transfusion · Trauma · Prehospital transfusion · AB plasma · Whole blood

Introduction

Trauma is the foremost cause of death for children and adults younger than forty-five in the United States [1]. In 2016, the World Health Organization ascertained that up to 20% of deaths resulting from trauma are preventable [2]. Hemorrhage contributes to up to 40% of all mortality after trauma and is one of the principal culprits for preventable fatalities [3]. Transfusion strategies have become crucial for reducing mortality after traumatic hemorrhage.

Physicians have been performing transfusions for trauma patients since the early twentieth century. This has contributed to declining trauma mortality over the decades, particularly from exsanguination [4, 5]. Part of this decline may result from the recent shift in focus to improving time to transfusion as a means to reduce mortality [6]. Two prominent areas of study, prehospital resuscitation and whole blood transfusion, aim to maximize the advantages of blood administration while minimizing time to treatment. Significant strides have been made to assess the safety, feasibility, and impacts of these interventions. We discuss the contemporary standard of care for transfusion in trauma along with recent and upcoming developments.

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Prehospital Resuscitation

Prehospital resuscitation evolved significantly over the past three decades. The historic goal of trauma resuscitation was restoration of vital signs to physiologic normal. Newer hemostatic centered approaches focus on adequate critical organ perfusion and tissue oxygenation until hemostasis is obtained. Expansion of prehospital resuscitation capabilities to include blood products and hemostatic agents has further facilitated this shift in approach.

Crystalloids

Crystalloid is ideal for prehospital conditions as it is inexpensive, readily available, and easily stored. Historically, an initial 2L bolus was recommended with a 3:1 replacement of estimated blood loss due to vascular redistribution of crystalloids; however, contemporary strategies minimize crystalloid use as adverse effects of excessive crystalloid are now apparent [7]. Investigation is ongoing to determine the optimal volume of prehospital crystalloid to administer

across different populations, as it remains the only resuscitation fluid available to nearly all ground based prehospital care in the US.

Permissive hypotension in the prehospital setting was popularized by Bickell and colleagues in 1994 after they demonstrated improved survival with delayed fluid resuscitation in penetrating torso trauma [8•]. Further, crystalloid volumes of > 500 mL were associated with a significant mortality increase in patients without prehospital hypotension [9]. Permissive hypotension balances establishing critical organ perfusion with limiting ongoing blood loss. A recent analysis of the Pan-Asia Trauma Outcomes Study supported this concept, adding that crystalloids are associated with poor functional outcomes along with higher mortality [10]. However, mortality rates in hypotensive patients rise when fluid resuscitation is completely restricted, particularly in blunt injury and those with prolonged prehospital times. Thus, the optimal crystalloid volume target is under investigation for cases where alternative mediums are unavailable in the field. A secondary analysis of a randomized prehospital resuscitation trial found the lowest mortality among patients receiving < 500 mL of crystalloid compared to no crystalloid or higher volumes in patients where prehospital blood products were unavailable [11].

Red Blood Cells

Prehospital blood product transfusion is becoming increasingly available; however, to date is generally in the setting of air medical or critical care transport assets. Red blood cells (RBCs) are the most common blood products administered in the prehospital setting [12]. Studies over the past few decades demonstrated the feasibility and advantage of prehospital transfusion leading to the expansion of prehospital transfusion capability [13, 14]. Several robust observational studies demonstrate modest improvement in mortality after adjusting for injury severity in both civilian and military patients [15, 16•, 17, 18]. In addition to mortality benefits, early administration of RBCs is associated with less overall blood product usage [19], which is important as type O blood necessary for trauma can be a scarce resource [20].

Plasma

Plasma, a mixture of water, salts, and various proteins, is the supernatant that remains when cells and cellular components are removed from blood. Suggested as a superior isometric buffer to crystalloids, plasma effectively restores intravascular volume. Originally, AB plasma was preferred in transfusion of untyped patients since no anti-A or anti-B immunoglobulins would be present, restricting the universal plasma donation pool to 4% of the population. However, group A plasma is now also available without typing as it demonstrates noninferiority to AB plasma and the impact of plasma ABO incompatibility on clinical outcomes is insignificant [21, 22, 23•, 24]. This lessens the supply limitation. Enthusiasm for plasma grew from the conceptual advantage of correcting coagulation deficits in hemorrhage; however, mounting evidence suggests effects on the immune system and endotheliopathy play a large role in the benefits of plasma resuscitation [25].

Two large, randomized trials were completed assessing prehospital plasma resuscitation. The multicenter Prehospital Air Medical Plasma (PAMPer) trial demonstrated a nearly 10% absolute reduction in 30-day mortality for prehospital plasma compared to standard care in patients at risk for hemorrhagic shock predominantly with blunt injury from a rural setting [26••]. In contrast, the single center Control of Major Bleeding After Trauma (COMBAT) trial showed no difference in 28-day mortality for prehospital plasma compared to standard care in an urban trauma system [27••]. Combined results from these two trials demonstrated prehospital plasma conferred a mortality benefit when transport times were longer than 20 min. Additionally, patients with blunt injuries, traumatic brain injuries, and moderate transfusion requirements receive the greatest benefit from plasma administration [28]. Additionally, the greatest benefit is realized when plasma is administered in conjunction with RBCs [11]. The Rapid Administration of Blood by HEMS in Trauma (RABBIT) trial in the Czech Republic was undertaken to confirm this finding although results have yet to be published [29].

One issue with frozen plasma is that once thawed, it must be used quickly. Plasma is considered old after just 24 h and remains viable for only 5 days. This makes it difficult to add to standard care in the prehospital setting since the need for plasma cannot be assessed early enough to allow time to thaw. A secondary analysis of the PAMPer trial demonstrated no significant difference in mortality for thawed plasma between 0 and 5 days old, improving the prehospital potential by expanding the transfusion window [30]. The ability of plasma to restore intravascular volume status makes it highly desirable in this setting and an area for future investigation. Never frozen liquid plasma is an alternative that has been adopted by many prehospital transfusion programs with shelf life of up to 21 days; however, in some areas it is not available or very limited in supply.

Platelets

Platelets are difficult to store and therefore administer in the prehospital setting. As such, data on platelet use in this setting are scarce; however, given the results from the PROPPR trial that early administration of platelets in the hospital decreases mortality, there is interest in platelet availability in the field [31]. Recently, the Mayo Clinic added platelets

to their prehospital transfusion capability with refrigeration storage to improve shelf life [32]. The most likely route of platelet availability in the prehospital setting will be as part of whole blood transfusion rather than as a unique blood product.

Adjuncts: Tranexamic Acid, Fibrinogen, and Prothrombin Complex Concentrate

Tranexamic acid (TXA), fibrinogen, and prothrombin complex concentrate (PCC) supplement transfusion in select patients to achieve hemostasis. TXA works by inhibiting fibrinolysis and is commonly used to terminate postpartum hemorrhage. The Study of Tranexamic Acid During Air and Ground Medical Prehospital Transport (STAAMP) was a randomized placebo controlled clinical trial of prehospital TXA, demonstrating a mortality benefit among patients receiving TXA within 1 h of injury and for those with severe shock (systolic blood pressure < 70) [33•]. Lack of replicated benefits in other trials has limited universal adoption in the prehospital setting [34].

Fibrinogen is the precursor to fibrin and a promoter of coagulation through fibrin aggregation. Fibrinogen is commonly transfused in Europe and the Fibrinogen in Trauma Induced Coagulopathy (FlinTIC) trial shows that fibrinogen improves clotting metrics, reduces organ failure, and improves 30-day survival when administered within 1 h of trauma [35].

PCC is a solution of clotting factors commonly administered for rapid reversal of bleeding in patients with iatrogenic or other clotting factor deficiencies. So far, only observational studies have been conducted on PCC in the prehospital setting with [36–38]. In these studies, only patients known to have high INRs or clotting deficiencies were administered PCC. There is growing interest these three adjuncts as they are easier to store and administer in the prehospital environment.

Whole Blood

Whole blood in the prehospital system is new and isolated to a few trauma systems. Whole blood has the logistical advantage in the prehospital environment of having all components (RBCs, plasma, platelets) in a single unit and thus reduces blood product storage requirements. To achieve a similar resuscitation as 1 unit of whole blood, a prehospital transfusion program would need to store 3 component units, each with differing shelf lives and storage temperature requirements.

Mayo Clinic became the first U.S. medical center to use cold whole blood in the prehospital setting in 2015. Since then, several studies were conducted or are in progress regarding whole blood transfusion in the prehospital setting. These studies have thoroughly demonstrated the safety profile of low titer group O whole blood (LTOWB) in both adult and pediatric populations [39–43]. Additionally, retrospective trials have found mortality benefits from LTOWB [44]. The Pragmatic Prehospital Group O Whole Blood Early Resuscitation Trial (PPOWER) confirmed viability of a large-scale clinical trial [45•]. The Study of Whole Blood in Frontline Trauma (SWIFT) and Type O Whole Blood and Assessment of Age During Prehospital Resuscitation (TOWAR) trials are in progress to evaluate the impact of whole blood on clinical outcomes. Recent military data have demonstrated a reduction in 6-h mortality for combat causalities receiving whole blood compared to standard component therapy [46].

There are still several challenges involved with whole blood transfusion in the prehospital setting including cost, storage, and expiration timing. While costs vary regionally, a Seattle based EMS program developed an economically feasible system with an average cost of $0.28 per mission and $1138 per transfusion [47]. A financial analysis of a Texas program predicted a $5100 total cost per life saved via whole blood [48]. Furthermore, another system operationalized whole blood administration in civilian trauma to improve accessibility and reduce waste. Their system involves storage of LTOWB units at 30 ground EMS and helicopter bases for 14 days before the unused blood is transferred to medical centers for the next 21 days prior to expiration to reduce waste. Transfusion of 450 units of LTOWB resulted in only 1–2% expiration and no prehospital complications [49, 50]. As the process of prehospital blood transfusion expands, these systems can serve as examples to be refined and expanded.

Predicting the Need for Transfusion in the Field

In trauma, deciding who will benefit from transfusion can be challenging. Many scoring systems exist to identify patients requiring transfusion after trauma, yet no score has been universally adopted [51]. Some scores rely on metrics that require inpatient testing, rendering them in-feasible in the prehospital setting, while others, including Criteria A of the Zhu et al. score and EBTNS scoring systems, are optimal for implementation in the prehospital setting [51, 52] (Table 1). Of note, the popular ABC scoring criteria requires a FAST exam with sonography which is not universally available in prehospital care. The newer BRI scoring system designed for prehospital flight management may be comparable to other high-performing prehospital scoring criteria but was not included in a recent meta-analysis comparing scoring criteria [51, 53]. Regardless of the scoring system utilized, any indication that massive transfusion will be necessary should result in rapid initiation of prehospital transfusion as earlier transfusion improves outcomes and reduces total volume

Table 1 *Left:* The EBTNS score is an example of a prehospital transfusion scoring criteria. All variables can be calculated in the prehospital environment. *Right:* The popular ABC scoring criteria, common for determining transfusion requirements in the hospital

EBTNS score			ABC score		
	Absent	Present		Absent	Present
Age 56–70 years	0	1	Systolic blood pressure ≤ 90 mmHg	0	1
Age > 70 years	0	2	Heart rate ≥ 120 bpm	0	1
Glasgow Coma Scale 3–8	0	3	Penetrating injury	0	1
Glasgow Coma Scale 9–13	0	1	Positive FAST	0	1
Heart rate < 60 bpm	0	4	Cutoff	≥ 2	
Heart rate ≥ 120 bpm	0	3			
Penetrating injury	0	2			
Systolic blood pressure < 90 mmHg	0	7			
Cutoff	≥ 6				

This scoring system requires ultrasound which is not universally available in the prehospital setting

required [54]. One active area of investigation is identifying patients with occult shock prior to decompensation.

In-Hospital

In many trauma patients, the first opportunity for resuscitation occurs on arrival at the trauma center. Approaches to transfusion for hemorrhagic shock after injury have evolved significantly over the last two decades from a 2-L crystalloid bolus followed by RBC based transfusion strategy to damage control resuscitation that emphasizes permissive hypotension, minimizing crystalloids, balanced transfusion, and early hemostasis.

Fixed Ratio Approach

The concept of low RBC to plasma ratio resuscitation first emerged from the military in 2007 [55•]. From this, numerous retrospective observational studies reported mortality improvements for patients receiving low compared to high RBC to plasma ratio resuscitation, as well as low RBC to platelet ratios. Given the potential biases of these studies the prospective observation PROMMTT study was conducted, showing reductions in early mortality for low ratio resuscitation [56•]. This culminated in the randomized PROPPR trial comparing 1:1:1 versus 1:1:2 plasma:platelets:RBC ratio transfusion strategies [57••]. The PROPPR trial found no significant difference in mortality between the two ratios; however, the 1:1:1 group had lower 6-h mortality from hemorrhage and better hemostasis. Guidelines for empiric treatment in trauma now involve transfusion of a ratio of plasma to platelets to RBCs of either 1:1:1 or 1:1:2 [58]. Methods to improve standardization and execution of the MTP are constantly being developed [59].

Massive Transfusion Protocols

The rise of 1:1:1 transfusion strategies gave birth to massive transfusion protocols (MTP) as a way for trauma centers to logistically execute low ratio transfusion strategies. Time to transfusion initiation is critical in these situations as time saving measures such as availability of blood products in the trauma bay are associated with superior outcomes [60]. MTP mobilize the resources to initiate large volume balanced transfusion, and now often incorporate initiation of other resuscitation adjuncts such as TXA. Some authors have suggested the implementation of an MTP with aggressive resuscitation may matter as much as the actual blood product ratio achieved.

A key component of the MTP is when to activate it. As in the prehospital setting, scores have been developed to aid with this assessment, and analysis of their performance demonstrates reliability although no single score has been universally adopted [51, 61•, 62]. The ABC score is one of the most common, comprised 1-point assigned for penetrating injury, hypotension, tachycardia, and a positive FAST examination (see Table 1). The American College of Surgeons guidelines from 2014 recommend using an ABC score cutoff of 2 as this identifies more than 95% of patients requiring massive transfusion [58]. In many scoring criteria, hemorrhagic shock, systolic blood pressure < 70, and severe tissue injury are included as important risk factors, although hematocrit may be the most accurate predictor [63]. Other important criteria for massive transfusion protocol activation include persistent hemodynamic instability, active bleeding unable to be controlled with noninvasive techniques, and

blood transfusion in the trauma bay. Methods to improve standardization and execution of the MTP are constantly being developed [59].

Thromboelastometry Guided Approach

An alternative to the fixed ratio MTP approach is point of care testing with personalized treatment recommendations, based on thromboelastography (TEG). The Strategy of Transfusion in Trauma (STATA) trial looked at the MTP vs TEG based resuscitation and found no additional harm from using TEG in a preliminary report [64]. Final results of the trial have yet to be published. TEG based resuscitation is a measure of hemostasis and can inform transfusion decisions of additional products tailored towards specific hemostatic deficiencies. Some small studies suggest TEG based transfusion strategy is superior to fixed ratio transfusion; however, systematic reviews failed to show reduced mortality, morbidity, or blood product usage in trauma [65, 66]. Most centers take a strategy of initial low fixed ratio transfusion with activation of MTP and switch to a viscoelastic guided resuscitation to tailor transfusions and reduce blood product requirements (Table 2).

Individual Product Considerations

A variety of blood products and adjuncts are available for resuscitation of the bleeding trauma patients. Each has unique advantages, disadvantages, and logistical considerations. Additionally, supply and demand, as well as cost issues may affect the local availability and practice patterns.

Red Blood Cells

The importance of blood transfusion in trauma has been established for over a century, yet novel innovations continue to improve outcomes. RBCs are transfused in units of 225–350 mL with hematocrit of 65–80% that are intended to raise the Hgb by 1 g/dL. Trauma patients requiring transfusion receive type O blood (O Rh- in women of childbearing age) initially until blood screen results are available. Any additional transfusion should be appropriately typed to preserve type O blood for acute transfusions.

One concern with RBC usage is storage. The Red Cell Storage Duration Study (RECESS) in cardiac surgery patients and the Age of Blood Evaluation (ABLE) in critically ill adults altered the conception that increased RBC age is associated with worse outcomes as those studies found no benefit of using newer RBCs [67, 68]. These findings alleviated some of the storage concerns. Availability is another concern. RBC transfusions have steadily declined since 2008, but so has collection of RBCs. The rate of decline in transfusion recently slowed, suggesting the donation level cannot continue to decline [69, 70]. Unfortunately, the number of individual donors decreased by 8.5% from 2017 to 2019, with repeat donors decreasing by over 14% [71]. This trend will be monitored to assess whether a shortage is imminent.

Contemporary RBC transfusion research is focused on developing novel storage processes, improving leukoreduction methods and exploring techniques for freeze drying and lyophylized products to expand access.

Plasma

Plasma has several benefits during resuscitation including replenishing coagulation factors, protecting the endothelium during hemorrhagic shock, increasing fibrinogen, restoring physiologic pH, and expanding intravascular volume. According to the 2019 National Blood Collection and Utilization Survey (NBCUS), one unit of fresh frozen plasma or plasma frozen between 8 and 24 h of administration (PF24) costs an average of $50, which is largely unchanged from 2017. The amount of plasma distributed declined from

Table 2 Thromboelastogram interpretation and subsequent treatment recommendations

Thromboelastogram (TEG)				
Components	Definition	Normal values	Problem with	Treatment
R time	Time to start forming clot	5–10 min	Coagulation factors	FFP
K time	Time until clot reaches a fixed strength	1–3 min	Fibrinogen	Cryoprecipitate
Alpha angle	Speed of fibrin accumulation	53–72 degrees	Fibrinogen	Cryoprecipitate
Maximum amplitude (MA)	Highest vertical amplitude of the TEG	50–70 mm	Platelets	Platelets and/or DDAVP
Lysis at 30 min (LY30)	Percentage of amplitude reduction 30 min after maximum amplitude	0–8%	Excess fibrinolysis	Transexamic acid and/or aminocaproic acid

Adapted with permission from *Rebel Reviews (*https://rebelem.com/rebel-review/rebel-review-54-thromboelastogram-teg/thromboelastogram-teg/*)*

3,209,000 to 2,679,000 units (16.5%) and the amount transfused declined from 2,374,000 to 2,185,000 units (8%) over the same time period [71]. AB plasma transfusion declined from 341,000 units in 2017 to 255,000 units in 2019, possibly in part due to evidence that group A plasma is safe to use in most cases [22, 71]. Despite the potential benefits, plasma availability is severely limited by logistic concerns. Short shelf life, long time to thaw, and access difficulty in remote areas contribute to less-than-optimal transfusion rates.

Storing thawed plasma in the ED enables rapid transfusion initiation, decreases transfusion quantities of RBCs, plasma, and platelets, and is an independent predictor of reduced 30-day mortality [72]. Thawed plasma banks, like that of the University of Medicine Greifswald in Germany, may alleviate part of the issue by improving accessibility and reducing waste [73]. In their center, total plasma use declined by 66.7% over a decade likely due to the reduction in downstream plasma requirements with timely transfusion.

Platelets

Platelet transfusion, while supported by the PROPPR trial, has been the subject of investigation due to questionable efficacy [31, 74, 75]. A recent observational analysis of a French trauma registry from 2011 to 2019, however, backed the PROPPR results, demonstrating a significant reduction in 24 h mortality with early platelet transfusion [76]. Additional analysis is necessary to evaluate platelet efficacy in the hospital setting.

Adjuncts: TXA, Fibrinogen, PCC

TXA is commonly used in elective surgery to control bleeding. The Clinical Randomization of an Antifibrinolytic in Significant Hemorrhage (CRASH-2) trial found TXA significantly improved survival in patients with known or suspected hemorrhage after trauma [77••]. The follow-up CRASH-3 trial looking specifically at patients with head trauma found largely unimproved mortality in patients receiving early TXA, apart from a subgroup with moderate head injury and evidence of intracranial hemorrhage [78].

In line with the FlinTIC prehospital study, several studies have suggested a benefit of early fibrinogen administration after arrival at the hospital [79–83]. A meta-analysis is currently underway to evaluate the evidence for fibrinogen in this context [84].

PCC is also useful in the early management of bleeding patients for treating trauma induced coagulopathy and reducing the need for MTP [85, 86]. PCC may also be useful as an adjunct of fresh frozen plasma (FFP) for INR reversal after trauma [87]. The randomized PROCOAG trial was undertaken to test PCC as an alternative to FFP in trauma, although the results are not yet available.

Whole Blood

Whole blood was first transfused in the 1800s and made significant strides during World War 1 with the increased incidence of trauma. Early success and innovation in preservation techniques led to the establishment of blood banks and transfusion centers across the United States and Europe. In 1940, Edwin Cohn established the first technique for fractionation of blood into blood products. This method was an efficient way to distribute blood causing a shift from whole blood transfusion to blood product transfusion, especially in civilians. However, whole blood transfusion persisted in the military where fractionated products are hard to store and administer. Recent analysis demonstrating efficacy in military trauma renewed interest in whole blood viability for civilian trauma [46, 88].

Whole blood is quickly becoming the preferred transfusion medium in many trauma centers as studies continue to have promising results [23, 45, 89–91]. A recent large multicenter prospective observational study showed a survival benefit of whole blood resuscitation at 24 h and persisting to 60 days [92•]. Several meta-analyses and retrospective reviews exist with results favorable for whole blood administration, yet each emphasizes the need for additional studies to draw definitive conclusions [93–96]. The true efficacy, however, remains under investigation as thus far mostly pilot studies focused on safety or noninferiority are available. These promising results along with benefits observed in military studies convinced many centers to switch to whole blood already.

A few clinical trials are underway to assess the impact on outcomes of trauma center resuscitation with whole blood including the prehospital SWIFT and TOWAR trials and the trauma center-based Evaluation of a Transfusion Therapy Using Whole Blood in the Management of Coagulopathy in Patients with Acute Traumatic Hemorrhage (T-STORHM) in France and the Low-Titer O Positive Whole Blood Versus Component Therapy for Emergent Transfusion in Trauma Patients at Loma Linda University. These studies may provide additional clarity on appropriate use of whole blood transfusion; however, the rapid uptake of whole blood as standard care may deter a definitive large scale multicenter randomized trial if centers are unwilling to revert to a component-based transfusion strategy for hemorrhage after trauma (Fig. 1).

Transfusion Complications

Transfusion, while an effective measure to save lives, is not risk-free, especially massive transfusion for trauma. Complications of transfusion include hypothermia, coagulopathy,

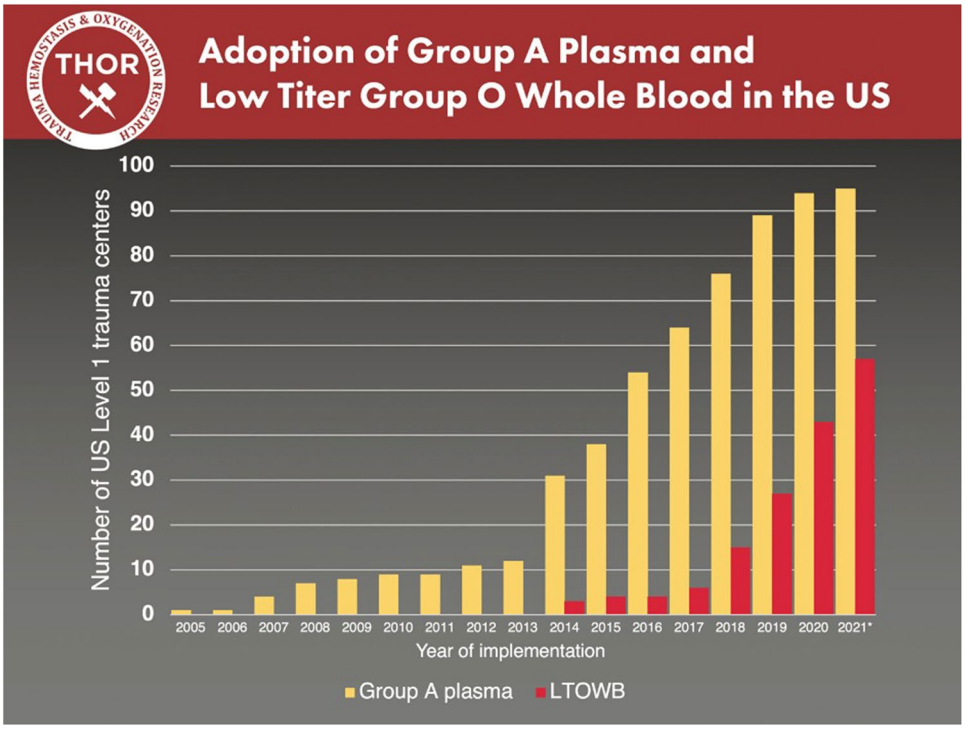

Fig. 1 Whole blood and group A plasma usage in level 1 trauma centers over time. Over the past several years, whole blood and group A plasma have boomed in popularity as the resuscitation product of choice in severe traumatic hemorrhage. Reproduced with permission from *Transfusion* Vol. 61, No. S1, July 2021

thrombocytopenia, electrolyte abnormalities, acid–base disorders, infection, transfusion related acute lung injury, and transfusion associated circulatory overload. In a 2021 UK based study, 12.2% of complications were deemed non-preventable while 81.3% were preventable errors and 6.5% were possibly preventable demonstrating the room for improvement [97].

Disease transmission, one of the most feared transfusion complications during the HIV epidemic, has decreased more than 10,000-fold due to established safety guidelines and better practices [98]. However, other transfusion reactions have been more difficult to address. Transfusion reactions are categorized as acute or delayed depending on whether they occur within 24 h from transfusion initiation. The risk of adverse transfusion reactions (ATRs) is under investigation as these events are possibly preventable and result in increased morbidity but rarely mortality. ATR incidence varies with transfusion medium and is lowest for RBCs and highest for platelets, although use of whole blood derived platelets may result in less adverse reactions than apheresed platelets [97, 99, 100].

Leukoreduction or leukodepletion has successfully diminished the prevalence of specific transfusion reactions. Leukoreduction involves filtration and removal of white blood cells from blood or blood products to reduce the frequency of febrile nonhemolytic transfusion reactions, reduce CMV transmission, and reduce HLA rejection along with several other proposed benefits [101–103]. In the United States, the FDA regulates leukocyte concentration in blood. Strategies such as double filtration, pre-storage leukoreduction, and filtration in cold rather than room temperature show promise for improving the technique [104–106]. As these processes continue to improve, the hope is that transfusion will retain maximum benefit while the risk is minimized. Many ATRs remain difficult to predict and preemptively diminish so treatment is primarily supportive [107].

Conclusion

Transfusion critically impacts survival in trauma patients. Mounting evidence for the importance of time to transfusion coupled with organizational and technological advances led to an emergence of prehospital transfusion of blood products over the past few years. At the same time, a relative boom of whole blood transfusion resulted from effectiveness in military studies and demonstrated superiority of balanced resuscitation. Increasing availability of plasma, improving operationality and storage capabilities for blood products, including adjunctive transfusion mediums, and developing individually tailored resuscitation strategies with thromboelastography are other recent improvements. Freeze-dried or lyophilized products are under active investigation. The extent of these recent advances highlights the degree to which transfusion in trauma is evolving to optimize patient care.

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