Use of Dried Plasma in Prehospital and Austere Environments

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The importance of early transfusion for patients with hemorrhagic shock, particularly early administration of plasma in proportion with red cells, has become widely recognized during the past decade.[1,2] Recent studies have demonstrated survival benefit when transfusion is initiated before arrival at the trauma center. A retrospective study of more than 500 military casualties found that mortality was reduced when transfusion was initiated prehospital (mortality hazard ratio, 0.39; 95% CI, 0.16 to 0.92).[3] A multicenter, prospective, randomized study of 501 civilian trauma patients with hemorrhagic shock demonstrated that plasma administration during helicopter transport reduced mortality by approximately one third (23.2% *vs.* 33.0%, $P = 0.03$).[4] However, a similar single-center study in a system with rapid ground transport found no survival benefit for prehospital plasma.[5] This apparent discrepancy was addressed in a *post hoc* analysis, which found that when prehospital transport time was greater than 20 min, mortality increased in patients that received crystalloid-based resuscitation (hazard ratio, 2.12; 95% CI, 1.05 to 4.30; $P = 0.04$) but not when patients received plasma (hazard ratio, 0.78; 95% CI, 0.40 to 1.51; $P = 0.46$).[6]

It is not surprising that a number of centers have incorporated prehospital transfusion into their emergency medical system protocols.[7,8] However, logistical requirements limit out-of-hospital transfusion. Fresh frozen plasma (FFP) must be stored at −18°C, takes approximately 30 min to thaw, must be stored refrigerated, and has a shelf-life of only 5 days after thawing. Additionally, carrying thawed FFP on helicopters can be expensive.[9] Adams *et al.*[9] found that the main cost drivers were delivery, storage, and inventory management at helicopter bases and that helicopter crews transfused just 7% of the supplied FFP. Overall, it appeared that the challenges were greater the further the helicopter base was from the supporting blood center. Constraints related to use of FFP in the prehospital setting also limit its use in austere environments, as may be encountered in humanitarian assistance operations or natural disasters.[10] Although not yet widely available, lyophilized plasma offers advantages that could enable the broader use of plasma for prehospital transfusion.[9,10]

Lyophilized plasma (also called freeze-dried plasma) is produced by freezing and sublimation of plasma in a process that takes several days. Coagulation factor levels remain within the normal range after lyophilization, with minimal changes (generally less than 10%) from the frozen starting plasma.[11] Lyophilized plasma appears in the glass bottle as a lyophilized cake, crumble, or powder. Dried plasma for medical use was first developed in the 1930s, and millions of units were used during World War II.[11] While viewed as effective for resuscitation and transfusion, lyophilized plasma was largely abandoned by the 1960s due to the risk of hepatitis and other disease transmissions.[12] By the 1990s, pathogen reduction, screening, and testing methodologies made the production of safe and effective lyophilized plasma possible, and modern products have been available in France, Germany, and South Africa since then.[11,13–15] However, dried plasma is not available in most countries, including the United States.[10,16] As of this writing, there are three commercially available lyophilized plasmas, which are available in their respective countries and in limited others.

In France, the French Army Blood Transfusion Center reestablished lyophilized plasma production in 1991. They currently produce a pooled, ABO-universal, pathogen-reduced lyophilized plasma (table 1).[13] In the early 1990s, the German Red Cross developed a pathogen-reduced, pooled lyophilized plasma, which was used through 2006 (table 1). In 2007, the German Red Cross stopped pooled plasma production and began producing LyoPlas N-w, a single-donor (each produced unit is from a single donor) lyophilized plasma, due to the risk of Creutzfeldt–Jakob disease transmission.[14] Since 2007, 450,000 units of Lyoplas N-w have been distributed.[19] Bioplasma FDP (National Bioproducts Institute, South Africa), a pooled, pathogen-reduced, ABO-universal lyophilized plasma, has been in use in South Africa since 1996 (table 1).[11] These products generally have the same

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Table 1. Characteristics of Commercially Available Lyophilized Plasmas

	French Lyophilized Plasma	LyoPlas N-w	Bioplasma FDP
Manufacturer	The French Military Blood Institute (Centre de Transfusion Sanguine des Armées)	German Red Cross (DRK-Blutspendedienstes West)	National Bioproducts Institute
Country of manufacture	France	Germany	South Africa
How supplied	Volume: 200 ml; glass bottle containing lyophilized plasma; glass bottle containing water for injection; transfer set for reconstitution; transfusion set	Volume: 200 ml; glass bottle containing lyophilized plasma; bag containing water for injection; transfer set for reconstitution; transfusion set that allows reconstituted plasma to be transfused either from the bottle or from the bag	Volume: 200 or 50 ml; glass bottle containing lyophilized plasma; glass bottle containing water for injection; transfer set for reconstitution
Pooled or single unit	Pooled (< 11 donor units/lot)	Single donor	Pooled (≤ 1,500 donor units/lot)
Pathogen reduction	Amotosalen Pathogen Reduction (INTERCEPT System, Cerus Corporation, USA)	None	Solvent/detergent pathogen reduction
Blood type	ABO-universal	ABO type–specific	ABO-universal
Hemovigilance programs	> 1,100 units (2003–2013); no adverse events reported[13]	> 300,000 units solvent/detergent LyoPlas (through 2006); > 230,000 units LyoPlas N-w (2007–2013); no increase in adverse events compared to FFP[14]	372,485 units (1996–2006); no increase in adverse events compared to FFP[15]
Indications for use	Same as frozen plasma	Same as frozen plasma	Same as frozen plasma Contraindicated: Severe Protein S deficiency
Shelf-life and storage	2 yr at room temperature; use within 6 h after reconstitution	15 months at 2 to 25°C; use within 6 h after reconstitution	2 yr stored at < 25°C; use immediately after reconstitution
Reconstitution	< 6 min	Approximately 5 min	< 10 min
Production	Central production facility	Central production facility	Central production facility
Availability	Military and limited civilian use (France and limited availability for U.S. Military)	Military and general population (Germany and selected other countries)	General population (South Africa and selected other countries)

FFP, Fresh frozen plasma.

indications for use as other forms of plasma or pathogen-reduced plasma (table 1). Dried plasmas are prepared for use by adding the supplied reconstitution fluid into the bottle containing the plasma. The mixture is gently swirled and ready for infusion through a standard transfusion set and filter within 5 to 10 min. The standard sizes are 50 and 200 ml.[11] The current cost of lyophilized plasma is usually approximately two to three times more than frozen plasma.

New dried plasma products are being developed by several companies for licensure in the United States and other countries. Vascular Solutions, LLC, a subsidiary of Teleflex Inc. (USA) is developing a lyophilized single-donor plasma (EZPLAZ) that is intended to be packaged in a flexible blood bag.[16] This product is under review by the U.S. Food and Drug Administration (Silver Spring, Maryland) at the time of the writing of this article (October 2021).[20] Resusix, a pooled, solvent/detergent pathogen-reduced, spray-dried, universal plasma is being developed by Entegrion Inc. (USA) and is also proposed to be delivered in a bag.[16] Spray drying involves atomizing (fine spray) the plasma and brief exposure to a stream of hot, dry gas.[11] Octapharma (Switzerland) is developing a lyophilized solvent/detergent pooled plasma product, proposed to be packaged in glass bottles (Octaplas Lyo; Oliver Hegener, Ph.D., International Business Unit Critical Care, Octapharma AG, Lachen, Switzerland, August 2021, verbal communication). EZPLAZ, Resusix, and Octaplas Lyo are designed to be produced under centralized models. A spray-drying device and proprietary bag system (Frontline ODP System) for blood centers to produce spray-dried, single-donor plasma (decentralized model) is being developed by Velico Medical (USA).[16, 21–23] A phase I clinical trial has recently been approved for the Frontline ODP System.[24] Terumo BCT (USA) is developing a device for blood centers to make pooled (mini-pools, 10 donors) lyophilized plasma, also using a bag system.[16,25] EZPLAZ, On-Demand Plasma, and the Terumo BCT lyophilized plasma are expected to be ABO type–specific, while Octaplas Lyo and Resusix are projected to be universal. Because processing methods potentially impact the function and safety of any specific dried plasma (current or future), it will be important for the clinician to consider the characteristics (*e.g.*, method of drying, pathogen reduction, ABO type specificity) of any specific product.[11] With the potential for dried plasma to become more widely available in the near future, it is useful to understand current trends in use of lyophilized plasmas.

Update of Current Use

Early published experiences with modern lyophilized plasmas were in-hospital.[14,26,27] After initial case reports of military prehospital lyophilized plasma use, medical services (civilian and military) in several countries adopted lyophilized plasma for treatment of patients with trauma and hemorrhagic shock at the point of injury and during transport.[28–38] Thies *et al.*[8] found that 17% of European emergency medical systems had access to lyophilized plasma for prehospital use between 2016 and 2017 and suggested that

this number may be increasing. Published reports have documented more than 600 patients who have received lyophilized plasma in prehospital and austere settings (table 2).

French Lyophilized Plasma

Among 87 patients transfused with French lyophilized plasma in a French hospital in Afghanistan during 2010 and 2011, prothrombin time was improved (from 20.0 ± 9.1 s to 16.7 ± 4.0 s; $P < 0.01$), with no transfusion reactions.[13,26] A retrospective study examined patients at a level 1 trauma center who required at least 2 units of red blood cells after trauma and compared patients who also received FFP (n = 29) to patients who also received French lyophilized plasma (n = 43). Time to receive red cells was similar between groups, but patients transfused with dried plasma received plasma earlier (15 *vs.* 95 min; $P < .01$) and maintained a higher plasma:red cell transfusion ratio through 6 h, with reduced overall transfusion requirements, compared to patients that received FFP.[48] Garrigue *et*

Table 2. Published Reports of Lyophilized Plasma Use in Prehospital and Austere Environments

Citation	Product	Patients Treated with Lyophilized Plasma	Civilian of Military Care Providers	Comment
Glassberg *et al.* (2013)[35]	LyoPlas N-w	1*	Israeli military	Use of lyophilized plasma for point of injury transfusion in Israel. No transfusion-related adverse events reported.
Gokhale *et al.* (2014)[33]	LyoPlas N-w	1	British military	Use of lyophilized plasma in forward resuscitation in Afghanistan. No transfusion-related adverse events reported.
Gellerfors *et al.* (2015)[31]	LyoPlas N-w	1	Swedish military	Lyophilized plasma use for patient in Afghanistan. No transfusion-related adverse events reported.
Rottenstreich *et al.* (2015)[32]	LyoPlas N-w	1*	Israeli military	Prehospital intraosseus lyophilized plasma transfusion in pediatric patient. Syrian patient. Location not reported.* No transfusion-related adverse events reported.
Sunde *et al.* (2015)[29]	LyoPlas N-w	16 (includes 7 nontrauma)	Norwegian civilian	Use of lyophilized plasma in prehospital patients in Norway. No transfusion-related adverse events reported.
Shlaifer *et al.* (2017)[39]	LyoPlas N-w	109*	Israeli military	Prehospital use of lyophilized plasma in Israel and selected areas of regional conflict. Reported chills and shivering in one patient, which stopped when lyophilized plasma transfusion was discontinued.
Vitalis *et al.* (2018)[37]	French lyophilized plasma	7	French military	Prehospital use of lyophilized plasma in casualties in the Sahel. No transfusion-related adverse events reported.
Benov *et al.* (2019)[40]	LyoPlas N-w	75*	Israeli military	Patients treated with prehospital lyophilized plasma at the Syrian border. No transfusion-related adverse events reported.
Nadler *et al.* (2019)[41]	LyoPlas N-w	33*	Israeli military	Use of lyophilized plasma for prehospital resuscitation of traumatized Israeli, Palestinian, Syrian, and other pediatric patients in Israel and selected areas of regional conflict. Identified need for pediatric guidelines. No transfusion-related adverse events reported.
Oakeshott *et al.* (2019)[42]	LyoPlas N-w	216	British civilian	Helicopter emergency medical service prehospital use of lyophilized plasma over 20 months in England. No transfusion-related adverse events reported.
Shlaifer *et al.* (2019)[43]	LyoPlas N-w	48*	Israeli military	Retrospective study of patients that received prehospital lyophilized plasma *versus* patients that did not in Israel and selected areas of regional conflict. No transfusion-related adverse events reported.
Travers *et al.* (2019)[44]	French lyophilized plasma	25	French military	Use of lyophilized plasma in patients in the Sahel (5 prehospital). No transfusion-related adverse events reported.
Cuenca *et al.* (2020)[45]	French lyophilized plasma	11	U.S. military	Prehospital use of lyophilized plasma primarily in Afghanistan and Iraq. No transfusion-related adverse events reported.
Fisher *et al.* (2020)[46]	French lyophilized plasma	3†	U.S. military	Prehospital use lyophilized plasma near the point of injury primarily in Afghanistan and Iraq. No transfusion-related adverse events reported.
Vuorinen *et al.* (2020)[30]	LyoPlas N-w	18	Finnish civilian	Prehospital administration of lyophilized plasma and other blood products in Finland. No transfusion-related adverse events reported.
Ångerman *et al.* (2021)[38]	LyoPlas N-w	99 (includes 25 nontrauma)	Finnish civilian	Prehospital use of lyophilized plasma in Finland. No transfusion-related adverse events reported.
Cordier *et al.* (2021)[17]	French lyophilized plasma	1	French military	Prehospital use of lyophilized plasma in France. No transfusion-related adverse events reported.
Nadler *et al.* (2021)[47]	LyoPlas N-w	206	Israeli military	Lyophilized plasma for prehospital resuscitation for traumatic hemorrhage in Israel and selected areas of regional conflict. No transfusion-related adverse events reported.
Tsur *et al.* (2021)[18]	LyoPlas N-w	35*	Israeli military	Prehospital use of lyophilized plasma in Israel and selected areas of regional conflict. No transfusion-related adverse events reported.

A total of more than 600 patients were included. LyoPlas N-w (German Red Cross, Germany).

*May include patients reported by Nadler *et al.* (2021).[47] †Includes patients reported by Cuenca *et al.* (2020).[42]

al.[49] conducted a prospective randomized study and found that severely injured patients who were transfused with up to 4 units of French lyophilized plasma (reconstituted at bedside) received plasma sooner (14 *vs.* 77 min; $P < .01$) and maintained a higher plasma:red cell ratio than patients who received up to 4 units of FFP (ordered from the blood bank), with no adverse reactions.

Reports of the use of French lyophilized plasma in prehospital and austere environments have also been promising.[37,44–46] Vitalis *et al.*[37] reported the experience from a French Military Health Service in the Sahel region of Africa. French lyophilized plasma was provided to field medical teams located near the point of injury (combat rescue, combat medics), and this was augmented with red blood cells during medical evacuation (nurse, emergency physician) and other products at medical treatment facilities. Vitalis *et al.* reported that 7 of 28 severely injured casualties received a total of 22 units of French lyophilized plasma in the prehospital setting during the first year, which reduced time to the first transfusion without increasing transport time.[37] Two failures of lyophilized plasma reconstitution were reported and determined to be due to user error. No transfusion-related complications were reported.[37] A follow-up report identified 10 patients that received a total of 12 units of French lyophilized plasma before reaching a forward surgical team and twenty patients who received a total of 63 units at the forward surgical team (small surgical team operating in tents or available shelters), along with other blood components.[44] There were no transfusion-related adverse reactions. One report of failure to reconstitute was believed to be due to improper reconstitution procedures. The United States has also used French lyophilized plasma in military operations, with prehospital transfusion of 11 patients reported.[45,46] Similar to French reports, ease of storage and rapid availability for transfusion were viewed as advantageous. The authors noted the importance of specific training on reconstitution procedures for emergency personnel.

LyoPlas N-w

Hemovigilance data collected from 2007 to 2011 documented that more than 230,000 units of LyoPlas N-w were distributed to German facilities, compared to approximately 343,000 units of FFP, with similar rates of transfusion reactions (LyoPlas N-w, 0.023%; FFP, 0.018%).[14] A retrospective analysis of 109 trauma patients treated in Israel found that prehospital administration of LyoPlas N-w was feasible and safe (one mild reaction that ceased when transfusion stopped).[39] In five (4.6%) cases, prehospital teams reported difficulties with lyophilized plasma administration despite proper reconstitution and no visual particles in the fluid. The difficulties included slow or no flow even after vascular access change, possibly owing to an inability to transfuse the product with pressure from the glass bottle.[39] The largest study of prehospital use of lyophilized plasma reported to date was an observational study in which LyoPlas N-w was administered by helicopter emergency medical crews in the United Kingdom.[42] In that study, 216 patients transported after LyoPlas N-w was added to the prehospital transfusion protocol were compared to patients transported the year before, when prehospital transfusion was limited to red blood cells. Prehospital LyoPlas N-w and red cell transfusion was feasible in a 1:1 ratio and was associated with reduced red cell transfusion requirements and time to first transfusion.[42] In a retrospective database analysis of the experience of a helicopter emergency medical system in Finland, 74 patients with traumatic hemorrhage and 25 patients with hemorrhage not related to trauma received LyoPlas N-w as part of prehospital transfusion with no reported transfusion-related adverse events.[38] In a retrospective study of 33 pediatric trauma patients who were treated for hemorrhagic shock with LyoPlas N-w at the point of injury (one *via* intraosseous infusion), no transfusion-related reactions or technical difficulties were noted. Although a need for specific pediatric protocols was identified, it was concluded that in the prehospital scenario, LyoPlas N-w could be used safely and effectively for injured children.[41] Seventy-five Syrian patients who arrived at the Syrian–Israeli border between 2013 and 2017 with trauma and hemorrhagic shock were treated with prehospital LyoPlas N-w, with no adverse events or administration difficulties noted.[40] Most recently, a retrospective cohort study compared 48 patients who received prehospital LyoPlas N-w to 48 patients who did not and documented improved international normalized ratio among patients that received freeze-dried plasma, with no adverse effects or technical difficulties reported.[43] In the first 5 yr after the Israeli Defense Force adopted lyophilized plasma as the resuscitation fluid of choice for prehospital treatment of patients with hemorrhage, 206 patients were treated with LyoPlas N-w with no adverse events reported.[47] Currently, all Israeli military ground and air ambulances carry LyoPlas N-w, and each military advanced life support provider (physician/paramedic) carries two units (type AB) in his/her tactical vest.[47] Civilian ambulances in Israel carry lyophilized plasma for use only in remote areas. LyoPlas N-w is not currently used in hospitals in Israel.

The Central Military Hospital in Koblenz, Germany, which serves both civilian and military populations, has used Lyoplas N-w for more than 10 yr for the same indications as FFP. Due to its ease of storage and use, it is most often used in the trauma room, where a so-called "trauma bag" from the blood bank is filled with 4 units of red blood cells and 4 units of LyoPlas N-w (type AB). In the years 2010 to 2020, approximately 90% of LyoPlas N-w use was for major trauma and approximately 10% was for internal medicine, primarily for severe gastrointestinal bleeding. The hospital massive transfusion protocol recommends lyophilized plasma use with other blood products (1:1 ratio with red blood cells), as well as with coagulation factors

(*e.g.*, fibrinogen concentrate, which is commonly used for trauma resuscitation in Germany and Austria[51]) for patients with severe traumatic hemorrhage, especially those with need for massive transfusion or more than 4 units of red blood cells in the initial hours after trauma (trauma room, operating theater, stabilization phase in intensive care unit). While LyoPlas N-w is used interchangeably with FFP, a limitation is that in most locations, the supply of LyoPlas N-w is less than that of FFP, and therefore, it is primarily used only when treatment time is a factor.

In military operations, the German Armed Forces Medical Service has used LyoPlas N-w for many years, mostly in deployable hospitals during military operations. Because of the superior logistical characteristics of LyoPlas N-w with respect to transport, storage, and rapid preparation, FFP is not used in the deployed setting. LyoPlas is viewed by the German Military as equivalent to FFP in terms of safety and efficacy. Recent *in vitro* studies documented product stability under field conditions, confirming suitability for prehospital and austere environments.[52,53]

Bioplasma FDP

Since 1996, Bioplasma FDP has been used in South Africa.[15] Just 48 adverse events were documented after transfusion of 372,485 bottles of Bioplasma FDP from 1996 to 2006 in a formal hemovigilance program.[15] The data also showed an approximately 80% reduction in transfusion-related adverse events with BioPlasma FDP, compared to FFP.[15] Consensus guidelines for blood management in South Africa state that the product is used interchangeably with FFP in all types of patients, including those with significant blood loss, such as may result from trauma or postpartum bleeding.[54,55] In some locations in South Africa, such as KwaZulu-Natal (especially at rural hospitals), Bioplasma FDP is the primary plasma used. The safety and efficacy of Bioplasma FDP (n = 23) was compared to fresh dried plasma (n = 20; without pathogen reduction) in a prospective single-blinded trial in patients undergoing cardiopulmonary bypass. Plasma was transfused primarily for blood volume augmentation and excessive bleeding. There were no differences between groups in either physiologic or coagulation parameters, and there were no adverse events.[27] Retrospective studies have also reported transfusion of lyophilized plasma during initial trauma resuscitation, during damage control surgery, and in the intensive care unit.[56,57] To date, there have been no reports of prehospital administration of Bioplasma FDP.

Discussion

Several studies provide evidence of the therapeutic benefits of early transfusion of plasma and platelets in addition to red cells for resuscitation from traumatic hemorrhage,[1,2] thus effectively reconstructing whole blood.[58] However, practical constraints can limit the ability of emergency medical systems to administer plasma in the out-of-hospital setting. Similarly, whether in conflict or for humanitarian purposes, military operations often involve significant limitations on the ability to distribute standard blood products, combined with urgent need. Military medical departments of several nations were early adopters of modern lyophilized plasma.[13,14,34,59] Shortly thereafter, civilian emergency medical systems and trauma centers began adopting lyophilized plasma for use in the initial treatment of severe hemorrhage.[29,30,38,42,56,57] The growing level of civilian interest is reflected by the fact that the largest single report to date was for prehospital use of lyophilized plasma in a civilian helicopter emergency medical system.[42] At some hospitals, lyophilized plasma is the primary plasma provided and has been very successful, which raises the prospect that wider availability of lyophilized plasma may extend capabilities for small hospitals that have neither an in-house nor a nearby supporting blood bank.

Publicly available sources document that well over 1,000,000 units of lyophilized plasma have been distributed since the 1990s, with safety data comparable to that for frozen plasma.[13–15,19] Since 2013, published reports have included more than 600 uses of lyophilized plasma for patients in prehospital and austere environments (table 2). However, large prospective clinical trials have not been conducted with lyophilized plasma, either for in-hospital or out-of-hospital use.[60,61]

Hospital transfusion services face a number of challenges with using frozen plasma. FFP requires frozen storage (–18°C), takes approximately 30 min to thaw, and must be ABO type–matched.[62] Once thawed, plasma must be refrigerated and transfused within 5 days.[62] Stocking thawed plasma for emergencies is effective but complicates inventory management. Coagulation factors, cytokines, and microparticle content vary significantly among FFP units, with two- to three-fold concentration variability for some coagulation factors and implications for both factor replacement and transfusion reactions.[50,63] Unit-to-unit variability is reduced by pooling, but this necessitates pathogen reduction, with associated additional equipment and cost.[63,64] Specific product attributes determine the degree to which dried plasmas address challenges related to FFP (table 1). Room temperature storage and rapid reconstitution provide advantages in storage and inventory management for all dried plasmas. Pooled, pathogen-reduced lyophilized plasmas (Bioplasma FDP, French lyophilized plasma) have improved unit-to-unit consistency and are also ABO-universal. Additionally, solvent detergent treatment, as used in Bioplasma FDP, removes microparticles.[65] Single-donor dried plasmas, such as LyoPlas N-w, have unit-to-unit variability similar to FFP. Based on final product specifications, future dried plasmas can be expected to offer benefits consistent with current pooled or single-donor products, respectively.

Published reports suggest growing international recognition that lyophilized plasma can be a safe and effective alternative to FFP. Where available, lyophilized

plasma is considered interchangeable with FFP.[13,14,34,54,55,59] Lyophilized plasma is generally preferred when logistical issues are important, such as in austere environments or rural settings, or when speed of use/availability is an important factor, such as traumatic hemorrhage, perioperative hemorrhage, postpartum hemorrhage, or substantial gastrointestinal bleeding. Cold-chain requirements are challenging for humanitarian or military operations, and FFP bag breakage can be significant.[66] These issues are alleviated by lyophilized plasma. Although glass bottle packaging has been successful for lyophilized plasma, there are some limitations. Plastic bag or other breakage-resistant systems are potentially beneficial.[16,67]

In different countries and situations, prehospital medical personnel may have different levels of training. Therefore, the scope of practice, training, and supervision requirements should be clearly defined for each situation. As various organizations have implemented prehospital lyophilized plasma, misunderstandings regarding reconstitution procedures have been reported, highlighting the importance of training. Another factor is the balance between cost and availability. Even in countries where lyophilized plasma is available, it is not as widely available as FFP and is generally more expensive. However, cost differences are such that advantages of lyophilized plasma in terms of storage requirements, inventory management, reduced waste, and rapid availability can make it a cost-effective option.

Conclusions

Lyophilized plasma has coagulation factor and related protein concentrations that are similar to standard plasma products and, for pooled lyophilized plasmas, less variable. Published reports of use and hemovigilance data suggest that currently available lyophilized plasmas have similar efficacy and safety to their counterpart frozen products. The growing recognition of the potential application of lyophilized plasma when other plasma products are not available in a clinically timely manner will likely lead to the expanded use of dried plasma products when they become more widely available. However, attention should be paid to training requirements and the need for prospective clinical trials to extend safety and efficacy data.

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