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Access to Immediately Available Balanced Blood Products in a Rural State's Trauma System

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Abstract

Introduction: The Arkansas Trauma System was established by law more than a dozen years ago, and all participating trauma centers are required to maintain red blood cells. Since then, there has been a paradigm shift in resuscitating exsanguinating trauma patients. Damage Control Resuscitation with balanced blood products (or whole blood) and minimal crystalloid is now the standard of care. This project aimed to determine access to balanced blood products in our state's Trauma System (TS).

Methods: A survey of all trauma centers in the Arkansas TS was conducted, and geospatial analysis was performed. Immediately Available Balanced Blood (IABB) was defined as at least 2 units (U) of thawed plasma (TP) or never frozen plasma (NFP), 4 units of red blood cells (RBCs), 2 units of fresh frozen plasma (FFP), and 1 unit of platelets or 2 units of whole blood (WB).

Results: All 64 trauma centers in the state TS completed the survey. All level I, II, and III Trauma Centers (TCs) maintain RBC, plasma, and platelets, but only half of the level II and 16% of the level III TCs have thawed or never frozen plasma. A third of level IV TCs maintain only RBCs, while only 1 had platelets, and none had thawed plasma. 85% of people in our state are within 30 min of RBCs, almost two-thirds are within 30 min of plasma (TP, NFP, or FFP) and platelets, while only a third are within 30 min of IABB. More than 90% are within an hour of plasma and platelets, while only 60% are within that time from an IABB. The median drive times for Arkansas from RBC, plasma (TP, NFP, or FFP), platelets, and an immediately available and balanced blood bank are 19, 21, 32, and 59 minutes, respectively. A lack of thawed or non-frozen plasma and platelets are the most common limitations of IABB. One level III TC in the state maintains WB, which would alleviate the limited access to IABB.

Conclusion: Only 16% of the trauma centers in Arkansas can provide IABB, and only 61% of the population can reach IABB within 60 minutes. Opportunities exist to reduce the time to balanced blood products by selectively distributing WB, TP, or NFP to hospitals in our state trauma system.

Keywords

whole blood, damage control resuscitation, rural, thawed or non-frozen plasma, balanced blood products

Key Takeaways

- Not all trauma centers that maintain the required component blood products can provide them immediately
- A lack of thawed or non-frozen plasma and platelets are the most common limitations of IABB.

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Background

The development of trauma systems has decreased mortality and morbidity of the traumatically injured, combatting the leading cause of death in children and young adults.[1-3] In blunt and penetrating trauma, rapid identification and treatment of hemorrhagic shock are critical in caring for traumatically injured patients.[4] This is highlighted in the Advanced Trauma Life Support (ATLS) course developed in the late 1970s and propagated by the American College of Surgeons Committee on Trauma.[5,6] Balanced blood product administration is the gold standard for the resuscitation of hemorrhagic shock.

Whole blood (WB) was identified as the standard of care in hemorrhagic shock more than a hundred years ago during WWI. However, care migrated away from WB over the second half of the 20th century due to component separation technology that allowed for components to be stored separately, thus improving shelf-life and efficiency for patients who were deficient in only a component of blood. Subsequent studies showed that moderate volumes of crystalloid were safe in all, but the most seriously injured were widely propagated with ATLS and applied to all patients.[7] As a result, plasma and platelets were abandoned in caring for bleeding trauma patients by the end of the 20th century in favor of large volumes of crystalloids and RBCs based on fears over the transmission of HIV and other blood-borne pathogens.[8]

Over the past two decades, there has been a dramatic pendulum shift based on a growing body of the literature describing trauma-induced coagulopathy and dilution-associated coagulopathy resulting from the administration of large volumes of crystalloid for patients in hemorrhagic shock.[9] These lessons were relearned during recent conflicts in southwest Asia[10] and have shifted the paradigm back to whole blood (or balanced resuscitation approximating whole blood), which was deemed the most efficacious at resuscitation for hemorrhage more than a century ago.[11] Accepted ratios for balanced resuscitation are 1:1:1 (plasma, platelets, and RBCs) and 1:2 (plasma to RBCs).[12] In this study, we used a geospatial approach to examine the ability of a rural state's TS to provide balanced resuscitation. The goal of this study was to characterize the ability of state trauma centers to provide IABB to bleeding trauma patients within 60 minutes and identify potential deficits in blood product distribution.

Methods

Design

This study, evaluating the accessibility to blood products in a rural state, was deemed Institutional Review Board exempt by the University of Arkansas for Medical Sciences IRB. A survey was conducted of all 64 state-designated TCs in the Arkansas Trauma System (ATS). This included four TCs outside the state's geographic border that contribute to the care of Arkansans. There were six state-verified level I, four level II, nineteen level III, and thirty-five level IV facilities (Figure 1). Each facility reported the quantity and type of typically available blood products: RBCs, plasma (FFP or thawed/never frozen, or cryoprecipitate), and platelets. Immediately available balanced blood (IABB) was defined as a minimum of 2 units of whole blood or 2 units of thawed or NF plasma, 4 units of red blood cells, 2 units of fresh frozen plasma, and 1 unit of platelets.

Setting

Arkansas is a mixed urban and rural state with a population of 2 915 918 and a land mass of 134 771 km^2. The only ACS-verified Adult level I Trauma Center is centrally located in the capital city, Little Rock. Additional Arkansas state-designated level I TCs that contribute to the care of the critically injured in Arkansas are Springfield, MO (n = 2) and Memphis, TN (n = 1). These facilities participated in the survey and were included in the analysis. Additionally, two Pediatric level I TCs are included in this study (Little Rock, AR, and Memphis, TN).

Geospatial Analysis

Population data was obtained from the 2010 U.S. Census Bureau TIGER/Line Shapefiles. Each trauma center in the study was geocoded using Google Maps (Google, Mountain View, CA) and then input into ArcGIS™ (ESRI, Redlands, CA). The data was analyzed in ArcGIS™. Using census tracts (N = 686), the Network Analyst feature was used to evaluate drive time surrounding each hospital system at 30-, 60-, 90-, and 120-minute increments (Figure 1). This was configured as the time driven by ground emergency vehicle from the census tract centroid to the nearest facility. The hospitals were then separated by blood product availability. Hospital systems that were IABB capable (n = 11) were mapped, and drive time distance from the nearest census tracts was calculated (Figure 2). The hospitals were further divided into facilities with RBCs, plasma (including thawed [TP] and never frozen [NFP]), fresh frozen plasma (FFP), and platelets. The drive time to these facilities, calculated in 30-minute increments up to 180 minutes, was then summarized as a mean and represented in Table 1.

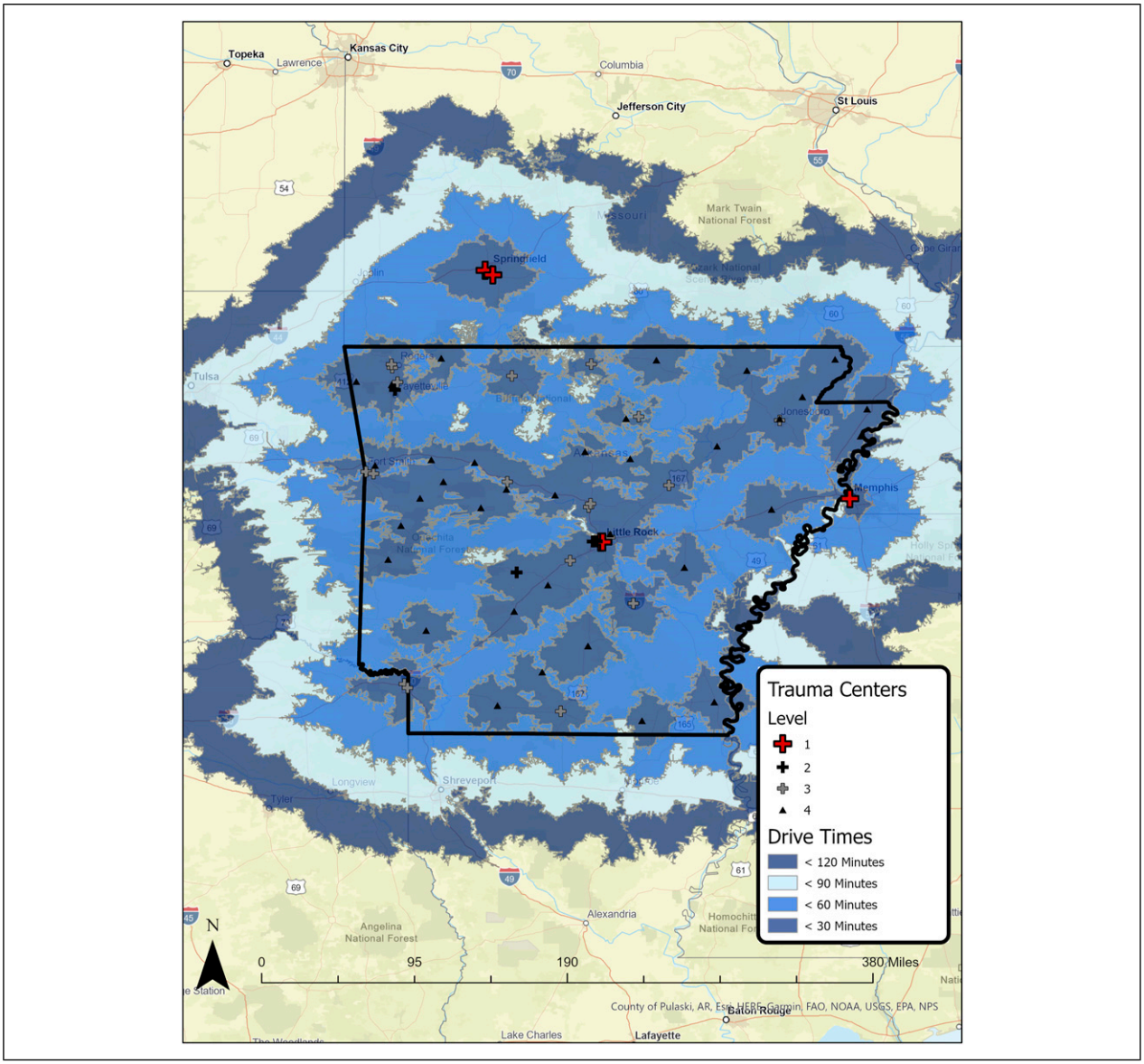

Figure 1. Distribution of Hospitals in a Rural Trauma System.

Results

Immediately Available Balanced Blood

Eleven trauma centers met the criteria for IABB and reported immediate availability of RBCs, thawed or never frozen plasma, and platelets, including all level I TCs (n = 6) (Table 1) and two level II and three level III TCs. There were no level IV trauma centers that met the criteria for IABB. Thus, 17% (n = 11) of the TCs could provide IABB resuscitation. At the time of the survey, only one facility maintained whole blood for resuscitation. The population in the state with access to immediate balanced product resuscitation within 30 minutes by ground transport was 964 316 (33%). This number increased as drive time increased, with 1 778 001 people (61%) able to reach balanced resuscitation in 1 hour (Table 1). At 120 minutes of ground transport time, 97% of the state's population could reach IABB. The median drive time to IABB was 40 minutes (Table 1).

Access to Individual Blood Products. All participating TCs reported maintaining RBCs. All level I, II, or III TCs reported available plasma and platelets, in addition to RBCs. The amount of product available for transfusion varied by hospital from 400 to 2 units of RBCs. Further, only 11 facilities maintained thawed or never frozen plasma, 52 FFP, 31 platelets, and 34 cryoprecipitate. Only one (3%) level IV TC reported maintaining platelets available for transfusion, and 23 (66%) maintained FFP. No level IV TCs kept thawed or never frozen

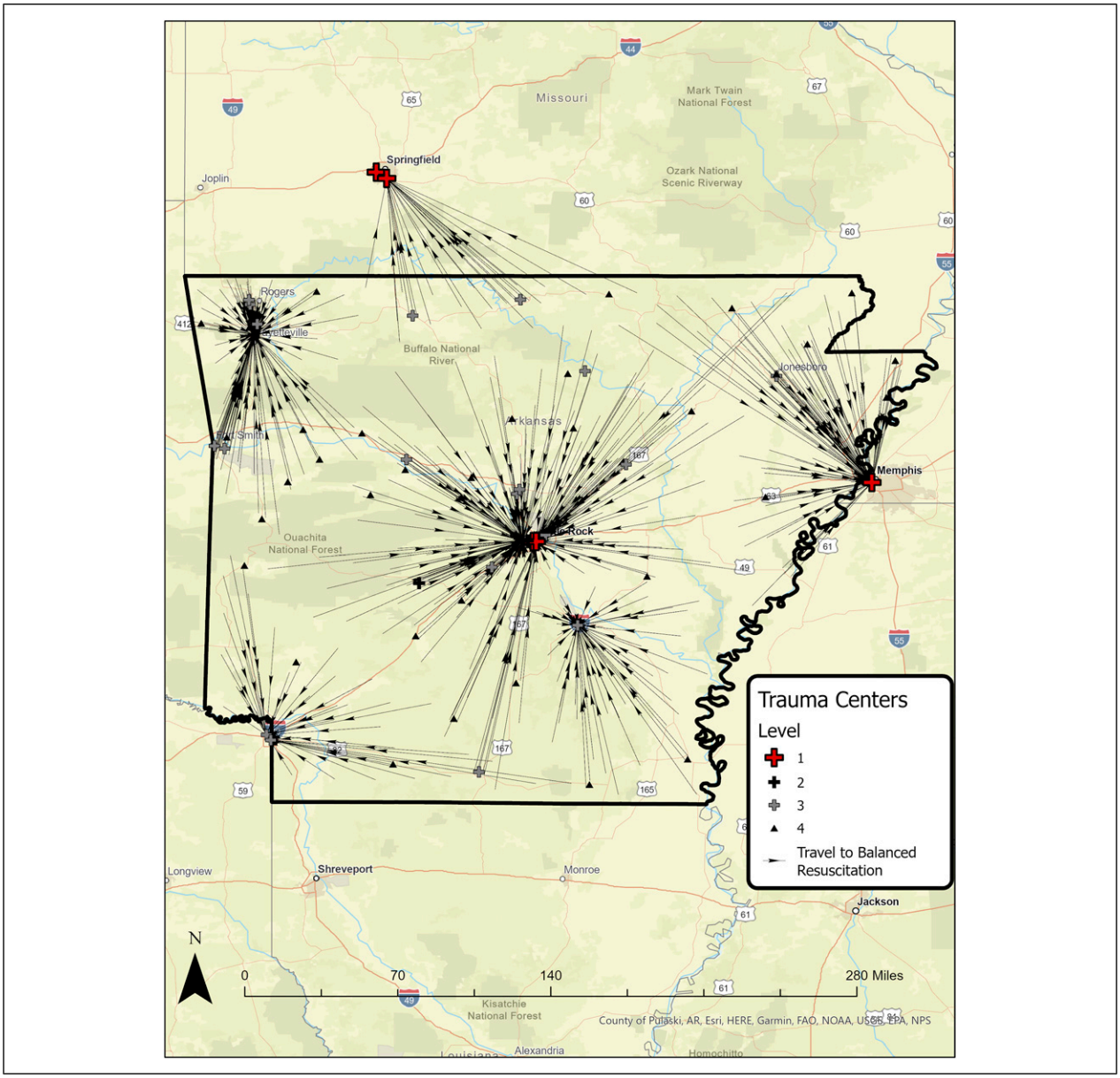

Figure 2. Distribution of Immediately Available Balanced Blood.

plasma. The percentage of the population within 30 minutes of RBC transfusion was 85% (n = 2 473 577). When increasing the drive time to 60 minutes, 99.7% (n = 2 905 760) of the population was within the coverage area. Median drive times to RBCs, plasma, and platelets were 20, 30, and 33 minutes, respectively (Table 1).

Discussion

This study shows that access to balanced resuscitation within the state of Arkansas depends on the location of the injured patient and the surrounding trauma centers' capabilities. The ATS requires that state-designated level I-III TCs maintain RBC, plasma, platelets, and cryoprecipitate. Despite these TCs maintaining all required individual products, half of the level II TCs and 84% of level III TCs did not meet the standard for IABB. This is primarily due to the absence of non-frozen plasma at these facilities. The FFP stored at these TCs is excluded from IABB due to the required thaw time (~45 minutes).

Additionally, this only accounts for 45% (n = 29) of all the TCs in the state. When including the level IV TCs, only 17% of all TCs were IABB capable. This likely exceeds the capabilities of other rural areas outside of our state as the current standard for level III centers in Resources of Optimal Care of the Injured Patient[13] is limited

Table 1. Percentage of IABB at Trauma Centers and Median Drive times.

	RBC	Plasma	Platelets	Balanced and Available Blood Bank
Level I	6	6	6	6
	100%	100%	100%	100%
Level 2	4	4	4	2
	100%	100%	100%	50%
Level 3	19	19	19	3
	100%	100%	100%	16%
Level 4	35	23	1	0
	100%	66%	3%	0%
All	64	52	30	11
	100%	81%	47%	17%
Min. from the blood product for the average person in the state?	19.2	21.1	31.5	58.8
Time to blood products: % population (n = 2 915 918)				
30 minutes	84.8%	81.2%	65.3%	33.1%
60 minutes	99.7%	99.2%	91.6%	61.0%
90 minutes	99.9%	99.9%	98.8%	85.4%
120 minutes	100%	100%	99.9%	96.5%

to readily available RBCs and FFP. Also, there are no designated level IV centers in these guidelines, so it is unlikely that all level IV centers outside the ATS maintain RBCs for transfusion. Since the survey's completion, additional hospitals within the ATS have obtained whole blood for transfusion. This did not significantly alter the results of this paper, as these were already IABB-capable facilities.

Accessibility to RBCs, platelets, and plasma follows similar trends when examined individually. The level I-III TCs have all the required blood products, but when including level IV TCs there is a paucity of both plasma and platelets. 66% of level IV TCs reported available plasma, and only 3% reported carrying platelets. This deficit is reflected in the population coverage and median drive times to individual blood products and IABB.

A growing body of the literature shows balanced resuscitation with both plasma and platelets decreases mortality and improves resource utilization.[10,11,14-16] However, using a geospatial approach to evaluate the distribution of blood bank resources at trauma centers is not well studied. Blood bank resource distribution is primarily a logistics issue and would benefit from further geospatial analysis to ensure that it is appropriately distributed to decrease disparities in care. This is certainly more feasible than upgrading non-designated centers into TCs or building new facilities in underserved areas. Other efforts to improve access to appropriate care could include evaluating facilities for whole blood storage, "pit-stops" where whole blood could be picked up by EMS vehicles en route to TCs where a surgeon capable of stopping non-compressible torso trauma are already in place. Additionally, more EMS systems are carrying and transfusing whole blood to exsanguinating patients.

This study is limited by not considering accessibility to air transport or en route transfusion initiated by air ambulances. Further, population data are only a snapshot and may not accurately reflect the changes in the population of an area during certain times. This is frequently seen in urban areas during working hours as the population commutes into the city, and the U.S. Census Bureau data do not reflect this change. Additionally, hospital survey results do not quantify the reduction in the blood product after an individual transfusion event and before resupply.

Immediately available balanced blood resuscitation is available to 61% of Arkansans within a 1-hour drive. Further research is needed to identify facilities that would benefit from adding whole blood or individual component blood to increase accessibility to IABB.

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