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Low-Titer O+ Whole Blood Implementation in the EMS System for Metropolitan Oklahoma City and Tulsa: Significance, Success, & Sharing Lessons Learned

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ABSTRACT

Objectives: Over 300 emergency medical services (EMS) organizations across the United States have implemented transfusion programs for traumatic injuries using packed red blood cells, platelets, plasma, or whole blood before hospital arrival. Beginning in December of 2022, the EMS System for Metropolitan Oklahoma City (OKC) and Tulsa began carrying low-titer O-positive whole blood (LTOWB) for adult patients in traumatic hemorrhagic shock, specifically those exhibiting elevated shock indexes. We aim to describe establishing our prehospital LTOWB program and its first two years of operations across OKC and Tulsa.

Methods: We used an observational study design and retrospective descriptive analysis of patients receiving LTOWB by paramedic transfusion from the Emergency Medical Services Authority Ambulance Service, Oklahoma City Fire Department, or Tulsa Fire Department between December 1, 2022, and February 1, 2025. Descriptive analysis and univariate logistic regression quantify the relationship of patient characteristics against survival to hospital arrival and survival to hospital discharge outcomes.

Results: Penetrating trauma was the most common mechanism of injury recorded for patients receiving EMS LTOWB (71.6%). Following LTOWB transfusion, prehospital vital signs (systolic blood pressure, heart rate, and shock index) significantly improved ($p < 0.05$). Systolic blood pressure improvement conferred 9.7 times greater odds of survival to hospital arrival (95% CL 1.6–58.6). Occurrence of prehospital traumatic arrest was significantly related to lower odds of survival to hospital arrival and survival to hospital discharge (OR 0.01 and OR 0.03, respectively).

Conclusions: Transfusion of LTOWB in a large, urban EMS system in the Southwestern United States confers a positive benefit to patients with measurable improvement in median systolic blood pressure, heart rate, and shock index. Continuous review of cases and misses empowered our system in dynamic protocol adjustments to best meet our population's needs. Patients often had secondary deterioration during transit, illustrating that blood transfusion “bought” temporary time during transport of critically injured patients to definitive care.

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Introduction

In traumatic injury, time is the enemy of first responders dedicated to improving patient survival (1). Rapid transport to trauma facilities for life-threatening hemorrhage has long been the standard solution (2). However, many traumatic injuries occur far from trauma facilities, challenging the clinician with maintaining hemostasis and ongoing perfusion of critical organs over longer transport intervals. Leaders in the oversight of prehospital emergency response have long sought better solutions for hemorrhagic shock. Some of the earliest documented patient improvement after out-of-hospital whole blood transfusion originates from World War II (3). These early accounts of successful transfusion encouraged today's

innovative emergency medical services (EMS) practices of replacing crystalloids with low-titer O+ whole blood (LTOWB).

The San Antonio (Texas) Fire Department and the Southwest Texas Regional Advisory Council (STRAC) established one of the first prehospital LTOWB programs (4). Supporting evidence identified LTOWB as the preferred product as it conveyed the lowest risk of alloimmunization (5). In January 2020, STRAC held its first “Whole Blood Academy” to share transfusion rationales and implementation strategies for EMS medical oversight teams.

Since 2019, the number of agencies carrying prehospital blood products nationwide has grown, with numbers surpassing 300 in early 2026 (6). Published literature on the clinical benefits of prehospital transfusion of blood products

varies (7). We aim to describe the establishment of our pre-hospital LTOWB program and its first two years of operations across Oklahoma City (OKC) and Tulsa.

Methods

Study Design and Population

We used an observational study design and retrospective descriptive analysis of all prehospital LTOWB transfusions in the EMS System for Metropolitan OKC and Tulsa during the first two years of implementation (1 December 2022 to 1 February 2025). The OKC Fire Department operates 37 fire stations and four supplemental ambulances, attending to 715,000 residents across 620sq mi (8). The Tulsa Fire Department staffs 30 stations serving over 415,000 residents across 186.8sq mi (8). Both cities contract with Emergency Medical Services Authority as the primary ambulance transport agency, coordinating 124,279 responses in OKC and 121,750 responses in Tulsa during 2025 (9).

The protocol for this retrospective study was reviewed and considered exempt by the Institutional Review Board for the Protection of Human Subjects of the University of Oklahoma (IRB # 18200). All data were fully de-identified before analysis, and patient confidentiality was maintained in accordance with Health Insurance Portability and Accountability Act regulations.

Case Identification

Eligible patients for transfusion of up to two LTOWB units were identified according to age, systolic blood pressure (SBP), shock index (SI), and arrest criteria outlined in local treatment protocol (10). Contraindications for administration included situations of ground-level falls, burns, non-traumatic blood loss, religious objection, and absence of return of spontaneous circulation (ROSC) following traumatic arrest. Approximately four months after the program began, isolated head injuries were added as a contraindication. On-line medical oversight consultation with a member of the system's Office of the Medical Director was required for children under the age of six. These same personnel were available for around-the-clock consultation to discuss eligibility for LTOWB transfusion outside of approved indications. Paramedics serving as Field Operations Supervisors were credentialed for blood management and transfusion by attending a six-hour course addressing LTOWB handling, identifying hemorrhagic shock, protocol review, and practical exercises in the transfusion of LTOWB. "Blood paramedics" responded to scenes based on prompting from telecommunicators identifying potential hemorrhage based on the caller's description of injury or on-scene EMS request for blood. These "blood paramedics" also had the ability to self-dispatch based on review of computer-aided dispatch notes or real-time radio communication within the EMS system.

Variables and Outcome Measures

Prehospital variables collected for analysis include demographics (sex, age, race/ethnicity), mechanism of injury,

presence of traumatic circulatory arrest, paramedic primary clinical impression, Medical Priority Dispatch System (MPDS) card number, origin of request for LTOWB, transport distance, prehospital vital signs (SBP, heart rate, and derived SIs), and time intervals (scene interval calculated as difference between first arriving unit at-patient timestamp and transporting unit departure timestamp, time to LTOWB transfusion calculated as difference between first arriving unit at-patient timestamp and blood transfusion treatment timestamp, and transport interval calculated as difference between scene departure timestamp and trauma center arrival timestamp). Outcome variables include post-LTOWB SBP, heart rate, and derived SIs, emergency department SBP, heart rate, calculated SI, amount and types of crystalloids and blood products transfused in hospital, length of hospital stay, survival to hospital arrival, survival to hospital discharge. If the patient was receiving chest compressions, vital signs are considered missing during resuscitation. Prehospital vital sign change was calculated as the difference between pre-transfusion vital signs, captured at the nearest timestamp before treatment initiation, and post-transfusion vital signs, captured at nearest timestamp after documented transfusion completion. Vital sign change at the emergency department was calculated as the difference between pre-transfusion vital signs and the first set of vital signs collected in the emergency department.

Statistical Analysis

Prehospital data were collected from ambulance and fire department electronic health records (ESO Solutions, Austin, TX) for identified LTOWB cases. Inpatient and outcome data were collected from respective trauma receiving facilities via health record query and monthly prehospital blood continuous quality improvement (CQI) meetings. Counts and percents are presented for categorical data. Continuous data were tested for normality using the Kolmogorov-Smirnov test. Normal data were described using averages and standard deviation, with comparison using paired t-tests. Non-normal data were described using medians and interquartile ranges, with comparison using Wilcoxon Signed Rank. Calculated differences in SBP, heart rate, and SIs were captured per patient, and aggregation was performed on the entire population. Little's MCAR test was used to assess patterns in data missingness. No imputation methods were used to estimate missing values. Univariate logistic regression evaluated the significance of predictors against outcomes of survival to hospital arrival and survival to hospital discharge. The established alpha threshold for significance is 0.05. All statistical analyses were conducted using SAS v 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

In total, 134 patients met transfusion criteria. Of these, 113 units of LTOWB were administered to 109 patients between December 2022 and February 2025. Age was not normally distributed, with a median patient age of 34.5years (IQR 27.2–46.1; Table 1). During the first two years of program

Table 1. Patient characteristics.

	All LTOWB Cases (N=109)
AGE	
In years (Median, IQR)	34.5 (27.2–46.1)
SEX	
Male	99 (90.8%)
Female	10 (9.2%)
RACE/ETHNICITY	
Non-Hispanic, White	45 (41.3%)
Non-Hispanic, Black	42 (38.5%)
Other	22 (20.2%)
PRIMARY IMPRESSION	
Injury of Thorax (Upper Chest)	22 (20.2%)
Injury of Abdomen	18 (16.5%)
Injury of Thigh (Upper Leg)	14 (12.8%)
Injury of Head	12 (11.0%)
Hemorrhage	8 (7.3%)
Other	35 (32.2%)
MECHANISM OF INJURY	
Gunshot Wound (GSW)	48 (44.0%)
Stabbing/Laceration	30 (27.5%)
Motor Vehicle Collision (MVC)	25 (23.0%)
Medical	6 (5.5%)
ON-LINE MEDICAL CONSULT OVERRIDE APPROVAL FOR BLOOD ADMIN	
Yes	9 (8.3%)
TIME INTERVALS in MM:SS	
TIME TO BLOOD [First Medical Contact (FMC) to Blood Admin] (Median, IQR)	15:00 (11:00–20:08)
SCENE INTERVAL [At Patient Side to Scene Departure] (Median, IQR)	14:46 (11:00–19:00)
TRANSPORT INTERVAL [Scene Departure to Hospital Arrival] (Median, IQR)	11:00 (8:03–15:08)
PRE-LTOWB VITAL SIGNS	
Systolic Blood Pressure (Median, IQR)	84.5 (73–98)
Heart Rate (Mean, SD)	110.8 (27.1)
Shock Index (Mean, SD)	1.32 (0.45)
VITAL SIGN IMPROVEMENT PREHOSPITAL (Post-LTOWB Vital Signs – Pre-LTOWB Vital Signs)	
Systolic Blood Pressure (Mean, SD)	+26.8 (6.0–45.0)*
Heart Rate (Median, IQR)	–4.0 (–4.0 – +4.0)*
Shock Index (Median, IQR)	–0.31 (–0.80 – –0.11)*
BINARY VITAL SIGN IMPROVEMENT PREHOSPITAL=YES	
Systolic Blood Pressure	65 (59.6%)
Heart Rate	61 (56.0%)
Shock Index	65 (59.6%)
VITAL SIGN IMPROVEMENT AT ED (Hospital ED Vital Signs – Pre-LTOWB Vital Signs)	
Systolic Blood Pressure (Median, IQR)	+8.0 (–5.0 – +33.0)*
Heart Rate (Median, IQR)	–5.5 (–17.0 – +6.0)*
Shock Index (Median, IQR)	–0.10 (–0.63 – +0.08)*
BINARY VITAL SIGN IMPROVEMENT AT ED=YES	
Systolic Blood Pressure	57 (52.3%)
Heart Rate	65 (59.6%)
Shock Index	63 (57.8%)
ORIGIN OF REQUEST FOR BLOOD	
Emergency Medical Telecommunicator	70 (64.2%)
“Blood Paramedic” Self-Dispatch	14 (12.9%)
On-Scene EMS/Fire Clinician	12 (11.0%)
Requested by Multiple Parties	4 (3.7%)
Unknown or External Agency	9 (8.2%)
TRAUMATIC INJURY	
Yes	103 (94.5%)
TRAUMATIC ARREST	
Yes	17 (15.6%)
TRANSPORT DISTANCE	
In miles (Median, IQR)	7.7 (5.4–9.6)
SURVIVAL TO HOSPITAL ARRIVAL	
Yes	99 (90.8%)
TRANSFERRED FROM EMERGENCY DEPARTMENT TO OPERATING ROOM AMONG ADMISSIONS	
Yes	63 (63.6%)
SURVIVAL TO HOSPITAL DISCHARGE	
Yes	79 (72.5%)
LENGTH OF HOSPITAL STAY AMONG SURVIVORS TO HOSPITAL DISCHARGE	
In days (Median, IQR)	5 (0–8)
IN-HOSPITAL FLUID RESUSCITATION in UNITS (Median, IQR)	
Packed Red Blood Cells (PRBC)	0 (0–3)
Fresh Frozen Plasma (FFP)	0 (0–2)
Cryoprecipitate	0 (0–0)
Platelets	0 (0–0)
Whole Blood (Total)	1 (0–3)
Whole Blood – in ED	0 (0–2)
Whole Blood – in OR	0 (0–0)

IQR: Interquartile Range; LTOWB: Low-Titer O-Positive Whole Blood; FMC: First Medical Contact; ED: Emergency department; OR: Operating Room; *: Improvement in vital sign significantly differs from zero based on paired T-Test or Wilcoxon Signed Rank $p < 0.05$.

implementation, 103 (94.5%) of the transfused patients had traumatic injuries. The most common primary injury locations were the thorax (20.2%), abdomen (16.5%), thigh (12.8%), and head (11.0%). A small proportion of patients did not meet standing order criteria and were approved for LTOWB transfusion by on-line medical consult (8.3%). The most common MPDS determinant codes were 27 – Stabbing/Gunshot Wound/ Penetrating Trauma and 29-Traffic Collision/Transportation Incident (61.5% and 21.1%, respectively; Figure 1).

“Blood paramedic” response was most commonly activated by an emergency medical telecommunicator (64.2%), followed by self-dispatch (12.9%). The median scene interval was 14m 46s, with a median interval from first medical contact to blood transfusion of 15m (Table 1). The median transport distance was 7.7 miles, with a median transport duration of 11m (Table 1). Out of the 17 patients who experienced a prehospital arrest, ten achieved ROSC prior to transfusion and six arrested after the start of blood transfusion. All LTOWB-receiving patients were transported to trauma centers. After hospital arrival, 63.6% of transfused patients admitted were transferred to an operating room and 9.2% of patients were determined deceased on arrival. Overall, 79 patients survived to hospital discharge (72.5%).

Systolic blood pressure, heart rate, and shock index improvement were measured as the per-patient difference in pre-LTOWB and post-LTOWB vitals. Less than ten percent of vital sign data were missing and were deemed missing at random ($p=0.99$). Over half of the patients had measurable improvements in SBP (59.6%), heart rate (56.0%), and SIs (59.6%) after prehospital LTOWB transfusion (Table 1). Measurable changes among patients receiving LTOWB included a mean SBP increase of 26.8mmHg and a median heart rate decrease of 4.0 bpm ($p<0.001$ and $p=0.002$, respectively). Prehospital SI significantly decreased by a median of 0.31 points ($p<0.001$). Upon hospital arrival, sustained vital sign differences measured a median SBP increase of 8.0mmHg,

and a median heart rate decrease of 5.5 bpm compared to pre-LTOWB vitals ($p=0.001$ and $p=0.002$, respectively). Initial SI in the emergency department was significantly decreased by 0.10 points compared to pre-LTOWB SI ($p<0.001$). Among those who survived to hospital discharge, the median hospital length of stay was 5 days (IQR 0–8).

Univariate Significance

Survival to Hospital Arrival

Patients experiencing prehospital traumatic arrest had lower odds of survival compared to those without (8/17, 47.1% vs 91/92, 98.9%; OR 0.01, 95% CL 0.001–0.09). An increase in prehospital SBP was associated with 9.7 times greater odds of survival to hospital arrival (63/65, 96.9% vs 13/17, 76.5%; 95% CL 1.60–58.60).

Survival to Hospital Discharge

Assigned MPDS determinant code was not significantly related to patient survival to hospital discharge ($p=0.92$, Figure 1). Traumatic arrest remained a significant predictor of mortality, with patients having lower odds of survival to hospital discharge compared to those without an arrest (2/17, 11.8% vs 77/92, 83.7%; OR 0.03, 95% CL 0.01–0.13). Odds of survival to discharge grew minimally per bpm increase in initial emergency department heart rate (OR 1.02, 95% CL 1.00–1.03). Finally, patients who required in-hospital transfusion of fresh frozen plasma (FFP) had slightly higher odds of mortality (14/31, 45.2% vs 16/78, 20.5%; OR 0.93, 95% CL 0.88–0.99).

Discussion

Roughly 340,000 responses occurred in the 26 months following program implementation with 109 patients receiving prehospital LTOWB. The majority of our population had

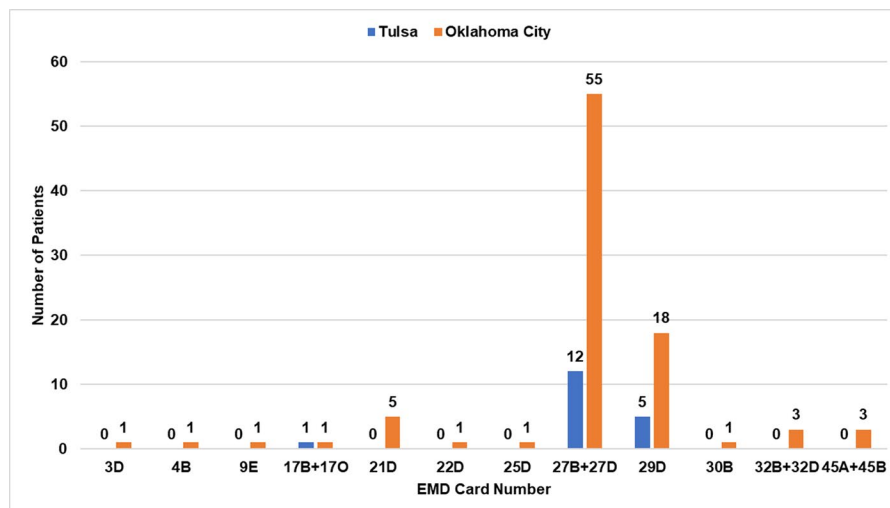


Figure 1. Frequency of LTOWB cases distributed by medical priority dispatch system (MPDS) determinant code. Count of Patients by MPDS Determinant Code is broken down by city to show similar response patterns in each metropolitan area represented in the sample. MPDS codes are grouped by numerical descriptors with sub-categories of acuity level (Alpha – Echo): 3 – Animal Bites/ Attacks, 4 – Assault/ Sexual Assault/ Stun Gun, 9 – Cardiac or Respiratory Arrest/ Death, 17 – Falls, 21 – Hemorrhage (Bleeding)/ Lacerations, 22 – Inaccessible Incident/ Other Entrapments (Non-Traffic), 25 – Psychiatric/ Mental Health Conditions/ Suicide Attempt/ Abnormal Behavior, 27 – Stab/ Gunshot/ Penetrating Trauma, 29 – Traffic Collision/ Transportation Incident, 30 – Traumatic Injuries (Specific), 32 – Unknown Problem (Person Down), 45 – Interfacility Transport. MPDS was an insignificant predictor of survival to hospital arrival ($p=0.97$) and survival to hospital discharge ($p=0.92$).

measurable SBP, heart rate, and SI improvement following prehospital blood transfusion using paired comparisons. However, blood served as a temporizing measure, with a lower proportion of patients having sustained SBP improvement at hospital intake compared to their post-transfusion SBP (52.3% vs 59.6%). This supports the conclusion that initial restoration of blood pressure and cardiac output may lack longevity without surgical or interventional hemorrhage control (11).

One of the main challenges in adopting a prehospital blood program lies in obtaining funding (12). Understanding the fluctuations of injuries meeting prehospital-initiated transfusion criteria led system leaders to limit LTOWB provisioning to two to three units per metropolitan area. Our system was rigorous in maintaining the integrity of units to allow the blood bank to recycle unused units to trauma facilities for hospital use. Zero LTOWB units were wasted during the first two years of program implementation as our system attempted to uphold stewardship guidelines outlined by STRAC (13). Collaboration with trauma facilities and the regional blood bank proved integral in developing strategies to serve our population best while following published blood stewardship guidelines.

Ongoing monthly CQI discussions were a key component of identifying missed opportunities and logistical strategies to improve time to treatment. These monthly discussions enabled timely adjustments to protocol and ongoing professional education, based on case-to-date findings. One such adjustment relates to injury presentation. In our population, 11% of documented paramedic primary impressions were 'Injury of Head'. Following the first four months of the program, prehospital blood transfusion in traumatic brain injury was deemed to offer minimal benefit to patients transported in our system. Thereafter, based on recommendations from hospital-based clinicians supported by published research, medical oversight added a contraindication for isolated head injuries (14). A similar adjustment was made to include age-based dosing for children (15).

Limitations

Our study contains several noteworthy limitations. The primary limitations of this study are its retrospective nature and small sample size. Request for dispatch of blood units resulted from consideration of multiple factors, including the proximity of "blood paramedics", transport destinations, and injury characteristics. Therefore, we acknowledge the clinician, telecommunicator, and medical oversight's discretionary influence on transfusion prevalence. Additionally, we are limited in the ability to establish causality as cases were not randomized to treatment assignment, nor were comparisons made to a control group. Small sample sizes reduce statistical power, preventing multivariable modeling. Non-normal data distribution led to reliance on medians and data ranks instead of absolute values. Cases were gathered from the metro areas of OKC and Tulsa and will limit generalizability. Lastly, vital sign data were missing for 9.2% of encounters; while not uncommon among prehospital clinical records, it limited modeling capabilities (16).

Conclusions

Transfusion of LTOWB within a large urban EMS system in the southwestern United States conferred positive improvements in systolic blood pressure, heart rate, and shock index during EMS clinical care for patients in hemorrhagic shock. Although vital signs measurably improved, they quickly deteriorated over short transport intervals, with patients often in recurrent shock upon hospital arrival. Still, prehospital improvement in pre- vs post-LTOWB systolic blood pressure was significantly correlated with patient survival to hospital arrival. These findings may be informative to EMS systems considering transfusion capabilities.

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Author Contributions

CRedit: **Anna M. Bailey:** Formal analysis; **Curtis L. Knoles:** Project administration, Writing – review & editing; **David S. Howerton:** Project administration, Writing – review & editing; **Duffy McAnallen:** Project administration; **Matthew L. Cox:** Project administration; **Patrick Cody:** Project administration; **Jeffrey M. Goodloe:** Project administration, Supervision.

Declaration of Generative AI in Scientific Writing

The authors did not use a generative artificial intelligence (AI) tool or service to assist with preparation or editing of this work. The author(s) take full responsibility for the content of this publication.

Disclosure Statement

The authors report there are no conflicts of interest to declare.

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References

1. Meyer DE, Vincent LE, Fox EE, O'Keeffe T, Inaba K, Bulger E, Holcomb JB, Cotton BA. Every minute counts: time to delivery of initial massive transfusion cooler and its impact on mortality. *J Trauma Acute Care Surg.* 2017;83(1):19–24. doi:10.1097/TA.0000000000001531.
2. Alarhayem AQ, Myers JG, Dent D, Liao L, Muir M, Mueller D, Nicholson S, Cestero R, Johnson MC, Stewart R, et al. Time is the enemy: mortality in trauma patients with hemorrhage from torso injury occurs long before the "golden hour. *Am J Surg.* 2016;212(6):1101–5. doi:10.1016/j.amjsurg.2016.08.018.
3. Kendrick DB. Blood program in world war II. Washington: Office of the Surgeon General. Department of the Army; 1964.
4. Jenkins D. Pre-hospital whole blood [PowerPoint Slides]. San Antonio (TX): Southwest Texas Regional Advisory Council; 2018.

- Sept 6. STRAC Air Medical Provider Advisory Group (AMPAG). [accessed 2026 Jul 9]. https://www.strac.org/wp-content/uploads/2023/09/AMPAG_Whole_Blood_092018.pdf.
5. Strandenes G, Berséus O, Cap AP, Hervig T, Reade M, Prat N, Sailliol A, Gonzales R, Simon CD, Ness P, et al. Low titer group O whole blood in emergency situations. *Shock*. 2014;41 Suppl 1(Suppl 1):70–5. PMID: 24569505. doi:10.1097/SHK.0000000000000150.
 6. Prehospital Blood Transfusion Coalition. US. Prehospital Blood Program Interactive EMS Map. Prehospital Blood Transfusion Coalition. 2025 [accessed 2026 Jul 9]. <https://prehospitaltransfusion.org/blood-program-interactive-map/>
 7. Hadadi HA, Alsubaie NBM, Alfaifi AYS, Alzahrani MSA, Alhazmi AA, Alanazi ANG, Aljulajil ARD, Alzeer AAA. Prehospital blood transfusion: systematic review. *Rev Diabet Stud*. 2025;10:430–47. <https://diabeticstudies.org/index.php/RDS/article/view/1217>.
 8. U.S. Census Bureau. QuickFacts: Tulsa city, Oklahoma; Oklahoma City city, Oklahoma; Oklahoma [Internet]. Washington (DC): U.S. Census Bureau; 2025 [accessed 2026 Jul 9]. <https://www.census.gov/quickfacts/fact/table/tulsacityoklahoma,oklahomacityyoklahoma,OK/PST045225>.
 9. Emergency Medical Services Authority. 2025 annual report [Internet]. Oklahoma City (OK): Emergency Medical Services Authority; 2026 [accessed 2026 Jul 9]. <https://emsaok.gov/annual-report/>.
 10. Office of the Medical Director for Emergency Medical Services in Oklahoma City and Tulsa. 17O – low titer O+whole blood (LTOWB) [Internet]. Oklahoma City (OK): Office of the Medical Director for Emergency Medical Services in Oklahoma City and Tulsa; 2026 [accessed 2026 Jul 9]. http://okctulomd.com/assets/front/ems_protocol/199._PROTOCOL_17_O_.pdf.
 11. Bonanno FG. Management of hemorrhagic shock: physiology approach, timing and strategies. *J Clin Med*. 2022;12(1):260. doi:10.3390/jcm12010260.
 12. Schaefer RM, Bank EA, Krohmer JR, Haskell A, Taylor AL, Jenkins DH, Holcomb JB. Removing the barriers to prehospital blood: a roadmap to success. *J Trauma Acute Care Surg*. 2024;97(2S Suppl 1): s 138–S144. doi:10.1097/TA.0000000000004378.
 13. Bullock W, Schaefer R, Wampler D, Stringfellow M, Dieterle M, Winckler CC. Stewardship of prehospital low titer o-positive whole blood in a large urban fire-based EMS system. *Prehosp Emerg Care*. 2022;26(6):848–54. Epub 2021 Nov 22. PMID: 34644237. doi:10.1080/10903127.2021.1992052.
 14. Pélieu I, Kull C, Walder B. Prehospital and emergency care in adult patients with acute traumatic brain injury. *Med Sci*. 2019;7(1):12. doi:10.3390/medsci7010012.
 15. Leeper CM, Yazer MH, Cladis FP, Saladino R, Triulzi DJ, Gaines BA. Use of uncrossmatched cold-stored whole blood in injured children with hemorrhagic shock. *JAMA Pediatr*. 2018;172(5):491–2. doi:10.1001/jamapediatrics.2017.5238.
 16. Abir M, Taymour RK, Goldstick JE, Malsberger R, Forman J, Hammond S, Wahl K. Data missingness in the Michigan NEMSIS (MI-EMSIS) dataset: a mixed-methods study. *Int J Emerg Med*. 2021;14(1):22. doi:10.1186/s12245-021-00343-y.