International Journal of Paramedicine

Published by the National EMS Management Association (USA)

RESEARCH REPORTS

FROM AMBULANCE TO THE ICU: A RETROSPECTIVE COHORT STUDY ON EMS VASOPRESSOR USE REVEALS KEY DIFFERENCES

Hans Gao, MD[1]; Samuel I. Garcia, MD[2]; Aidan Mullan[3]; Daniel Fiterman Molinari, MD[1]; Aaron Klassen MD, MA[1]

Author Affiliations: 1. Department of Emergency Medicine, Mayo Clinic, Rochester, MN, USA; 2. Department of Pulmonary, Critical Care and Sleep Medicine, Mayo Clinic College of Medicine and Science, Rochester, MN, USA; 3. Department of Biostatistics, Mayo Clinic, Rochester, MN,USA.

**Corresponding Author*: gao.hans@mayo.edu

Recommended Citation: Gao, H., Garcia, S. I., Mullan, A., Molinari, D. F., & Klassen, A. (2025). From ambulance to the ICU: A retrospective cohort study on EMS vasopressor use reveals key differences. *International Journal of Paramedicine*. (10), 37-54. https://doi.org/10.56068/IPNA1247. Retrieved from https://internationaljournalofparamedicine.com/index.php/ijop/article/view/3281

Keywords: emergency medicine; critical care; vasopressor; shock; inotrope; transport emergency medical services, EMS, paramedicine

Received: November 27, 2024
Revised: March 24, 2025
Accepted: April 7, 2025
Published: April 16, 2025

Funding: External funding was not used to support this work.

Disclosures: The authors declare no conflicts of interest in relation to this study. The views and opinions expressed in this article are solely those of the author(s). They do not reflect the positions or policies of the Mayo Clinic Ambulance Service or the Mayo Clinic.

Presentation: This work was presented as a poster at NAEMSP 2024, held in Austin, Texas, on January 12, 2024.

Acknowledgements: Our group would like to thank Carson Rogerson, M.A.S. and Chad P. Liedl, R.N. for their work in extracting the data from Mayo Clinic Ambulance Service records. We would also like to commend the EMS crews who took care of these critically ill patients and collected the data analyzed.

ABSTRACT

Objective: Vasopressors are critical for patients experiencing shock. This observational study aims to characterize the usage of vasopressors by EMS, and to assess how vasopressor usage differs between transport and hospital environments.

Methods: A retrospective cohort study was performed from December 2019 to December 2022. Inclusion criteria were adult patients who received vasopressor infusions during transport by a large, multi-site air and ground ambulance service. These patients were followed for 12 hours after hospital admission to determine which vasopressors they required in the inpatient setting. Patients who received high-dose norepinephrine, defined as infusions higher than 0.3 µg/kg/min, were also analyzed as a subgroup.

Results: A total of 1212 patients were enrolled in this study. The vasopressor most used was norepinephrine, which was administered to 1013 (83.6%) patients. Epinephrine was administered to 163 (13.4%) patients. Vasopressin was administered to 103 (8.5%) patients, while 60 (5.0%) received dopamine. In total, 505 (41.7%) of patients received multiple vasopressors during EMS transport: two vasopressors in 409 (33.7%) and three or more in 102 (8.4%). Most patients who received vasopressors during transport continued to require vasopressors six hours after admission (n = 836, 69.0%). High-dose norepinephrine was administered to 108 (10.7%) patients during transport, 39 (5.5%) patients six hours after admission, and 16 (2.5%) patients 12 hours after admission. For these patients requiring high-dose norepinephrine, supplemental vasopressors were used in 51 (47%) patients during transport, 33 (85%) patients six hours after admission, and 14 (88%) patients 12 hours after admission. While 163 (13.4%) patients received epinephrine infusion during EMS transport, none of these patients required epinephrine infusion in the hospital ($p < 0.001$).

Conclusions: Multiple vasopressors were employed by EMS during transport, with norepinephrine being the most frequent. Other common choices for vasopressors included epinephrine and vasopressin. Most patients who received vasopressors during transport continued to require vasopressors after admission. Compared to the hospital setting, the transport setting more frequently uses high-dose norepinephrine, and is less likely to use additional vasopressors to supplement high-dose norepinephrine. The transport setting also makes greater use of epinephrine.

INTRODUCTION

Shock is a life-threatening condition characterized by inadequate oxygen delivery to cells and tissues (Baran et al., 2019; Vincent & De Backer, 2013). Shock is associated with high in-hospital mortality, with rates between 33% and 52% (Bloom et al., 2022; Jones et al., 2004; Poloujadoff et al., 2006; Wang et al., 2011). Prompt recognition and treatment of shock is therefore essential to improve outcomes (Jouffroy et al., 2022).

Fluid resuscitation and vasopressor administration are the standard treatments for patients experiencing various states of hypotension (Evans et al., 2021; Feldman et al., 2020). In the past, the initiation of vasopressors by EMS was rare due to the perceived need for central venous access and unavailability of infusion pumps (Quinn et al., 2022). However, recent research has shown that these agents can be safely administered through peripheral IV lines, and infusion pumps have been made more accessible to EMS crews (Araiza et al., 2022; Quinn et al., 2022; Raynovich et al., 2013; Tian et al., 2020). The usage of vasopressors in the hospital setting is well-studied (Gaviria-Mendoza et al., 2021; Jentzer et al., 2020; Thongprayoon et al., 2016). However, there is sparse data on vasopressor usage in the EMS setting. Administering vasopressors during transport presents several challenges, including lack of invasive hemodynamic monitoring, limited storage space for medications, and difficulties in preparing medications for administration (Feldman et al., 2020). Given these limitations, it is hypothesized that considerable differences in the choice and dosing of vasopressors may exist between EMS providers and hospital ICU teams.

Gaining a better understanding of vasopressor utilization during EMS transport would be valuable and insightful for both EMS crews and ICU teams. From the EMS perspective, this will help with decisions about which vasopressors are best to stock in order to improve readiness for treating patients who require vasopressor support. The primary objective of this study is to assess the utilization of various vasopressor agents by EMS. The secondary objectives are to compare vasopressor usage based on transport type and origin, and to compare vasopressor administration in the EMS versus hospital setting.

METHODS

Study Setting – Large multi-site multi-state air and ground ambulance service

The study ambulance service is hospital-affiliated and offers critical care services from one airplane base, three helicopter bases, and ground bases in 15 cities. The service also conducts interfacility transports from hospitals both affiliated and unaffiliated with the ambulance service's affiliated hospital system. The hospital affiliated with the study ambulance service is a level I adult and pediatric trauma center, a comprehensive stroke center, and a STEMI Receiving Center. Between December 2019 and December 2022, 1605 patients (0.70% of total transported) received vasopressor infusions during transport by RAS.

The study ambulance service operates in Minnesota and Wisconsin. In Minnesota, paramedics are allowed to practice at the scope determined by the agency director without additional oversight from state regulatory agencies. In Wisconsin, laws permit paramedics to initiate only epinephrine, norepinephrine or phenylephrine. Specially licensed am-

bulance services, including the study ambulance service, are also permitted to maintain and titrate medications during interfacility transport.

The study ambulance service has detailed guidelines regarding the usage of vasopressors. Epinephrine, norepinephrine, and infusion pumps are universally available to critical care transport crews and advanced life support (ALS) crews. Critical care transport teams are staffed by a critical care registered nurse with a second crew member who is either another critical care registered nurse or a critical care paramedic. Advanced Life Support ambulances are staffed with either a two-paramedic crew or a paramedic-EMT crew. All nurses and paramedics undergo training in initiating and titrating these vasopressors (Mayo Clinic Process/Medical Direction Committee, 2023). While push-dose epinephrine is permitted in limited circumstances, it is only used as a bridge to vasopressor infusions.

For patients started on vasopressors prior to interfacility transport, crews are authorized to continue and adjust these medications, based on orders from the referring physician or based on standing orders in patient care guidelines (Mayo Clinic Process/Medical Direction Committee, 2023). Once the transport begins, crews are limited to using the vasopressors available in the vehicle, consisting of those stocked by the ambulance service and those sent by the referring facility.

ALS crews are authorized to independently initiate vasopressors in patients who have a return of spontaneous circulation following cardiac arrest (Mayo Clinic Process/Medical Direction Committee, 2023). For all other situations, crews need authorization through medical consultation via phone or radio. Crews are permitted to administer epinephrine and norepinephrine through peripheral IV lines, if a central line is not available. According to patient care guidelines, both vasopressors should started at 0.05 µg/kg/min, with a maximum dose of 1 µg/kg/min (Mayo Clinic Process/Medical Direction Committee, 2023).

Hospital ICU teams at the Mayo Clinic adhere to guidelines that limit both epinephrine and norepinephrine to 0.3 µg/kg/min, as doses in excess of this have been associated with poorer outcomes (Domizi et al., 2020; Mayo Clinic Enterprise IVAG Workgroup, 2022). Hospital ICU teams also have access to additional vasopressors, life support devices and interventions not available in the prehospital environment.

Study Design

A retrospective cohort study was performed including data collected over three years from December 2019 to December 2022. Inclusion criteria were adult patients who received vasopressor infusion during transport by the study ambulance service. The following medications were classified as vasopressors and used for chart abstraction: dobutamine, dopamine, epinephrine, milrinone, norepinephrine, phenylephrine, and vasopressin.

Patients who had no available matching hospital records were excluded from this study. These include patients who were transported to unaffiliated hospitals, as well as unidentified patients who were registered under a placeholder name. Patients with inaccurate registration information causing mismatched EMS and hospital records were excluded as well.

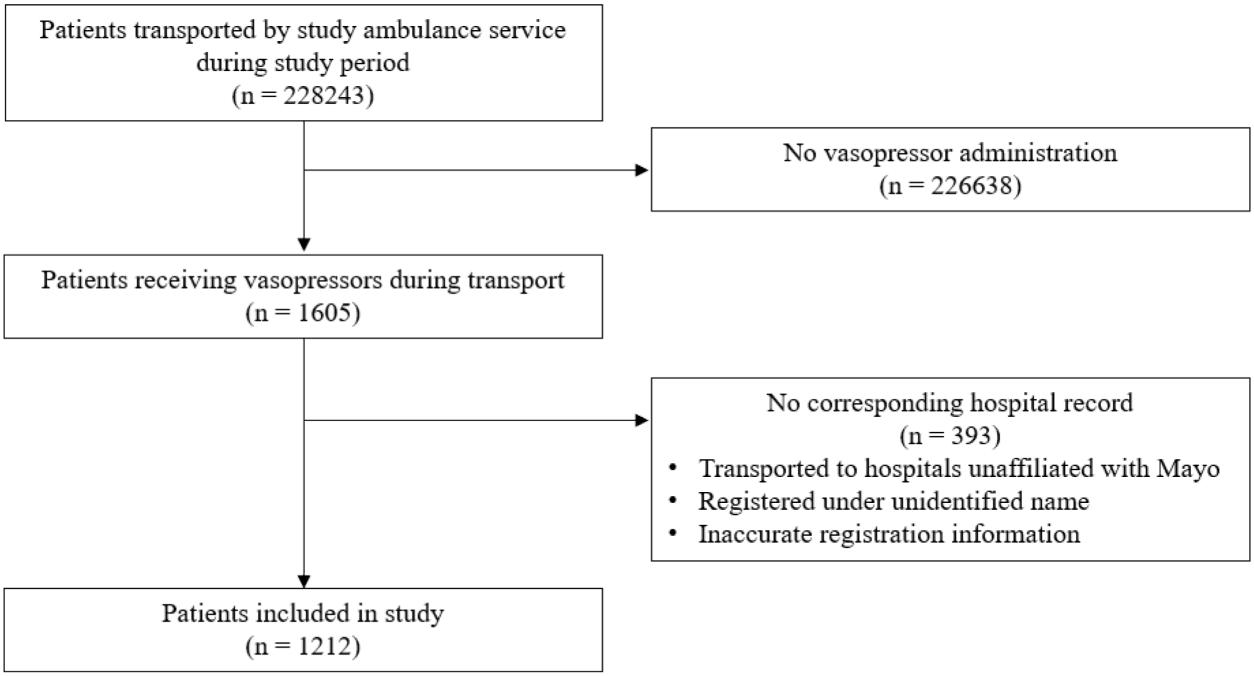

Figure 1: Inclusion and exclusion flowchart.

The flow diagram for inclusion and exclusion are displayed in Figure 1.

Patients transported multiple times by the study ambulance service were counted multiple times for data analysis reasons, as these were documented as separate EMS runs.

Patient care data was extracted from ambulance service electronic medical records. Information obtained included demographic information, run type (scene vs. interfacility), transport facility of origin (Mayo Clinic-affiliated vs. unaffiliated), medical information, and suspected causes of hypotension. Vasopressor administration data was collected from hospitals at the time of admission, 6-hours post-admission, and 12-hours post-admission.

Doses of norepinephrine or epinephrine higher than 0.3 µg/kg/min were defined as high doses. Patients are deemed to have received high-dose norepinephrine or epinephrine if they exceeded that rate at any time during transport.

Ethics approval was granted through the Mayo Clinic Institutional Review Board, under IRB 22-012805.

Statistical Analysis

Numeric features were summarized with medians and interquartile ranges (IQRs); categorical features were summarized with frequency counts and percentages. The types of vasopressors administered to patients were compared between origin of EMS transport and between pre-hospital and hospital settings (admission, 6-hours post-admission, and 12-hours post-admission) using Chi-squared and Barnard's unconditional exact tests. Differences in vasopressor administration were summarized with rate differences (RDs) and 95% confidence intervals (CIs). The dosage of norepinephrine administered was also compared between pre-hospital and hospital settings using Kruskal-Wallis tests. Pairwise post-hoc comparisons between settings were performed using Wilcoxon rank-

sum tests with a false-discovery rate p-value correction to account for multiple comparisons. All tests were two-sided and p-values less than 0.05 were considered significant. Analysis was performed using R version 4.2.2.

RESULTS

EMS Vasopressor Usage

There were 1605 patient care records involving patients receiving vasopressors from RAS; 393 were excluded because no corresponding hospital record was identified. A final cohort of 1212 patients was established for review.

A summary of patient demographics and overall vasopressor use is shown in Table 1. Of the 1212 patients, the median age was 67 years (IQR 56 - 76), and 695 (57.3%) were male. Fifty-one patients (4.2%) were pediatric patients.

Septic shock was the most common indication for vasopressor administration, accounting for 47.0% of all cases. Cardiogenic shock was the second most common, comprising 25.3% of cases, with cardiac arrest specifically representing 9.1%. Multifactorial shock accounted for 8.7% of cases, while nontraumatic hemorrhage made up 5.2%.

Among vasopressors used by EMS, norepinephrine was the most frequently administered (83.6%), followed by epinephrine (13.4%), vasopressin (8.5%), dopamine (5.0%), milrinone (3.8%), phenylephrine (1.8%), and dobutamine (1.1%).

Most patients (n = 701, 57.8%) received only a single vasopressor during transport. Approximately one-third of patients (n = 409, 33.7%) received two vasopressors. The remainder (n = 102, 8.4%) required three or more vasopressors.

EMS Norepinephrine Dosing

EMS norepinephrine use is shown in Table 2. The median dose of norepinephrine was 0.10 µg/kg/min (IQR: 0.05 – 0.20). High-dose norepinephrine was administered to 108 (10.7%) patients. There were also six (0.6%) patients who received norepinephrine at 1 µg/kg/min or higher, exceeding the limit explicitly recommended by ambulance service guidelines.

	N = 1212
Age, years	
Median (Q1, Q3)	67 (56, 76)
Sex, n (%)	
Female	500 (41.3%)
Male	695 (57.3%)
Transgender	1 (0.1%)
Unknown/Did Not Disclose	16 (1.3%)
Race, n (%)	
American Indian/Alaskan Native	5 (0.4%)
Asian	14 (1.2%)
Black or African American	21 (1.7%)
Hispanic or Latino	22 (1.8%)
White	818 (67.5%)
Unknown/Did Not Disclose	332 (27.4%)
Indications, n (%)	
Sepsis	570 (47.0%)
Non-Arrest Cardiac Indication	196 (16.2%)
Cardiac Arrest	110 (9.1%)
Multifactorial	105 (8.7%)
Nontraumatic Hemorrhage	63 (5.2%)
Other/Unknown	167 (13.8%)
EMS Origin, n (%)	
Mayo Clinic	956 (78.9%)
OSH	233 (19.2%)
Scene	23 (1.9%)
Vasopressor Administered, n (%) *	
Norepinephrine	1013 (83.6%)
Epinephrine	163 (13.4%)
Vasopressin	103 (8.5%)
Dopamine	60 (5.0%)
Milrinone	46 (3.8%)
Phenylephrine	22 (1.8%)
Dobutamine	13 (1.1%)
Total Different Vasopressors Administered	
Median (Q1, Q3)	1 (1, 2)
Patients on 2 vasopressors	409 (33.7%)
Patients on 3 or more vasopressors	102 (8.4%)
* Percentages do not add up to 100%, as many patients received multiple vasopressors	

Table 1. Summary of patient demographics, visit characteristics, and overall vasopressor use.

None of the patients in our study received epinephrine infusions in excess of 0.3 µg/kg/min.

	EMS (N = 1013)
Average Dose (IQR) µg/kg/min	0.10 (0.05, 0.20)
Patients given dose > 0.3 µg/kg/min	108 (10.7%)
Patients given dose > 1.0 µg/kg/min	6 (0.6%)

Table 2. Norepinephrine dosing.

EMS Vasopressor Usage by Run Type (Scene vs. Interfacility)

Vasopressor usage was compared between patients by run type, as either unplanned emergency transport from the scene or prearranged interfacility transport (Table 3). Norepinephrine was the most widely used vasopressor for both groups, with epinephrine being the second most widely used. However, patients being transported from the scene were more likely to be on epinephrine (35% vs. 13%; RD = 21.7%, 95% CI: 1.1 to 43.5%; $p = 0.039$), while interfacility transport patients were more likely to receive norepinephrine (84% vs. 61%; RD 23.2%, 95% CI: 2.5 to 44.5%; $p = 0.039$).

Vasopressor	Scene (N = 23)	Interfacility (N = 1189)	Rate Difference (95% CI)	*p*-Value
Norepinephrine	14 (61%)	999 (84.0%)	23.2% (2.5%, 44.5%)	0.028
Epinephrine	8 (35%)	155 (13.0%)	-21.7% (-43.5%, -1.1%)	0.039
Vasopressin	0 (0%)	103 (8.7%)	8.7% (-12.0%, 29.5%)	0.42
Dopamine	2 (9%)	58 (4.9%)	-3.8% (-24.5%, 16.9%)	0.72
Milrinone	0 (0%)	46 (3.9%)	3.9% (-17.0%, 24.8%)	0.73
Phenylephrine	0 (0%)	22 (1.9%)	1.9% (-18.9%, 22.6%)	> 0.99
Dobutamine	0 (0%)	13 (1.1%)	1.1% (-19.6%, 21.8%)	> 0.99
* Percentages do not add up to 100%, as some patients received multiple vasopressors				

Table 3. Administration of vasopressors by transport type.

Interfacility Transport Vasopressor Usage by Facility of Origin

Patients undergoing prearranged transport between healthcare facilities were further divided based on whether the transport originated at an affiliated hospital or unaffiliated hospital (see Table 4). In both groups, norepinephrine was the most widely used, while epinephrine was the second most widely used. Patients being transported from affiliated hospitals were more likely to be receive norepinephrine ($p < 0.001$). Patients being transported form unaffiliated hospitals were more likely to receive milrinone ($p < 0.001$).

	Mayo-Affiliated (N = 956)	Unaffiliated (N = 256)	*p*-Value
Norepinephrine	816 (85.4%)	183 (71.5%)	< 0.001
Epinephrine	123 (12.9%)	32 (12.5%)	0.96
Vasopressin	88 (9.2%)	15 (5.9%)	0.11
Dopamine	41 (4.3%)	17 (6.6%)	0.16
Milrinone	22 (2.3%)	24 (9.4%)	< 0.001
Phenylephrine	18 (1.9%)	4 (1.6%)	0.94
Dobutamine	12 (1.3%)	1 (0.4%)	0.32
* Percentages do not add up to 100%, as some patients received multiple vasopressors			

Table 4. Administration of vasopressors during interfacility transport by hospital of origin.

EMS vs. Hospital Vasopressors

Differences in vasopressor usage between the EMS and hospital settings are shown in Table 5. Of the 1212 patients who received vasopressors

during EMS transport, 1033 (85.2%) continued to receive vasopressors at time of admission. Similar patterns were observed at 6 hours and 12 hours after admission, with 69.0% and 60.3% of patients continuing to receive vasopressors respectively.

	EMS (N = 1212)	Admission (N = 1033)	6-Hr Post-Adm (N = 836)	12-Hr Post-Adm (N = 731)	*p*-Value
Norepinephrine	1013 (83.6%)	907 (87.8%)	714 (85.4%)	630 (86.2%)	0.040
Epinephrine	163 (13.4%)	0 (0%)	0 (0%)	0 (0%)	< 0.001
Vasopressin	103 (8.5%)	153 (14.8%)	270 (32.3%)	268 (36.7%)	< 0.001
Dopamine	60 (5.0%)	39 (3.8%)	47 (5.6%)	37 (5.1%)	0.29
Milrinone	46 (3.8%)	27 (2.6%)	43 (5.1%)	48 (6.6%)	< 0.001
Phenylephrine	22 (1.8%)	12 (1.2%)	8 (1.0%)	5 (0.7%)	0.12
Dobutamine	13 (1.1%)	0 (0%)	0 (0%)	0 (0%)	< 0.001
* Percentages do not add up to 100%, as some patients received multiple vasopressors					

Table 5. Frequency of vasopressor usage by setting.

Norepinephrine was the most commonly used vasopressor in both EMS and hospital settings. It was administered to over 80% of patients in both groups, though its usage was slightly lower in EMS compared to the hospital ($p = 0.040$). Epinephrine, the second most frequently used vasopressor in EMS, was not administered to any patients in the hospital setting ($p < 0.001$). Vasopressin ranked third in EMS usage but was the second most commonly used vasopressor in the hospital, with significantly higher administration in the hospital setting ($p < 0.001$). Other vasopressors, including dobutamine, dopamine, milrinone, and phenylephrine, were used infrequently in both settings.

The median dose of norepinephrine administered by EMS was 0.10 µg/kg/min, slightly higher than the median dose in the hospital (0.07–0.08 µg/kg/min, $p < 0.001$). Figure 2 illustrates the doses of norepinephrine used in EMS and hospital settings, while Figure 3 tracks the patients on norepinephrine across these settings.

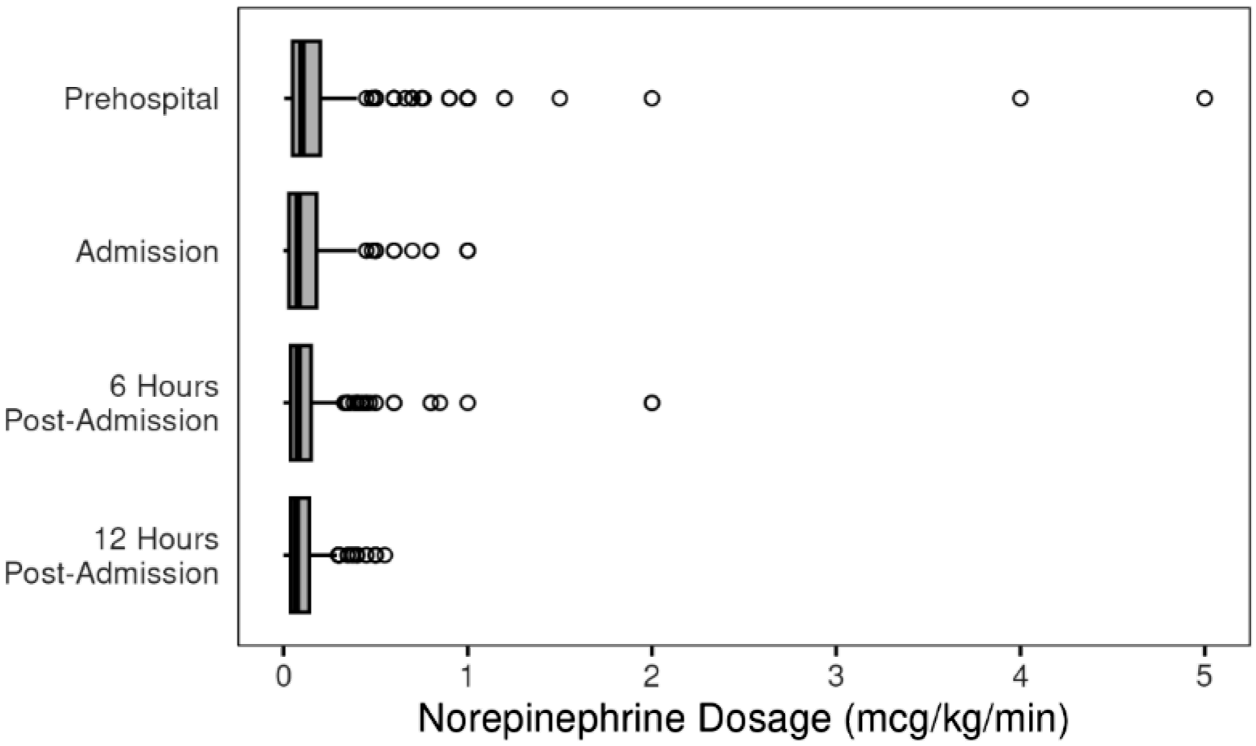

Figure 2: Dosage of norepinephrine by setting

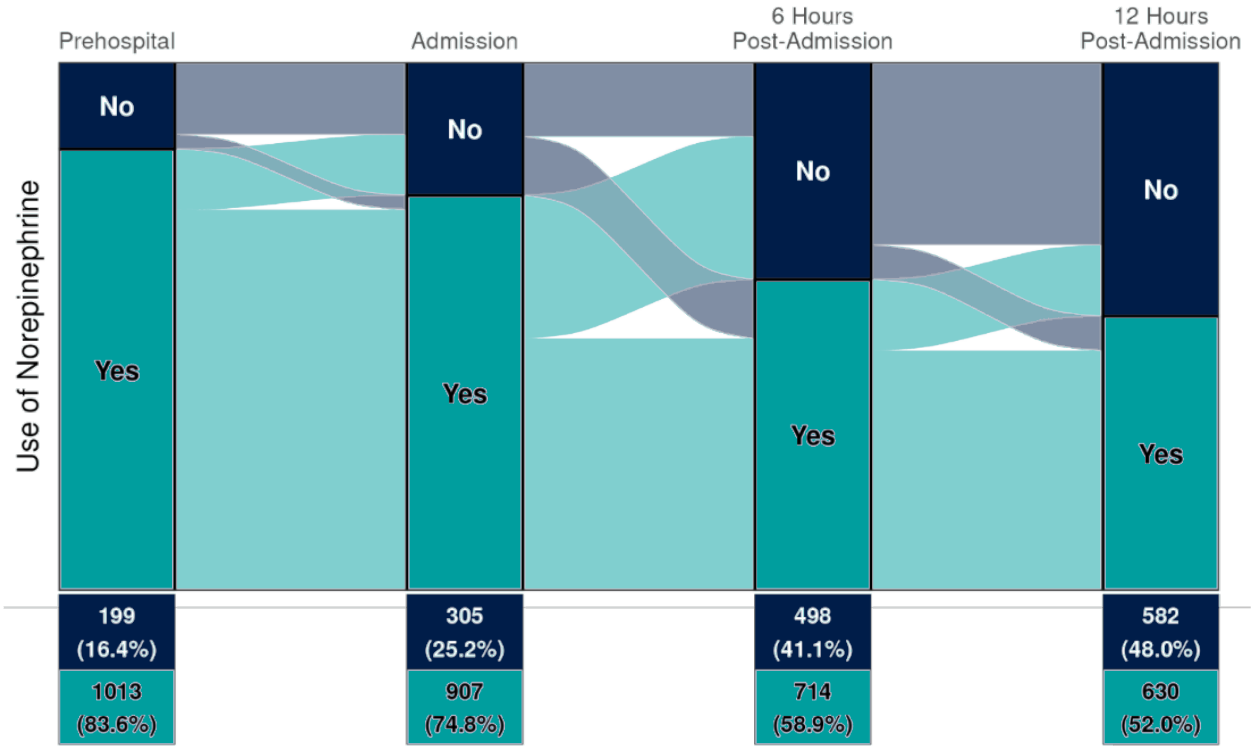

Figure 3: Continued administration of norepinephrine across settings.

	Prehospital/EMS (N = 1013)	Admission (N = 907)	6-Hr Post-Adm (N = 714)	12-Hr Post-Adm (N = 630)	*p*-Value
Median dose (Q1, Q3)	0.10 (0.05, 0.20)	0.08 (0.03, 0.18)	0.08 (0.04, 0.15)	0.07 (0.04, 0.14)	< 0.001
Norepinephrine Threshold: 0.3 µg/kg/min					
Patients given dose > 0.3 µg/kg/min	108 (10.7%)	44 (4.9%)	39 (5.5%)	16 (2.5%)	< 0.001
Other vasopressors during the same period for patients given > 0.3 µg/kg/min norepinephrine					
Epinephrine	30 (27.8%)	0 (0%)	0 (0%)	0 (0%)	
Vasopressin	14 (13.0%)	20 (45.5%)	30 (76.9%)	11 (68.8%)	
Dopamine	2 (1.9%)	2 (4.5%)	1 (2.6%)	2 (12.5%)	
Milrinone	0 (0%)	1 (2.3%)	0 (0%)	0 (0%)	
Phenylephrine	3 (2.8%)	0 (0%)	2 (5.1%)	1 (6.2%)	
Dobutamine	2 (1.9%)	0 (0%)	0 (0%)	0 (0%)	
Combined	51 (47.2%)	23 (52.3%)	33 (84.6%)	14 (87.5%)	< 0.001
Norepinephrine Threshold: 1.0 µg/kg/min					
Patients given dose > 1.0 µg/kg/min	6 (0.6%)	0 (0%)	2 (0.3%)	0 (0%)	0.025
Other vasopressors during the same period for patients given > 1.0 µg/kg/min norepinephrine					
Epinephrine	2 (33%)	---	0 (0%)	---	
Vasopressin	0 (0%)	---	1 (50%)	---	
Combined	2 (33%)	---	1 (50%)	---	
* Percentages do not add up to 100%, as some patients received multiple vasopressors					

Table 6. Frequency of norepinephrine doses exceeding max recommended rate.

EMS patients were also more likely to receive high-dose norepinephrine ($p < 0.001$). Additional data on usage of high-dose norepinephrine is shown in Table 6. During EMS transport, 108 patients (10.7%) received high-dose norepinephrine. Upon hospital admission, this number decreased to 44 patients (4.9%), and at 12 hours post-admission, only 16 patients (2.5%) still required high-dose norepinephrine.

EMS patients on high-dose norepinephrine were less likely to receive supplemental vasopressors ($p < 0.001$). During EMS transport and admission, supplemental vasopressors were used in 51 (47%) and 23 (52%) patients respectively. At 6 and 12 hours after admission, 33 (85%) and 14 (88%) patients were receiving supplemental vasopressors.

There were six cases (0.6%) in which EMS exceeded the recommended norepinephrine maximum of 1.0 µg/kg/min. It was less common for this limit to be exceeded in the hospital setting, with only two (0.3%) patients doing so ($p = 0.025$).

DISCUSSION

EMS Vasopressor Use

Norepinephrine was the most widely used agent by a large margin in both the EMS and hospital environments. However, the relative usage of norepinephrine, along with the usage of other vasopressors, still differed significantly with regards to transport type, transport origin, and environment.

Vasopressor Usage, Choice, and Transport Characteristics

The predominant use of norepinephrine is likely due to a combination of clinical and practical concerns. The most common causes of shock are septic shock and cardiogenic shock, which account for 62% and 16% of shock cases respectively (Chen et al., 2020). Norepinephrine is recommended as the first-line agent for septic shock, per Surviving Sepsis Campaign guidelines (Evans et al., 2021). In cardiogenic shock, norepinephrine is also associated with lower mortality and lower rates of refractory shock, when compared to dopamine or epinephrine (De Backer et al., 2010; Feldman et al., 2020; Levy et al., 2018). From a practical standpoint, norepinephrine is widely available, and vials have a long shelf-life of 18 months (Pfizer, 2022). Due to these factors, norepinephrine has been identified as a "one-size-fits-all" vasopressor, which would meet the needs of most shock patients encountered by EMS (Feldman et al., 2020).

It was rare for EMS crews to exceed the maximum norepinephrine dose of 1 µg/kg/min established in ambulance service guidelines, with this occurring in less than 1% of patients receiving norepinephrine. Our data may raise concerns that a strict limit on norepinephrine dosing at 0.3 µg/kg/min, similar to that used by hospital ICU teams, may be impractical during transport, as more than 10% of patients received norepinephrine doses above this rate (Domizi et al., 2020; Mayo Clinic Enterprise IVAG Workgroup, 2022).

Epinephrine, the second most used vasopressor by EMS, also has distinct advantages. Epinephrine is considered the first-line agent in anaphylactic shock, remains the mainstay of ACLS, and is used to treat bradycardia and hypotension after a return of spontaneous circulation (Brown et al., 2020; Campbell et al., 2014; Lokesh et al., 2018; Smida et al., 2024). Among the 163 patients who received epinephrine during EMS transport,

59 (36.2%) had cardiac arrest, while 18 (11.0%) were being treated for anaphylaxis. In our study, patients being transported from the scene were more likely to be administered epinephrine than patients undergoing interfacility transport. This difference could be due to the higher incidences of cardiac arrest cases amongst patients being transported from the scene. In our study, cardiac arrest accounted for 73.9% of scene transports, compared to 7.8% in the interfacility transport group. The epinephrine maximum dose of 1 µg/kg/min was never exceeded.

Vasopressin was the third most widely used vasopressor used by EMS, administered to 8.5% of patients. Surviving Sepsis Campaign guidelines recommend vasopressin for septic shock refractory to norepinephrine monotherapy (Evans et al., 2021). The combination of vasopressin and norepinephrine has been shown to have a lower risk of arrhythmia, when compared to norepinephrine alone (McIntyre et al., 2018; Nagendran et al., 2019). However, the Surviving Sepsis Campaign guidelines do not recommend vasopressin as the sole vasopressor in septic shock (Evans et al., 2021). Vasopressin is considered more dangerous to administer through peripheral access, so its usage is often restricted to patients with central lines (Kahn et al., 2002; Munroe et al., 2022). Vasopressin can also be expensive and scarce, further limiting its utility in EMS (Rivosecchi et al., 2024; Sizemore et al., 2022).

The fourth most widely used vasopressor, dopamine, was administered to 5.0% of patients. Dopamine, which had previosuly been carried by ambulance service critical care teams, was once the most widely used EMS vasopressor in the United States, according to data from the National EMS Information System in 2017 (V3 EMS Data Cube). However, it has since fallen out of favor. Two systematic reviews comparing dopamine to norepinephrine in septic shock indicated that dopamine was associated a higher incidence of arrhythmias and higher mortality (Avni et al., 2015; De Backer et al., 2010). One systematic review also found that dopamine is also associated with higher mortality in cardiogenic shock (De Backer et al., 2010). As such, Surviving Sepsis Campaign discourages the use of dopamine when norepinephrine is available, and the American Heart Association has also advised against dopamine in ischemic cardiogenic shock (Evans et al., 2021; O'Gara et al., 2013).

The inotropes milrinone and dobutamine were the fifth and seventh most widely used vasopressors in our study, being used in 3.8% and 1.1% of patients respectively. Although both are used in the management of cardiogenic shock, they are associated with higher risks of arrhythmias and mortality (Abraham et al., 2005; Cuffe et al., 2002; Petersen & Felker, 2008). The American Heart Association guidelines on cardiogenic shock only recommend inotropes after hemodynamic stabilization for most types of cardiogenic shock (van Diepen et al., 2017). Similarly, the Surviving Sepsis Campaign only recommends inotropes for very specific cases of septic shock associated with myocardial dysfunction (Evans et al., 2021). A recent randomized controlled trial comparing milrinone to dobutamine found no significant differences in outcomes (Mathew et al., 2021). Our study found that patients being transferred from unaffiliated hospital systems were more likely to receive milrinone than patients being transported from affiliated hospitals. The cause of this variation remains unclear, but it could reflect differences in institutional protocols.

Lastly, phenylephrine was the sixth most widely used vasopressor in our study. Although previous Surviving Sepsis Campaign guidelines from 2012 recommended phen-

ylephrine in some very limited cases of septic shock, the newest guidelines from 2021 make no mention of phenylephrine (Dellinger et al., 2013; Evans et al., 2021). By increasing systemic vascular resistance and afterload, phenylephrine may compromise cardiac function in many shock states, leading to worsening hemodynamics (Ducrocq et al., 2012; Thiele et al., 2011). Studies on neurogenic shock have also shown that phenylephrine use is associated with increased arrhythmias (Inoue et al., 2014; Readdy et al., 2015).

EMS vs. Hospital Usage of Vasopressors

Several intriguing phenomena emerged when comparing EMS vasopressor usage with hospital vasopressor usage. First, vasopressors were usually continued after EMS transport. Second, EMS was more likely to use high-dose norepinephrine, while being less likely to use supplemental vasopressors. Third, EMS made significantly greater use of epinephrine.

Most patients who received vasopressors from EMS continued to require vasopressors after hospitalization, with a majority continuing to require vasopressors at 12 hours. These results are consistent with a previous study on ICU vasopressor administration, which found that the median duration of vasopressor administration through peripheral IV access was 19 hours (Lewis et al., 2019). The gradual decrease in the percentage of patients receiving vasopressors over time in our data was likely due to patients being weaned off pressors as the underlying causes of their hypotension were addressed.

More than 10% of norepinephrine patients in the EMS setting received high-dose norepinephrine, compared to 2.5% to 5.5% in the hospital setting. Many guidelines on shock management recommend the initiation of a supplemental agent when norepinephrine requirements exceed 0.3 µg/kg/min (Evans et al., 2021; Mayo Clinic Enterprise IVAG Workgroup, 2022; Mayo Clinic Process/Medical Direction Committee, 2023). In our study, patients who require high-dose norepinephrine in the hospital are often placed on supplemental vasopressors, employed in 52.3% to 87.5% of such cases. In contrast, EMS employs supplemental vasopressors in less than half of such cases.

These differences in norepinephrine dosing and the use of supplemental vasopressors likely stem from multiple factors. Patients transported by EMS are often in a more acute phase of illness, with greater hemodynamic instability. This heightened instability would necessitate higher doses of norepinephrine to maintain target mean arterial pressures. Additionally, the resource and time constraints of the EMS transport setting may hinder the initiation of supplemental vasopressors. In contrast, the ICU setting provides additional personnel and pharmacy resources, allowing for more controlled titration and the timely introduction of supplemental vasopressors as needed.

Another key factor contributing to differences in norepinephrine dosing and supplemental vasopressor use would be the accessibility of supplemental vasopressors. EMS crews are limited to the vasopressors they stock or those provided by a referring hospital. Epinephrine and norepinephrine are the only two vasopressors stocked by the study ambulance service. While some patients are loaded into the ambulance with supplemental vasopressors already running, continuing these vasopressors once the initial dose is exhausted requires additional supply from the referring facility. In the absense of additional vasopressors, EMS crews may compensate by increasing the dosing of the primary

vasopressor. To ensure safe patient transport, it is essential that EMS crews have access to adequate supplies of vasopressors for the anticipated duration of the transport.

The use of epinephrine varies significantly between the EMS and hospital settings, likely due to its immediate availability for EMS personnel. Cases of cardiac arrest and anaphylaxis may also contribute to these differences. EMS crews are more likely to encounter patients immediately after cardiac arrest, and to treat patients in the acute phase of anaphylaxis (Lee et al., 2018). Epinephrine infusions act rapidly, with most patients experiencing resolution of anaphylaxis symptoms within six minutes (Fujizuka et al., 2022). Many cardiac arrest and anaphylaxis patients would have been weaned off epinephrine infusions during EMS transport.

Both epinephrine and vasopressin are deemed effective supplements to norepinephrine in septic shock, with similar survival and arrhythmia risks (Menich et al., 2019). However, vasopressin is generally preferred in the hospital setting. A recent systemic review and meta-analysis demonstrated that vasopressin supplementation is associated with reduced mortality and reduced incidence of atrial fibrillation in patients with distributive shock (McIntyre et al., 2018). The higher cost and central access requirements associated with vasopressin less of a barrier to use in the hospital setting.

Significance

To our knowledge, this is the first observational study to examine vasopressor use throughout a large EMS system without restriction to a specific indication. Moreover, this study also follows patients after EMS transport to characterize vasopressor usage after admission to the ICU. While a previous study has examined the usage of vasopressors across multiple EMS systems, it was limited to only two vasopressors and cases of cardiac arrest (Smida et al., 2024). Our broader study has important implications for clinicians, EMS medical directors, healthcare policymakers, and other EMS systems. As EMS crews continue to transport critically ill patients, there is an increasing need for a quantitative and systematic approach to analyzing the vasopressors used, as well as the factors that affect vasopressor usage. Our data may facilitate the development and implementation of future guidelines on EMS vasopressor usage and direct other EMS systems on which vasopressors to carry and stock.

Previous efforts at identifying a "one-size-fits-all" vasopressor have concluded that norepinephrine can treat the most frequently encountered causes of prehospital shock (Feldman et al., 2020). While norepinephrine was the most used vasopressor in both the EMS and ICU settings, our study also shows that a "one-size-fits-all" approach may fail to meet the needs of many patients. More than 40% of patients in our study required multiple vasopressors, and 16.4% of patients did not receive any norepinephrine during transport. It is not known whether patient outcomes would be impacted by having additional vasopressors available.

Our study yields several positive and promising results. It demonstrates that most vasopressor infusions during EMS transport were continued during and after admission to the hospital, and it was rare for crews to exceed the recommended limit in their guidelines. EMS crews are able to employ a wide variety of vasopressors, beyond those stocked in their ambulances. The choice of vasopressors used by EMS largely aligns with the latest healthcare research and guidelines.

However, our study also identifies several areas for improvement. Due to logistical constraints, the study ambulance service only stocks epinephrine and norepinephrine. While these were the most widely used vasopressors in our study, more than 20% of patients received other vasopressors. This highlights the challenges faced when determining how to stock an ambulance, given the space constraints and regulatory limitations. Hospital ICU teams could better prepare patients for transport by ensuring processes exist to provide EMS crews with adequate supplies of medications for known or anticipated patient needs during transport.

The optimal vasopressors for an EMS system to stock would depend on several factors, including the population served, the transport times, regulatory considerations and the capabilities of its personnel. In the case of the study ambulance service, which already carries epinephrine and norepinephrine, the addition of vasopressin may be the most beneficial, because it was the next most-used vasopressor and is considered the best adjuct to norepinephrine for septic shock. (Evans et al., 2021). However, in one state where the study ambulance service provides care, this would be prohibited by state regulation. Improving access to vasopressin in the EMS setting could help reduce the usage of high-dose norepinephrine and ensure better stability and outcomes for septic shock patients who do not respond to norepinephrine alone, but this would have financial, educational, logistic and regulatory implications.

LIMITATIONS

This study is limited by its retrospective and observational nature. This study is largely descriptive, with all inferential statistics unadjusted for potential confounders and without a prespecified analytic plan. Thus, all inferences are exploratory and hypothesis-generating for future studies.

Only a small number of patients were being transported from the scene, limiting analysis with respect to unplanned emergency transport from the scene. This study does not seek to analyze the effect of the underlying diagnosis, available IV access, or type of EMS crew involved. The study was also done within a single EMS system. Our results are not generalizable to EMS systems that extensively use push-dose vasopressors or those without access to IV pumps.

The retrospective nature of this study limits our ability to determine the specific factors influencing vasopressor selection and dosing in prehospital shock management. Similarly, we could not assess the blood pressure thresholds prompting vasopressor initiation or patient responses to infusion. A detailed analysis of vasopressor preferences based on shock etiology falls beyond the scope of this paper.

The inclusion and exclusionary criteria also led to some limitations. Patients were included when they received vasopressors during transport, regardless of the underlying disease process. There were several cases in which patients received vasopressors for reasons other than shock, such as airway protection in asthma. There were also several cases in which patients only developed hypotension after being started on sedation medications. Acutely ill patients transported from the scene are often registered under placeholder names by EMS, which may differ from names used by the hospital. These discrepancies could have caused more acutely ill patients to be excluded from our study,

decreasing the number of patients being transported from the scene and biasing the results.

While our paper seeks to identify differences in the ways that vasopressors are employed by EMS and hospitals, the analysis is still inferential. We also did not have a pre-registered or pre-established plan for data analysis.

CONCLUSION

This study identifies the most common vasopressors employed by EMS. The most ubiquitous vasopressor was norepinephrine, which was used in over 83% of patients. Other common choices for vasopressors by EMS included epinephrine and vasopressin. Although norepinephrine and epinephrine were the most widely used regardless of run type or transport facility of origin, these factors still had a significant effect on the choice of vasopressor agent. Compared to the hospital, EMS crews were more likely to use high-dose norepinephrine, more likely to use epinephrine, and less likely to use supplemental vasopressors.

REFERENCES

Abraham, W. T., Adams, K. F., Fonarow, G. C., Costanzo, M. R., Berkowitz, R. L., LeJemtel, T. H., Cheng, M. L., & Wynne, J. (2005). In-Hospital Mortality in Patients With Acute Decompensated Heart Failure Requiring Intravenous Vasoactive Medications. *Journal of the American College of Cardiology, 46*(1), 57–64. https://doi.org/10.1016/j.jacc.2005.03.051

Araiza, A., Duran, M., & Varon, J. (2022). Administration of vasopressors through peripheral venous catheters. *Canadian Medical Association Journal, 194*(21), E739–E739. https://doi.org/10.1503/cmaj.211966

Avni, T., Lador, A., Lev, S., Leibovici, L., Paul, M., & Grossman, A. (2015). Vasopressors for the Treatment of Septic Shock: Systematic Review and Meta-Analysis. *PLOS ONE, 10*(8), e0129305. https://doi.org/10.1371/journal.pone.0129305

Baran, D. A., Grines, C. L., Bailey, S., Burkhoff, D., Hall, S. A., Henry, T. D., Hollenberg, S. M., Kapur, N. K., O'Neill, W., Ornato, J. P., Stelling, K., Thiele, H., van Diepen, S., & Naidu, S. S. (2019). SCAI clinical expert consensus statement on the classification of cardiogenic shock. *Catheterization and Cardiovascular Interventions, 94*(1), 29–37. Portico. https://doi.org/10.1002/ccd.28329

Bloom, J. E., Andrew, E., Dawson, L. P., Nehme, Z., Stephenson, M., Anderson, D., Fernando, H., Noaman, S., Cox, S., Milne, C., Chan, W., Kaye, D. M., Smith, K., & Stub, D. (2022). Incidence and Outcomes of Nontraumatic Shock in Adults Using Emergency Medical Services in Victoria, Australia. *JAMA Network Open, 5*(1), e2145179. https://doi.org/10.1001/jamanetworkopen.2021.45179

Brown, J. C., Simons, E., & Rudders, S. A. (2020). Epinephrine in the Management of Anaphylaxis. The Journal of Allergy and Clinical Immunology: *In Practice, 8*(4), 1186–1195. https://doi.org/10.1016/j.jaip.2019.12.015

Campbell, R. L., Li, J. T. C., Nicklas, R. A., & Sadosty, A. T. (2014). Emergency department diagnosis and treatment of anaphylaxis: A practice parameter. *Annals of Allergy, Asthma & Immunology, 113*(6), 599–608. https://doi.org/10.1016/j.anai.2014.10.007

Chen, J.-T., Roberts, R., Fazzari, M. J., Kashani, K., Qadir, N., Cairns, C. B., Mathews, K., Park, P., Khan, A., Gilmore, J. F., Brown, A. R. T., Tsuei, B., Handzel, M., Lee Chang, A., Duggal, A., Lanspa, M., Herbert, J. T., Martinez, A., … Tonna, J. (2020). Variation in Fluid and Vasopressor Use in Shock With and Without Physiologic Assessment: A Multicenter Observational Study. *Critical Care Medicine, 48*(10), 1436–1444. https://doi.org/10.1097/ccm.0000000000004429

Cuffe, M. S. (2002). Short-term Intravenous Milrinone for Acute Exacerbation of Chronic Heart Failure: A Randomized Controlled Trial; *JAMA, 287*(12), 1541. https://doi.org/10.1001/jama.287.12.1541

De Backer, D., Biston, P., Devriendt, J., Madl, C., Chochrad, D., Aldecoa, C., Brasseur, A., Defrance, P., Gottignies, P., & Vincent, J.-L. (2010). Comparison of Dopamine and Norepinephrine in the Treatment of Shock. *New England Journal of Medicine, 362*(9), 779–789. https://doi.org/10.1056/nejmoa0907118

Dellinger, R. P., Levy, M. M., Rhodes, A., Annane, D., Gerlach, H., Opal, S. M., Sevransky, J. E., Sprung, C. L., Douglas, I. S., Jaeschke, R., Osborn, T. M., Nunnally, M. E., Townsend, S. R., Reinhart, K., Kleinpell, R. M., Angus, D. C., Deutschman, C. S., Machado, F. R., … Rubenfeld, G. D. (2013). Surviving Sepsis Campaign. *Critical Care Medicine, 41*(2), 580–637. https://doi.org/10.1097/ccm.0b013e31827e83af

Domizi, R., Calcinaro, S., Harris, S., Beilstein, C., Boerma, C., Chiche, J.-D., D'Egidio, A., Damiani, E., Donati, A., Koetsier, P. M., Madden, M. P., McAuley, D. F., Morelli, A., Pelaia, P., Royer, P., Shankar-Hari, M., Wickboldt, N., Zolfaghari, P., & Singer, M. (2020). Relationship between norepinephrine dose, tachycardia and outcome in septic shock: A multicentre evaluation. *Journal of Critical Care, 57*, 185–190. https://doi.org/10.1016/j.jcrc.2020.02.014

Ducrocq, N., Kimmoun, A., Furmaniuk, A., Hekalo, Z., Maskali, F., Poussier, S., Marie, P.-Y., & Levy, B. (2012). Comparison of Equipressor Doses of Norepinephrine, Epinephrine, and Phenylephrine on Septic Myocardial Dysfunction. *Anesthesiology, 116*(5), 1083–1091. https://doi.org/10.1097/aln.0b013e31824f9669

Evans, L., Rhodes, A., Alhazzani, W., Antonelli, M., Coopersmith, C. M., French, C., Machado, F. R., Mcintyre, L., Ostermann, M., Prescott, H. C., Schorr, C., Simpson, S., Wiersinga, W. J., Alshamsi, F., Angus, D. C., Arabi, Y., Azevedo, L., Beale, R., Beilman, G., … Levy, M. (2021). Surviving Sepsis Campaign: International Guidelines for Management of Sepsis and Septic Shock 2021. *Critical Care Medicine, 49*(11), e1063–e1143. https://doi.org/10.1097/ccm.0000000000005337

Feldman, R., Stanton, M., Chinn, M., Grawey, T., & Weston, B. (2020). Choosing a Vasopressor for a Prehospital Emergency Medical System: Consideration for Agent Selection and Review of Pharmacologic Profiles, Efficacy, and Safety in Treatment of Shock. *WMJ, 119*(4), 240-247. https://www.ncbi.nlm.nih.gov/pubmed/33428833

Fujizuka, K., Nakamura, M., Tamura, J., & Kawai-Kowase, K. (2022). Comparison of the efficacy of continuous intravenous infusion versus intramuscular injection of epinephrine for initial anaphylaxis treatment. *Acute Medicine & Surgery, 9*(1). Portico. https://doi.org/10.1002/ams2.790

Gaviria-Mendoza, A., Machado-Alba, J. E., Benítez-Mejía, J. F., Correa-Ruiz, S., Restrepo-López, J. S., Moreno-Gutiérrez, P. A., & Gómez-González, J. F. (2021). Trends of vasopressor use in intensive care units in Colombia. *Colombian Journal of Anesthesiology*. https://doi.org/10.5554/22562087.e996

Inoue, T., Manley, G. T., Patel, N., & Whetstone, W. D. (2014). Medical and Surgical Management after Spinal Cord Injury: Vasopressor Usage, Early Surgerys, and Complications. *Journal of Neurotrauma, 31*(3), 284–291. https://doi.org/10.1089/neu.2013.3061

Jentzer, J. C., Wiley, B., Bennett, C., Murphree, D. H., Keegan, M. T., Kashani, K. B., Bell, M. R., & Barsness, G. W. (2020). Temporal Trends and Clinical Outcomes Associated with Vasopressor and Inotrope Use in The Cardiac Intensive Care Unit. *Shock, 53*(4), 452–459. https://doi.org/10.1097/shk.0000000000001390

Jones, A. E., Stiell, I. G., Nesbitt, L. P., Spaite, D. W., Hasan, N., Watts, B. A., & Kline, J. A. (2004). Nontraumatic out-of-hospital hypotension predicts inhospital mortality. *Annals of Emergency Medicine, 43*(1), 106–113. https://doi.org/10.1016/j.annemergmed.2003.08.008

Jouffroy, R., Hajjar, A., Gilbert, B., Tourtier, J. P., Bloch-Laine, E., Ecollan, P., Boularan, J., Bounes, V., Vivien, B., & Gueye, P.-N. (2022). Prehospital norepinephrine administration reduces 30-day mortality among septic shock patients. *BMC Infectious Diseases, 22*(1). https://doi.org/10.1186/s12879-022-07337-y

Kahn, J. M., Kress, J. P., & Hall, J. B. (2002). Skin necrosis after extravasation of low-dose vasopressin administered for septic shock. *Critical Care Medicine, 30*(8), 1899–1901. https://doi.org/10.1097/00003246-200208000-00038

Lee, S. Y., Lee, S. C., Shin, S. D., Song, K. J., Ro, Y. S., Park, J. H., & Kong, S. Y. (2018). Epidemiology and outcomes of anaphylaxis-associated out-of-hospital cardiac arrest. *PLOS ONE, 13*(3), e0194921. https://doi.org/10.1371/journal.pone.0194921

Levy, B., Clere-Jehl, R., Legras, A., Morichau-Beauchant, T., Leone, M., Frederique, G., Quenot, J.-P., Kimmoun, A., Cariou, A., Lassus, J., Harjola, V.-P., Meziani, F., Louis, G., Rossignol, P., Duarte, K., Girerd, N., Mebazaa, A., Vignon, P., Mattei, M., … Guiot, P. (2018). Epinephrine Versus Norepinephrine for Cardiogenic Shock After Acute Myocardial Infarction. *Journal of the American College of Cardiology, 72*(2), 173–182. https://doi.org/10.1016/j.jacc.2018.04.051

Lewis, T., Merchan, C., Altshuler, D., & Papadopoulos, J. (2017). Safety of the Peripheral Administration of Vasopressor Agents. *Journal of Intensive Care Medicine, 34*(1), 26–33. https://doi.org/10.1177/0885066616686035

Lokesh, L., Fowler, R. L., Augustine, J. J., & Cabanas, J. G. (2018). Variabilities in the use of IV epinephrine in the management of cardiac arrest patients. *J Emerg Med Serv*(43), 1-5. https://www.jems.com/2018/10/15/variabilities-in-the-use-of-iv-epinephrine-in-the-management-of-cardiac-arrest-patients

Mathew, R., Di Santo, P., Jung, R. G., Marbach, J. A., Hutson, J., Simard, T., Ramirez, F. D., Harnett, D. T., Merdad, A., Almufleh, A., Weng, W., Abdel-Razek, O., Fernando, S. M., Kyeremanteng, K., Bernick, J., Wells, G. A., Chan, V., Froeschl, M., Labinaz, M., … Hibbert, B. (2021). Milrinone as Compared with Dobutamine in the Treatment of Cardiogenic Shock. *New England Journal of Medicine, 385*(6), 516–525. https://doi.org/10.1056/nejmoa2026845

Mayo Clinic Enterprise IVAG Workgroup. (2022). *Peripheral Intravenous Administration of Vasopressor Therapy Prescribing and Safe Use Guidelines: A Quality Improvement Initiative at RST and NWWI.*

Mayo Clinic Process/Medical Direction Committee. (2023). *Ambulance Service Patient Care Guidelines*. https://intranet.mayo.edu/charlie/ambulance-service-fla/files/2023/05/Dec-22-guidelines-2.pdf

McIntyre, W. F., Um, K. J., Alhazzani, W., Lengyel, A. P., Hajjar, L., Gordon, A. C., Lamontagne, F., Healey, J. S., Whitlock, R. P., & Belley-Côté, E. P. (2018). Association of Vasopressin Plus Catecholamine Vasopressors vs Catecholamines Alone With Atrial Fibrillation in Patients With Distributive Shock. *JAMA, 319*(18), 1889. https://doi.org/10.1001/jama.2018.4528

Menich, B. E., Miano, T. A., Patel, G. P., & Hammond, D. A. (2019). Norepinephrine and Vasopressin Compared With Norepinephrine and Epinephrine in Adults With Septic Shock. *Annals of Pharmacotherapy, 53*(9), 877–885. https://doi.org/10.1177/1060028019843664

Munroe, E., Claar, D., Tamae-Kakazu, M., Tatem, G., Blamoun, J., McSparron, J. I., & Prescott, H. C. (2022). Hospital Policies on Intravenous Vasopressor Administration and Monitoring: A Survey of Michigan Hospitals. *Annals of the American Thoracic Society, 19*(10), 1769–1772. https://doi.org/10.1513/annalsats.202203-197rl

Nagendran, M., Russell, J. A., Walley, K. R., Brett, S. J., Perkins, G. D., Hajjar, L., Mason, A. J., Ashby, D., & Gordon, A. C. (2019). Vasopressin in septic shock: an individual patient data meta-analysis of randomised controlled trials. *Intensive Care Medicine, 45*(6), 844–855. https://doi.org/10.1007/s00134-019-05620-2

O'Gara, P. T., Kushner, F. G., Ascheim, D. D., Casey, D. E., Chung, M. K., de Lemos, J. A., Ettinger, S. M., Fang, J. C., Fesmire, F. M., Franklin, B. A., Granger, C. B., Krumholz, H. M., Linderbaum, J. A., Morrow, D. A., Newby, L. K., Ornato, J. P., Ou, N., Radford, M. J., … Zhao, D. X. (2013). 2013 ACCF/AHA Guideline for the Management of ST-Elevation Myocardial Infarction. *Circulation, 127*(4). https://doi.org/10.1161/cir.0b013e3182742cf6

Petersen, J. W., & Felker, G. M. (2008). Inotropes in the management of acute heart failure. *Critical Care Medicine, 36*(Suppl), S106–S111. https://doi.org/10.1097/01.ccm.0000296273.72952.39

Pfizer. (2022). *Levophed - New Zealand Data Sheet*.

Poloujadoff, M.-P., Lapostolle, F., Lockey, D., Amathieu, R., Merouani, M., Galinski, M., & Adnet, F. (2006). Survival of severely shocked patients who present with absent radial pulse and unrecordable blood pressure in the pre-hospital phase. *Resuscitation, 69*(2), 185–189. https://doi.org/10.1016/j.resuscitation.2005.08.016

Quinn, E., Su, J., Fei, L., Liu, J., Friedman, M., Lobel, D., Kabiriti, S., Likourezos, A., Motov, S., & Eng, D. (2022). Perceptions and Barriers to Administering Vasopressors in the Prehospital Setting. *Cureus*. https://doi.org/10.7759/cureus.29614

Raynovich, W., Hums, J., Stuhlmiller, D. F., Bramble, J. D., Kasha, T., & Galt, K. (2013). Critical Care Transportation by Paramedics: A Cross-sectional Survey. *Air Medical Journal, 32*(5), 280–288. https://doi.org/10.1016/j.amj.2013.05.008

Readdy, W. J., Whetstone, W. D., Ferguson, A. R., Talbott, J. F., Inoue, T., Saigal, R., Bresnahan, J. C., Beattie, M. S., Pan, J. Z., Manley, G. T., & Dhall, S. S. (2015). Complications and outcomes of vasopressor usage in acute traumatic central cord syndrome. *Journal of Neurosurgery: Spine, 23*(5), 574–580. https://doi.org/10.3171/2015.2.spine14746

Rivosecchi, R., Collier, V., Barbash, I., Boeltz, A., Wang, S., Guo, X., Suh, K., Donadee, C., & Horvat, C. (2023). 938: Vasopressin utilization trends and cost analysis in septic shock patients. *Critical Care Medicine, 52*(1), S441–S441. https://doi.org/10.1097/01.ccm.0001001916.52399.cf

Sizemore, S., Patel, M. V. B., Carter, B., & Garrett, E. (2022). Adjusting vasopressin availability and formulation: A cost-savings initiative. *American Journal of Health-System Pharmacy, 79*(Supplement_3), S74–S78. https://doi.org/10.1093/ajhp/zxac142

Smida, T., Crowe, R. P., Martin, P. S., Scheidler, J. F., Price, B. S., & Bardes, J. M. (2024). A retrospective, multi-agency 'target trial emulation' for the comparison of post-resuscitation epinephrine to norepinephrine. *Resuscitation, 198*, 110201. https://doi.org/10.1016/j.resuscitation.2024.110201

Thiele, R. H., Nemergut, E. C., & Lynch, C. (2011). The Clinical Implications of Isolated Alpha1 Adrenergic Stimulation. *Anesthesia &Analgesia, 113*(2), 297–304. https://doi.org/10.1213/ane.0b013e3182120ca5

Thongprayoon, C., Cheungpasitporn, W., Harrison, A. M., Carrera, P., Srivali, N., Kittamongkolchai, W., Erdogan, A., & Kashani, K. B. (2016). Temporal trends in the utilization of vasopressors in intensive care units: an epidemiologic study. *BMC Pharmacology and Toxicology, 17*(1). https://doi.org/10.1186/s40360-016-0063-z

Tian, D. H., Smyth, C., Keijzers, G., Macdonald, S. P., Peake, S., Udy, A., & Delaney, A. (2019). Safety of peripheral administration of vasopressor medications: A systematic review. *Emergency Medicine Australasia, 32*(2), 220–227. Portico. https://doi.org/10.1111/1742-6723.13406

V3 EMS Data Cube. https://nemsis.org/view-reports/public-reports/ems-data-cube/

van Diepen, S., Katz, J. N., Albert, N. M., Henry, T. D., Jacobs, A. K., Kapur, N. K., Kilic, A., Menon, V., Ohman, E. M., Sweitzer, N. K., Thiele, H., Washam, J. B., & Cohen, M. G. (2017). Contemporary Management of Cardiogenic Shock: A Scientific Statement From the American Heart Association. *Circulation, 136*(16). https://doi.org/10.1161/cir.0000000000000525

Vincent, J.-L., & De Backer, D. (2013). Circulatory Shock. *New England Journal of Medicine, 369*(18), 1726–1734. https://doi.org/10.1056/nejmra1208943

Wang, H. E., Shapiro, N. I., & Yealy, D. M. (2011). Characteristics of out-of-hospital shock care*. *Critical Care Medicine, 39*(11), 2431–2439. https://doi.org/10.1097/ccm.0b013e3182257310