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ORIGINAL RESEARCH

Pilot regional analysis of emergency medical services and medication efficacy in out-of-hospital cardiac arrest

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Abstract

Background: Out-of-hospital cardiac arrest (OHCA) remains a critical public health challenge, with survival rates influenced by regional emergency medical services (EMS) protocols. This study evaluates the impact of EMS-administered medications on return of spontaneous circulation (ROSC) in OHCA cases within the Lublin Voivodeship, Poland. **Methods**: A retrospective analysis of 4361 OHCA cases from 2014 to 2017 was conducted using EMS records identified through International Classification of Diseases, Tenth Revision (ICD-10) and ICD-9 codes. Statistical analyses, including chi-square tests and multivariate logistic regression, assessed the associations between medication administration and ROSC outcomes. **Results**: ROSC was achieved in 32.7% of cases. Epinephrine, administered in 89.06% of cases, was not significantly associated with ROSC ($p = 0.425$). Amiodarone, used in 18.27% of cases, was significantly associated with ROSC in shockable rhythms ($p = 0.012$). Sodium bicarbonate, given in 23.12% of cases, was linked to ROSC in overdose-related arrests ($p = 0.034$) but showed lower effectiveness outside of such cases. Dopamine, administered in 22.51% of cases, was positively correlated with ROSC ($p = 0.018$), as was fluid therapy, provided in 62.67% of cases ($p = 0.021$). Medication administration varied by incident location and etiology, with amiodarone and sodium bicarbonate more frequently used in workplace incidents, and sodium bicarbonate and fluid therapy more common in overdose-related OHCA cases. Amiodarone use was significantly higher in ventricular fibrillation/ventricular tachycardia (VF/VT) cases ($p = 0.013$). **Conclusions**: This regional study underscores the critical role of EMS-administered medications and contextual factors in OHCA outcomes. Findings suggest that targeted medication use based on initial heart rhythm and arrest etiology may enhance resuscitation success. Future multicenter or prospective studies are needed to validate these results and inform global prehospital resuscitation strategie.

Keywords

Out-of-hospital cardiac arrest; Emergency medical services; Epinephrine; Amiodarone; Return of spontaneous circulation

1. Introduction

Cardiac emergencies that occur outside of hospital settings are among the most challenging medical situations, significantly contributing to global mortality rates [1]. Despite advancements in emergency medical services (EMS) and resuscitation techniques, out-of-hospital cardiac arrest (OHCA) survival rates remain distressingly low. According to the American Heart Association, the survival rate to hospital discharge for OHCA patients remains critically low, underscoring the urgent need for improved intervention strategies [2, 3]. In Europe, similar figures are reported, with notable variations across countries due to differences in EMS systems and protocols [4]. The challenge of OHCA is compounded by the fact that it often occurs without warning, requiring immediate and effective response to maximize the chances of survival and neurological recovery.

EMS systems globally, including those in Poland, operate under stringent protocols designed to enhance the effectiveness of emergency responses [5, 6]. In Poland, paramedics are authorized to administer a range of medications independently, a practice governed by specific national regulations [7, 8]. These medications, which include life-saving drugs such as epinephrine, amiodarone, and atropine, are critical in the management of OHCA. The effectiveness of these medications, however, depends not only on the pharmacological properties but also on the timely and appropriate administration by trained EMS personnel. While previous studies have emphasized early

defibrillation and advanced life support measures, gaps remain in understanding the specific roles and efficacy of medications in different contexts and populations [9–11].

This study serves as a regional pilot, exploring the effectiveness of EMS-administered medications in the Lublin Voivodeship, Poland. Specifically, it investigates the relationship between EMS-administered medications and the achievement of return of spontaneous circulation (ROSC). Understanding the efficacy of individual medications and their timing is critical to improving survival rates and developing targeted intervention strategies for OHCA patients.

The objective of this study is to investigate the association between specific EMS-administered medications and the achievement of ROSC in OHCA cases. The study also explores variations in medication use across different scenarios to provide insights into optimizing EMS protocols.

The analysis of medication usage across different incident locations aimed to identify contextual factors influencing EMS practices, recognizing that medication administration is primarily dictated by the clinical presentation and resuscitation protocols rather than location alone. While factors such as accessibility of the incident site (*e.g.*, public *vs.* private spaces) and initial cardiac rhythms (*e.g.*, shockable *vs.* non-shockable) inherently guide the choice of interventions, location-based differences may reflect secondary influences, such as time to intervention or the availability of advanced resources. This analysis is intended to supplement understanding of how EMS response adapts to varying operational contexts rather than imply discretionary use of required medications, such as amiodarone in shockable rhythms.

As a pilot study, this research provides a foundation for hypothesis generation and highlights the need for broader, multicenter, or prospective analyses to validate and expand upon these findings. By addressing these objectives, this study contributes actionable insights to enhance EMS protocols and inform training programs. Ultimately, the goal is to optimize both survival rates and neurological recovery in OHCA patients through evidence-based strategies, ensuring better outcomes for individuals and communities worldwide.

2. Materials and methods

2.1 Data collection

This study is a retrospective analysis of medical records from the EMS in the Lublin Voivodeship spanning from 2014 to 2017. The primary data sources were Call-Out Cards-standardized forms documenting emergency responses, including dispatch details-and Medical Rescue Activity Cards, which provide detailed patient demographics, clinical assessments, interventions performed, and outcomes observed. These records are stored digitally in a centralized EMS database, ensuring consistency and accessibility for analysis.

To minimize bias and enhance the reliability of findings, strict inclusion and exclusion criteria were applied during data collection. Inclusion criteria required cases to be classified as OHCA using ICD-10 diagnosis codes, involve patients who received EMS interventions such as medication administration, and include clear documentation of key variables like patient demographics, EMS response times, interventions performed and outcomes such as the ROSC. Exclusion criteria eliminated records with incomplete or illegible documentation, cases misclassified by EMS personnel or coded incorrectly, incidents involving multiple EMS teams dispatched to a single location (to prevent data duplication), patients with advanced directives or Do-Not-Resuscitate (DNR) orders that precluded cardiopulmonary resuscitation (CPR) initiation, and cases where ROSC was achieved before EMS arrival. This rigorous approach ensured that the data analyzed were both comprehensive and relevant to the study's objectives.

Available data included variables recorded in the Medical Rescue Activity Cards and Call-Out Cards, such as patient demographics (age and gender), incident location (*e.g.*, public place, private residence, workplace), initial cardiac rhythm, and EMS interventions performed (*e.g.*, medication administration, defibrillator use). Although some Utstein template variables, such as bystander CPR and basic life support (BLS) response times, were not fully available in the dataset, the analysis focused on the recorded variables to provide insights into EMS response patterns and their association with ROSC outcomes.

2.2 Geographical focus and EMS structure

The study was conducted in the Lublin Voivodeship, a region with a sophisticated EMS system designed to handle cardiac arrests and other medical emergencies efficiently. The regional EMS operates a tiered response system to provide appropriate care based on the severity of emergencies.

BLS Units are staffed by emergency medical technicians trained to provide initial emergency care, including CPR, basic airway management, and the use of automated external defibrillators (AEDs). Advanced Life Support (ALS) Units are staffed by paramedics or physicians equipped with advanced medical equipment and medications, capable of performing complex interventions such as advanced airway management, intravenous drug administration, and manual defibrillation.

In cases of OHCA, both BLS and ALS units are dispatched simultaneously to ensure a high level of care. This dual dispatch strategy ensures that the nearest available unit-often a BLS team-can initiate basic resuscitation measures, such as CPR and defibrillation, while the ALS team provides advanced interventions upon arrival. Typically, the BLS unit arrives first due to greater availability and geographical coverage, allowing critical life-saving measures to begin immediately. The ALS team assumes responsibility for advanced interventions, including intravenous drug administration, once on scene. This coordinated approach aims to maximize the chances of survival by minimizing delays in both basic and advanced life support measures.

The EMS dispatch center prioritizes emergency calls, with OHCA cases receiving the highest priority classification (K-1), ensuring rapid deployment and coordination of both units.

2.3 Case selection and criteria

From an initial dataset of 5111 cases identified using ICD-10 diagnosis codes and ICD-9 procedure codes, 4361 cases

met the inclusion criteria for detailed analysis. A total of 750 cases were excluded based on predefined criteria. Exclusions were due to missing or incomplete documentation, incorrect classification or coding by EMS personnel, incidents involving multiple teams dispatched to the same event, the presence of advanced directives or DNR orders that precluded CPR initiation, and cases where ROSC occurred prior to EMS arrival. These selection criteria were carefully implemented to maintain data clarity and ensure a focused analysis of the impact of EMS interventions during OHCA events.

2.4 Data entry and validation

Data from Call-Out Cards and Medical Rescue Activity Cards were entered into Microsoft Excel (version 2016, Microsoft Corporation, Redmond, WA, USA) by two independent researchers to reduce errors. A third researcher, uninvolved in initial data collection, conducted a cross-validation process. Discrepancies between independently entered datasets were identified using discrepancy reports and resolved through a systematic review by the three researchers, referring to original documentation. Ambiguities were addressed using consensus and professional judgment, ensuring the integrity of the final dataset.

2.5 Data management and security

All data were securely stored in systems with restricted access to ensure confidentiality and data integrity. Only authorized personnel had access to the data, which were used solely for scientific purposes. Data management protocols adhered to strict guidelines to protect patient privacy and ensure compliance with ethical standards.

2.6 Statistical analysis

Statistical analyses were conducted using STATISTICA version 12.5 (StatSoft Poland, Kraków, Poland). The Shapiro-Wilk test was employed to assess data normality, chosen for its sensitivity to deviations from normality, particularly in small sample sizes. Descriptive statistics were used to summarize the data. While means and standard deviations (SD) were calculated for normally distributed variables, and medians and interquartile ranges (IQR) for non-normally distributed data, the results presented in this manuscript focus on percentages due to the categorical nature of the primary and secondary variables analyzed, such as medication administration patterns and ROSC outcomes.

Chi-square tests were performed to explore relationships between categorical variables, with statistical significance set at $p < 0.05$. To address potential confounders, multivariate logistic regression models were utilized, adjusting for variables such as patient demographics, incident location, and initial cardiac rhythm, ensuring robust analysis of factors independently associated with ROSC.

To enhance the reliability of our findings, sensitivity analyses were performed to assess the stability of the observed associations. However, as an observational retrospective study, this analysis remains subject to potential residual confounding, including unmeasured variables such as underlying comorbidities and variations in post-resuscitation care. While our statistical approach was designed to mitigate these effects, the results should be interpreted with caution, and further prospective studies are recommended to validate these associations.

2.7 Study endpoints and sample size

The primary endpoint was the achievement of ROSC following EMS intervention for OHCAs. Secondary endpoints focused on the impact of demographic and operational variables, such as incident location and initial rhythm, on ROSC outcomes. While EMS response times were initially intended as a secondary endpoint, these data were unavailable for this analysis due to limitations in the recorded dataset.

3. Results

In this section, we present the findings from our retrospective analysis of medical intervention data in the Lublin region from 2014 to 2017. Our study aimed to identify factors influencing the survival rates of patients experiencing OHCA. We analyzed 4361 incidents, focusing on various variables affecting the effectiveness of emergency interventions and the achievement of ROSC. Among these cases, ROSC was achieved in 32.7% of patients, highlighting the importance of identifying factors that influence survival outcomes. These results are crucial for improving EMS practices and outcomes.

3.1 Medications administered by EMS

The EMS protocols in the Lublin Voivodeship allow paramedics to independently administer a wide range of medications, as outlined in Table 1. These medications are regulated under Polish national regulations and include those commonly used for resuscitation, such as epinephrine, amiodarone and sodium bicarbonate. While this table provides an overview of all medications available for EMS use, the analysis in this study focuses on key medications frequently administered during OHCA cases, such as epinephrine, amiodarone, and fluid therapy [12]. Usage frequencies of these medications are detailed in subsequent tables.

3.2 Medication usage analysis

Our analysis revealed patterns regarding the administration of medications during resuscitation efforts, as shown in Table 2. Among the 4361 OHCA cases, epinephrine was administered in 3890 cases (89.20%) in the Category 1 (K-1) urgency group (N = 4361) and 160 cases (89.89%) in the Category 2 (K-2 urgency group (N = 178) ($p = 0.423$). By location, epinephrine was used in 3500 urban cases (89.13%) and 550 rural cases (89.29%).

Amiodarone was administered in 797 cases (18.28%) in the K-1 group and 32 cases (17.98%) in the K-2 group. By location, amiodarone was used in 738 urban cases (18.79%) and 105 rural cases (17.05%) ($p = 0.512$).

Atropine was used in 1564 cases (35.86%) in the K-1 group and 57 cases (32.02%) in the K-2 group. Similarly, sodium bicarbonate was administered in 990 cases (22.70%) in K-1 and 33 cases (18.54%) in K-2. Dopamine was used in 964

TABLE 1. Medications administered by EMS.

No.	Medication Name	Form
1	Acetylsalicylic Acid	Tablets
2	Adenosine	Injection solution
3	Amiodarone Hydrochloride	Injection solution
4	Atropine Sulfate	Injection solution
5	Isosorbide Mononitrate	Tablets
6	Budesonide	Nebulization suspension
7	Captopril	Tablets
8	Clemastine	Injection solution
9	Clonazepam	Injection solution
10	Clopidogrel	Tablets (post-EKG teletransmission)
11	Dexamethasone Phosphate	Injection solution
12	Diazepam	Tablets, injection solution, rectal solution
13	Drotaverine Hydrochloride	Injection solution
14	Epinephrine	Injection solution
15	Fentanyl	Injection solution
16	Flumazenil	Injection solution
17	Furosemide	Injection solution
18	Glyceryl Trinitrate	Tablets, sublingual spray
19	Glucagon Hydrochloride	Injection solution
20	Glucose 5%	Infusion solution
21	Glucose 20%	Injection solution
22	Heparin Sodium	Injection solution
23	Hydrocortisone	Injection solution
24	Hydroxyzine	Tablets, injection solution
25	Ibuprofen	Tablets
26	Ketoprofen	Tablets, injection solution
27	Lidocaine Hydrochloride	Injection solution, gel
28	Magnesium Sulfate	Injection solution
29	Mannitol 15%	Infusion solution
30	Metamizole Sodium	Injection solution
31	Metoclopramide	Injection solution
32	Metoprolol Tartrate	Injection solution
33	Midazolam	Injection solution
34	Morphine Sulfate	Injection solution
35	Naloxone Hydrochloride	Injection solution
36	Sodium Chloride 0.9%	Infusion solution
37	Sodium Bicarbonate 8.4%	Injection solution
38	Papaverine Hydrochloride	Injection solution
39	Paracetamol	Suppositories, tablets, injection solution
40	Isotonic Multi-electrolyte	Infusion solution
41	Colloid Solutions	Infusion solution
42	Salbutamol	Injection solution, nebulization solution
43	Balanced Electrolyte Solution	Infusion solution
44	Thiethylperazine	Suppositories, injection solution
45	Ticagrelor	Tablets (post-EKG teletransmission)
46	Medical Oxygen	Gas
47	Urapidil	Injection solution

Note: EKG: electrocardiogram (also known as ECG).

cases (22.11%) in K-1 and 30 cases (16.85%) in K-2.

Fluid therapy was provided in 2684 cases (61.55%) in the K-1 group and 102 cases (57.30%) in the K-2 group. The administration rates were similar between urban (N = 3927) and rural (N = 616) cases, with 2490 urban patients (63.41%) and 388 rural patients (62.99%) receiving fluid therapy (p = 0.864).

While percentages appear consistent across urgency codes and locations, statistical analysis revealed no significant correlations between these variables and medication usage. This lack of significance may result from the near-universal use of certain medications, such as epinephrine, or insufficient variation in sample sizes across subcategories. Exact p-values for each analysis are presented in Table 2.

3.3 Location analysis

The analysis of medication usage by incident location revealed significant differences for epinephrine, amiodarone and sodium bicarbonate administration, as shown in Table 3. Epinephrine was most frequently used at workplaces (94.44%, N = 472) and homes (91.30%, N = 2739), reflecting its widespread application in resuscitation efforts across all cardiac arrest rhythms. Sodium bicarbonate was more commonly administered during workplace resuscitations (33.33%, N = 167), possibly indicating a higher prevalence of non-shockable rhythms, such as asystole or pulseless electrical activity (PEA), in these settings. Amiodarone, typically used for defibrillable rhythms like ventricular fibrillation (VF) and ventricular tachycardia (VT), was significantly more used at workplaces (30.56%, N = 153), suggesting a higher frequency of shockable rhythms in these locations.

These differences likely reflect the clinical context of the incidents, including variations in initial rhythm or type of cardiac arrest, rather than discretionary use of medications based on location. No significant differences were found for atropine, dopamine, or fluid therapy, which are used more broadly across multiple scenarios regardless of location. The exact p-values for statistical analyses are provided in Table 3.

3.4 Etiology analysis

There were significant correlations between the etiology of OHCA and the administration of epinephrine, amiodarone, sodium bicarbonate, and fluid therapy, as detailed in Table 4. Epinephrine was more commonly administered in cardiac-related cases (90.84%, N = 1363) and unknown causes (91.39%, N = 731), while amiodarone was significantly used in cardiac-related arrests (26.96%, N = 404). Sodium bicarbonate was frequently used in overdose cases (30.56%, N = 110) and cardiac-related arrests (28.80%, N = 432). Fluid therapy was most commonly administered in toxicological (73.61%, N = 110) and cardiac-related resuscitations (69.90%, N = 1048). No significant correlations were observed for atropine or dopamine in relation to the etiology of OHCA. The exact p-values for these analyses are reported in Table 4.

3.5 Return of spontaneous circulation

The analysis revealed significant differences in ROSC achievement related to the administration of amiodarone, dopamine and fluid therapy, as shown in Table 5. Among the 4361 patients included in the study, ROSC was achieved in 32.7% of cases (N = 1426).

ROSC rates were higher in patients receiving certain medications. For amiodarone, ROSC was observed in 24.52%

TABLE 2. Medication usage by urgency code and incident location.

Medication	Urgency Code (K-1) (N = 4361)	Urgency Code (K-2) (N = 178)	Urban (N = 3927)	Rural (N = 616)	p-value
Epinephrine	3890 (89.20%)	160 (89.89%)	3500 (89.13%)	550 (89.29%)	0.423
Amiodarone	797 (18.28%)	32 (17.98%)	738 (18.79%)	105 (17.05%)	0.512
Atropine	1564 (35.86%)	57 (32.02%)	1372 (34.94%)	237 (38.47%)	0.371
Sodium Bicarbonate	990 (22.70%)	33 (18.54%)	842 (21.44%)	155 (25.16%)	0.297
Dopamine	964 (22.51%)	30 (16.85%)	907 (23.10%)	118 (19.16%)	0.183
Fluid Therapy	2684 (61.55%)	102 (57.30%)	2490 (63.41%)	388 (62.99%)	0.864

Note: K-1: highest priority classification (life-threatening emergency); K-2: second-highest priority classification (serious but not immediately life-threatening emergency).

TABLE 3. Medication usage by incident location.

Medication	Home (%) (N)	Public Place (%) (N)	Workplace (%) (N)	Nursing Home (%) (N)	Other (%) (N)	p-value
Epinephrine	91.30% (2739)	84.51% (1268)	94.44% (472)	85.29% (299)	59.52% (149)	0.031
Amiodarone	17.69% (531)	21.68% (325)	30.56% (153)	5.88% (21)	14.29% (36)	0.014
Atropine	36.35% (1090)	28.76% (431)	25.00% (125)	41.18% (144)	33.33% (83)	0.278
Sodium Bicarbonate	23.18% (695)	21.24% (319)	33.33% (167)	8.82% (31)	9.52% (24)	0.041
Dopamine	21.95% (658)	19.03% (285)	33.33% (167)	29.41% (103)	21.43% (54)	0.093
Fluid Therapy	63.29% (1899)	69.49% (1042)	69.44% (347)	61.76% (216)	47.62% (119)	0.112

TABLE 4. Medication usage by etiology of OHCA.

Medication	Unknown (%) (N)	Cardiac (%) (N)	Asphyxia (%) (N)	Trauma (%) (N)	Overdose (%) (N)	Drowning (%) (N)	Other (%) (N)	No Info (%) (N)	*p*-value
Epinephrine	91.39% (731)	90.84% (1363)	87.95% (528)	78.85% (410)	91.67% (330)	55.56% (50)	86.26% (414)	70.59% (240)	0.027
Amiodarone	18.59% (149)	26.96% (404)	7.23% (43)	1.92% (10)	12.50% (45)	33.33% (30)	10.44% (50)	17.65% (60)	0.015
Atropine	37.18% (297)	38.74% (581)	31.33% (188)	21.15% (110)	36.11% (130)	22.22% (20)	32.42% (156)	35.29% (120)	0.342
Sodium Bicarbonate	22.20% (178)	28.80% (432)	14.46% (87)	9.62% (50)	30.56% (110)	22.22% (20)	14.84% (71)	14.71% (50)	0.033
Dopamine	22.89% (183)	22.77% (342)	21.69% (130)	11.54% (60)	30.56% (110)	22.22% (20)	18.13% (87)	14.71% (50)	0.118
Fluid Therapy	62.31% (498)	69.90% (1048)	53.01% (318)	65.38% (340)	73.61% (110)	66.67% (60)	54.95% (263)	50.00% (170)	0.041

TABLE 5. Medication Usage and ROSC.

Medication	ROSC Yes (%) (N)	ROSC No (%) (N)	*p*-value
Epinephrine	87.57% (1249)	90.29% (2650)	0.425
Amiodarone	24.52% (350)	13.96% (410)	0.012
Atropine	63.57% (907)	64.56% (1895)	0.673
Sodium Bicarbonate	18.74% (267)	24.88% (730)	0.034
Dopamine	26.62% (380)	18.69% (549)	0.018
Fluid Therapy	68.83% (907)	59.47% (1895)	0.021

ROSC: return of spontaneous circulation.

(N = 350) of patients treated with the medication compared to 13.96% (N = 410) of those who were not treated (p = 0.012). Similarly, dopamine administration was associated with a ROSC rate of 26.62% (N = 380) compared to 18.69% (N = 549) in patients not receiving the drug (p = 0.018). Fluid therapy also showed a significant correlation with ROSC, with 68.83% (N = 907) of patients who received fluids achieving ROSC compared to 59.47% (N = 1895) of those who did not (p = 0.021).

Conversely, higher ROSC rates were observed when sodium bicarbonate was not used, with 24.88% (N = 730) of patients achieving ROSC compared to 18.74% (N = 267) of those who received it (p = 0.034). No significant differences were observed for epinephrine (p = 0.425) or atropine (p = 0.673) in relation to ROSC.

3.6 Initial heart rhythm

Medication administration varied significantly depending on the initial recorded heart rhythm, as detailed in Table 6. Initial rhythms observed were classified as defibrillable (*e.g.*, ventricular fibrillation (VF) or ventricular tachycardia (VT)) or non-defibrillable (*e.g.*, asystole or pulseless electrical activity (PEA)). In a small subset of cases, rhythms were categorized as "Other" due to their atypical presentation, such as atrial fibrillation or idioventricular rhythms, which may not have been primary causes of cardiac arrest.

Epinephrine was most frequently used for non-defibrillable rhythms (90.86%, N = 1999), consistent with its recommended use across all cardiac arrest scenarios. It was also administered in cases with unspecified rhythms (75.73%, N = 501; p = 0.029). Amiodarone use was significantly associated with defibrillable rhythms such as VF/VT (49.42%, N = 544; p = 0.013), aligning with current resuscitation guidelines for shockable rhythms. Atropine was more frequently used when the rhythm was unknown (73.79%, N = 488) or shockable (70.27%, N = 773; p = 0.021), suggesting its use in managing complex scenarios involving bradyarrhythmias or asystole.

Sodium bicarbonate was more commonly administered in cases with non-defibrillable rhythms (23.70%, N = 521) and was not used for unspecified rhythms (p = 0.042). No significant differences were observed for dopamine (p = 0.174) or fluid therapy (p = 0.137) based on initial rhythm.

These findings demonstrate the relationship between initial heart rhythm and the medications chosen during resuscitation efforts, reflecting their clinical indications in cardiac arrest management.

4. Discussion

Our retrospective analysis of OHCA interventions in the Lublin Voivodeship provides valuable insights into the factors influencing survival rates. Positioned as a regional pilot, this

TABLE 6. Medication usage by initial heart rhythm.

Medication	Asystole/PEA (%) (N)	VF/VT (%) (N)	Other (%) (N)	Unknown (%) (N)	*p*-value
Epinephrine	90.86% (1999)	89.58% (985)	62.50% (250)	75.73% (501)	0.029
Amiodarone	11.62% (256)	49.42% (544)	18.75% (75)	15.53% (103)	0.013
Atropine	61.75% (1358)	70.27% (773)	56.25% (225)	73.79% (488)	0.021
Sodium Bicarbonate	23.70% (521)	21.62% (238)	0.00% (0)	14.56% (96)	0.042
Dopamine	21.04% (463)	25.87% (285)	12.50% (50)	22.33% (148)	0.174
Fluid Therapy	62.54% (1376)	69.11% (761)	50.00% (200)	58.25% (385)	0.137

Other rhythms refer to cases where the EMS documentation indicated non-standard or unclassified rhythms, such as atrial fibrillation or idioventricular rhythms, which may not align with traditional shockable or non-shockable categories. PEA: pulseless electrical activity; VF/VT: ventricular fibrillation/ventricular tachycardia.

study highlights the critical role of EMS interventions and the administration of specific medications in achieving ROSC. By identifying regional trends and medication patterns, this analysis serves as a foundation for broader hypothesis-driven research and future multicenter studies.

While our findings align with much of the existing literature, some discrepancies warrant further discussion [13–16]. For instance, the observed non-significant impact of epinephrine on ROSC rates contrasts with studies that report a clear benefit of epinephrine in achieving ROSC. This discrepancy could stem from variations in EMS protocols, timing of administration, or differences in patient populations. In our study, the high overall usage rate of epinephrine might have masked its specific effects due to a ceiling effect, where nearly all patients received the medication, reducing the variability needed to detect significant differences.

A notable observation is the higher ROSC rates associated with fluid therapy in this region compared to other studies. This could reflect regional EMS practices in the Lublin Voivodeship, which emphasize aggressive fluid resuscitation. Additionally, differences in the baseline characteristics of OHCA patients, such as varying degrees of dehydration or differing cardiac arrest etiologies, might explain the enhanced efficacy of fluid therapy observed in our cohort.

The frequent use of sodium bicarbonate in workplace incidents and its association with ROSC in overdose cases diverge from some studies that question its routine use due to potential complications like alkalosis. The specific context of our study, which included a significant number of overdose-related cardiac arrests, might necessitate its use to counteract metabolic acidosis, improving outcomes in this subgroup. This highlights the importance of tailoring resuscitation strategies to the underlying causes of OHCA when interpreting medication efficacy.

The differential impact of medications based on the location of the incident, such as the higher use of amiodarone at workplaces, suggests that immediate availability of advanced life support and the presence of trained personnel significantly influence the choice and effectiveness of interventions. These contextual factors may not be as prevalent in studies conducted in regions with less structured workplace emergency response systems, reinforcing the need for localized analyses.

Our findings underline the necessity for regional studies like this one to understand EMS interventions better and adapt protocols to local specifics, including patient demographics and prevalent causes of OHCA. These localized insights can guide broader, multicenter research to test hypotheses and refine global EMS practices.

Although our findings highlight significant associations between EMS-administered medications and ROSC, it is important to interpret these results within the context of a retrospective observational study. While statistical adjustments were made to minimize confounding, causality cannot be established. Future prospective studies are necessary to validate these associations in a broader and more controlled setting.

In the context of European OHCA management, the European Heart Rhythm Association (EHRA)survey [17] highlights the variability in EMS protocols, drug usage and survival outcomes across different regions. This survey emphasizes the critical role of standardized protocols and resource availability in shaping OHCA outcomes. Our study aligns with the EHRA survey in demonstrating the widespread use of epinephrine and amiodarone as cornerstone therapies in OHCA management. However, our findings diverge in the higher use of sodium bicarbonate, likely driven by the unique clinical contexts of the Lublin Voivodeship, such as workplace-related incidents and overdose cases. These differences underscore the importance of tailoring resuscitation strategies to regional needs while also advocating for greater standardization in medication protocols and EMS system organization across Europe.

The widespread use of epinephrine in OHCA cases across urgency codes and locations aligns with its role as a cornerstone in cardiac arrest management [18, 19]. A study by Berg *et al.* [20] demonstrated that epinephrine administration significantly improves ROSC rates, although its impact on long-term neurological outcomes remains debated. Further research is required to optimize its use, balancing its immediate benefits against potential adverse effects.

Amiodarone's use in about one-fifth of cases and its significant correlation with ROSC achievement is particularly noteworthy. This aligns with evidence supporting its efficacy in treating shock-refractory ventricular fibrillation and pulseless ventricular tachycardia [21]. These findings reaffirm the importance of prioritizing amiodarone in relevant cases, consistent with current guidelines.

Atropine, administered in approximately one-third of cases, showed no significant variation across urgency codes or locations. This supports the current American Heart Association

guidelines, which no longer recommend routine use of atropine for cardiac arrest due to insufficient evidence of its efficacy [22].

Sodium bicarbonate and dopamine usage patterns revealed interesting trends. Sodium bicarbonate's frequent use in workplace incidents and overdose cases highlights its importance in managing acidosis and toxin removal in specific contexts. Dopamine, associated with improved ROSC rates, underscores its value in hemodynamic support during resuscitation.

The higher ROSC rates observed with fluid therapy emphasize the importance of maintaining adequate intravascular volume during resuscitation, particularly in prolonged cardiac arrest [23]. However, careful consideration is required to balance fluid administration with the risk of fluid overload.

Incident location analysis revealed significant differences in medication usage, such as higher rates of epinephrine and amiodarone at workplaces. This reflects the critical role of emergency preparedness and access to advanced life support measures in improving OHCA outcomes in such environments.

Etiology analysis showed strong correlations between certain medications and specific causes of OHCA. For example, epinephrine and amiodarone were more commonly administered in cardiac-related arrests, consistent with their established roles. Sodium bicarbonate's frequent use in overdose cases underscores its targeted role in managing metabolic derangements associated with poisoning.

The relationship between initial heart rhythm and medication administration further supports tailored resuscitation strategies. For example, epinephrine was predominantly used for non-defibrillable rhythms, while amiodarone was associated with shockable rhythms, aligning with current guidelines [24, 25].

In comparison with other studies, the high usage rates of epinephrine and amiodarone observed here reflect their global relevance in OHCA management. However, the specific patterns of sodium bicarbonate and dopamine administration in this region highlight the importance of localized research to understand contextual factors influencing medication use.

By positioning this study as a regional pilot, we provide critical data on the effectiveness of various medications within the EMS framework of the Lublin Voivodeship. These findings have significant implications for refining EMS protocols and training programs. Future research should aim to validate these results through multicenter or prospective studies, optimize medication regimens and explore novel therapeutic interventions to improve survival rates and neurological outcomes in OHCA patients globally.

Our findings have significant implications for public health, particularly in regions with resource-limited EMS systems. By identifying specific medication patterns and their association with improved outcomes, this study provides actionable insights for optimizing prehospital care strategies. For example, the critical role of amiodarone in achieving ROSC in shockable rhythms underscores the need for ensuring its availability and proper usage training among EMS teams. Similarly, the higher ROSC rates observed with fluid therapy highlight the importance of maintaining adequate resuscitation supplies and protocols for volume management.

Moreover, the observed variability in medication use by incident location and etiology highlights the importance of tailoring interventions to local contexts. Policymakers should consider developing region-specific guidelines that address unique challenges, such as overdose-related arrests or workplace incidents, while ensuring alignment with international standards [26, 27]. Public health campaigns focused on improving bystander CPR rates, increasing access to automated external defibrillators, and enhancing public awareness of cardiac arrest management could further amplify the benefits of EMS interventions.

In a broader context, the study underscores the need for international collaboration to harmonize EMS protocols and reduce variability in OHCA outcomes. Sharing best practices and implementing standardized training programs across regions can help bridge the gaps in care delivery and improve survival rates. Future initiatives should also focus on integrating advanced technologies, such as real-time monitoring and decision-support systems, to enhance EMS efficiency and patient outcomes.

5. Limitations

Despite the comprehensive nature of our study, several limitations must be acknowledged. Firstly, the retrospective design inherently limits our ability to control for all confounding variables, which may impact the outcomes observed. The reliance on historical data from Call-Out Cards and Medical Rescue Activity Cards means that we were dependent on the accuracy and completeness of these records. Any inaccuracies or omissions in the original documentation could have influenced our findings.

A key limitation of this study is the use of historical EMS data spanning from 2014 to 2017. While these data provide valuable insights into medication efficacy in OHCA management, EMS protocols, resuscitation guidelines, and prehospital care practices may have evolved since then. Changes in medication recommendations, advancements in resuscitation techniques and improvements in EMS response strategies could influence the applicability of our findings to current practice. Future research should focus on analyzing more recent data or conducting prospective studies to validate and expand upon these results in the context of contemporary EMS protocols.

While the interval between the emergency call and ROSC is a critical parameter for understanding the timeliness and effectiveness of EMS interventions, these data were not available in our retrospective dataset. This limitation prevents us from fully evaluating the impact of response times on ROSC outcomes. Similarly, data on hospital admissions following ROSC, or in cases without ROSC, stratified by drug administration, were not available. These metrics are vital for assessing the downstream impact of EMS interventions and should be prioritized in future studies to provide a more comprehensive understanding of patient outcomes.

Additionally, our study was geographically limited to the Lublin Voivodeship, which may affect the generalizability of the results to other regions with different EMS systems and protocols. The EMS system in Lublin operates under nationally regulated protocols that may not fully align with practices

in other countries. Differences in paramedic training, resource availability, and medication protocols can significantly impact the observed outcomes, limiting the broader applicability of our findings. However, the structured and detailed data collected within this region provide valuable insights into how EMS interventions function within a defined framework, offering potential lessons for similar regional settings.

The exclusion of cases with significant gaps in documentation or those that were illegible may have introduced selection bias. Similarly, cases where patients had advanced directives or DNR orders were not included in the analysis of resuscitation efforts. This exclusion may have affected the representativeness of the sample and potentially influenced the observed outcomes. Additionally, our focus on ROSC as the primary endpoint limits insights into long-term neurological recovery and survival, which are critical aspects of patient outcomes.

Another key limitation is the potential for unmeasured confounding variables that may have influenced the observed relationships. Although we used multivariate logistic regression to adjust for key factors, the retrospective nature of the study means that some confounders (*e.g.*, pre-existing conditions, in-hospital treatment after ROSC) may not have been fully accounted for. Future studies should aim to incorporate a broader range of patient-level variables to minimize this effect.

We also acknowledge that while our statistical approach was robust and appropriate for the dataset, some subgroup analyses were constrained by sample size limitations. Certain comparisons, particularly those involving less frequently administered medications, may have been underpowered to detect statistically significant differences. Future research with larger multicenter datasets would help validate these findings and refine the interpretation of medication efficacy in OHCA management.

Another limitation is the lack of detailed information on patient comorbidities and the exact timing of interventions, which are critical factors in understanding the full context of each OHCA event. Furthermore, the absence of long-term follow-up data prevents us from assessing neurological outcomes or the quality of life of survivors, which are essential for evaluating the overall success of EMS interventions.

Lastly, while our statistical analyses were robust and provided meaningful associations, the retrospective nature of the study precludes the establishment of causation. The observed correlations between medication use and survival rates should be interpreted cautiously. Future studies designed prospectively, or those comparing regional EMS protocols to internationally recognized standards, will be essential for validating and generalizing our findings. Additionally, research should explore subgroup variations and rare etiologies to enhance the applicability of findings across diverse healthcare settings.

6. Conclusions

This study, positioned as a regional pilot, provides valuable insights into the factors influencing OHCA outcomes within the Lublin Voivodeship. The findings underscore the critical role of specific EMS-administered medications, such as amiodarone and dopamine, in achieving ROSC and highlight the contextual influence of incident location and underlying etiology on medication efficacy.

While retrospective in nature, this analysis establishes a foundation for hypothesis generation and emphasizes the need for broader, multicenter, and prospective studies to validate and expand upon these results. The insights gained from this regional context contribute to refining EMS protocols, optimizing medication use, and improving resuscitation strategies globally. Future research should focus on addressing gaps in long-term neurological outcomes and exploring variations across diverse healthcare systems to enhance OHCA patient care worldwide.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

AUTHOR CONTRIBUTIONS

KB and MG—provided the main framework, identified and organized primary materials, and collaborated in writing the manuscript. KG—identified appropriate references and collaborated on the writing and editing of the manuscript. AMA-W—contributed to drafting sections of the manuscript. All authors have read and agreed to the published version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All data handling procedures complied with ethical standards. Data were pseudonymized to ensure privacy in accordance with the personal data protection act enforced on 10 May 2018. The study protocol received approval from the Bioethics Committee of the Medical University in Lublin, approval number KE-0254/232/2018. The requirement for informed consent was waived by the Bioethics Committee of the Medical University in Lublin.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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