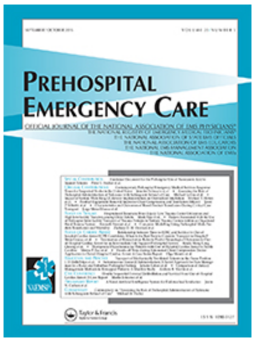

Prehospital Emergency Care

ISSN: 1090-3127 (Print) 1545-0066 (Online) Journal homepage: https://www.tandfonline.com/loi/ipec20

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Abstract

Background

Emergency Medical Services (EMS) often respond to 911 calls using red lights and sirens (RLS). RLS is associated with increased collisions and increased injuries to EMS personnel. While some patients might benefit from time savings, there is little evidence to guide targeted RLS response strategies.

Objective

To describe the frequency and nature of 911 calls that result in potentially life-saving interventions (PLSI) during the call.

Methods

Using data from ESO (Austin, Texas, USA), a national provider of EMS electronic health records, we analyzed all 911 calls in 2018. We abstracted the use of RLS, call nature, and interventions performed. A liberal definition of PLSI was developed a priori through a consensus process and included both interventions, medications, and critical hospital notifications. We calculated the proportion of calls with RLS response and with PLSI performed, both overall and stratified by call nature.

Results

There were 5,977,612 calls from 1,187 agencies included in the analysis. The majority (85.8%) of calls utilized RLS, yet few (6.9%) resulted in PLSI. When stratified by call nature, cardiac arrest calls had the highest frequency PLSI (45.0%); followed by diabetic problems (37.0%). Glucose was the most frequently given PLSI, n =69,036. When including multiple administrations to the same patient, epinephrine was given most commonly PLSI, n = 157,282 administrations).

Conclusion

In this large national dataset, RLS responses were very common (86%) yet potentially life-saving interventions were infrequent (6.9%). These data suggest a methodology to help EMS leaders craft targeted RLS response strategies.

Keywords:

Emergency Medical Service, Prehospital, Red Lights and Sirens, Interventions, Safety

Background

Historically, ambulance responses to requests for emergency medical assistance have emphasized short response times, often facilitated by using "red lights and sirens" (RLS) under the presumption that RLS helps safely reduce response times and thus benefits patients. On average, RLS reduces ambulance travel times by 1.5 (urban) to 3.6 (rural) minutes,[1–4] but RLS is also associated with increased risk and severity of ambulance crashes,[5–10] and has not been shown to improve patient outcomes.[11–15] There has also been a recognition that routine use of RLS should be decreased.[16, 17]

Still, the perception persists that some conditions—such as major trauma, witnessed cardiac arrest, anaphylaxis, and severe respiratory distress—might benefit from rapid ambulance response. To that end, many EMS agencies now employ dispatch systems that allocate resources and assign response modes based on information collected from 9-1-1 callers. Although several studies have demonstrated the ability of dispatchers to identify high-acuity patients,[18–22] to our knowledge no studies have yet demonstrated a benefit for patients assigned an RLS response.

The objective of this study was to determine the proportion of 911 scene responses with RLS that resulted in a potentially life-saving intervention (PLSI) being performed, overall and stratified by call nature.

Methods

This retrospective, observational study utilized the 2018 research database maintained by ESO (Austin, Texas), a national provider of EMS electronic health record (EHR) services. The 2018 ESO research dataset contains de-identified, detailed EHR information for 7,574,879 events attended by 1,289 EMS agencies that have consented to the inclusion of their data. The dataset is compliant with the National EMS Information System (NEMSIS) data dictionary and includes data about the patient, the incident, and any interventions. Call nature is documented by dispatchers based on each agency's dispatch criteria. The institutional review board at Baylor Scott & White Healthcare approved this study.

Defining Potentially Life-Saving Interventions

We identified PLSIs by distributing a list of all of the interventions reported in the dataset among the four authors, who independently reviewed the list to categorize each item as a PLSI or not a PLSI. Mindful that any list of interventions for this purpose would be subjective, we intentionally chose to use a liberal definition of "to reverse a critical condition or rapidly improve hemodynamic stability." If an intervention might, in some cases, be considered potentially life-saving, we included it, opting to err on the side of inclusion rather than exclusion. We also included STEMI, stroke, sepsis, and trauma alerts as PLSI, recognizing that expediting transport and speeding hospital treatment might be a PLSI.

All interventions that three or more of the authors identified as a PLSI were included on the PLSI list, and any intervention that all four authors identified as not a PLSI was omitted. Where only one or two authors identified an intervention as a PLSI, the item was reviewed by the group with the final determination based on consensus; if consensus could not be reached the intervention was not included as a PLSI. Inter-rater agreement among the authors was evaluated using intraclass correlation coefficient (ICC),[23, 24] overall and for procedural interventions and medication (including intravenous fluid) interventions separately.

Inclusion and Exclusion Criteria

We included all 911 responses to an emergency scene, regardless of whether the responding unit had transport capability or not, that involved RLS at any point during response. We excluded interfacility transfers, calls without patient contact, and calls with missing response mode data or call nature data.

Analysis

Our primary outcome was the proportion of RLS responses to a 911 scene that resulted in at least one PLSI at any point during the call. We also stratified the frequency of PLSI by the dispatcher-reported call nature to better identify call types that might most benefit from RLS response. We used dispatcher-reported call nature, rather than EMS provider impression or reported chief complaint, in order to focus on information that is available at the time of the decision to use RLS during response. Finally, to address the possibility that early arrival on scene through the use of RLS might have mitigated the progression of disease and averted the need for PLSI, we performed a sensitivity analysis comparing the overall proportion of responses requiring PLSI across response time quartiles.

Results

The consensus process identified 42 PLSI. (Supplemental Table 1) There was significant interrater agreement for classifying interventions as PLSI vs. non-PLSI, with an overall ICC of 0.43 (CI: 0.38-0.47, $p<0.001$). Agreement was better for procedural interventions (ICC = 0.50; CI: 0.41-0.59, $p<0.001$) than for medications and intravenous fluids (ICC = 0.39; CI: 0.34-0.45, $p<0.001$).

In total, there were 7,574,879 total responses, including non-911 responses; 5,977,612 responses were to 911 calls with 5,126,266 (85.8%) of them using RLS. We excluded 483,033 records without a documented call nature and 987,432 records without any patient contact (e.g., no patient found), leaving a final analysis sample of 3,843,123 responses by 1,187 unique EMS agencies. Most responding agencies were community non-profit (65.9%), utilized all paid staffs (78.7%) and provided Advanced Life Support care (78.4%) (Table 1).

Of all included RLS responses, only 6.9% had a PLSI performed at any point in the call. When stratified by call nature, cardiac arrest had the highest rate of PLSI (45.0%), followed by diabetic problem (37.0%) (Table 2). Of those calls dispatched with a call nature of cardiac arrest, only 54.2% were found to be in arrest upon arrival. When looking only at those cardiac arrest call natures in which EMS considered the call to actually be an arrest (as opposed to dispatched as an arrest and later found not to be), the proportion of PLSI increased to 70.1%. Overall, the PLSI rate exceeded 10% for 13/52 (25%) call natures.

Table 3 shows the 10 most frequently administered PLSIs. Overall, some form of glucose (oral glucose or dextrose) was the PLSI administered to the most patients (n=69,036). When accounting for interventions given multiple times to the same patient, epinephrine was the most frequent PLSI (n= 157,282 administrations). Epinephrine was also the most frequent PLSI in responses dispatched as cardiac arrest (n = 17,216 responses).

There was no significant difference in the proportion of responses resulting in PLSI across the four response time quartiles (range: 6% to 7%; see Supplemental Table 2).

Discussion

Regardless of dispatch call nature, 85.8% of all 911 responses in this dataset utilized RLS to the scene. Only 6.9% of RLS scene responses resulted in PLSI at any time during the response. The proportion of responses with PLSI ranged from 0.0% for calls dispatched as mass casuality incidents to 45.0% for calls dispatched as cardiac arrest.

The intent behind responding to 911 calls using RLS is to save time, with the assumption that faster responses to medical emergencies will result in better patient outcomes. Various studies have identified average time-savings of between 1 and 4 minutes when RLS is used during responses to 911 scenes.[1–4] However, any time savings associated with RLS use, whether during response or transport, comes with an increased risk for vehicle collisions.[8–10] Given the increased risk of RLS, determining the patient benefit of this mode of operation is critical.

While we are the first to investigate the performance of PLSI following RLS response to the scene, studies evaluating PLSI in the Emergency Department (ED) following RLS transports have seen similar results. O'Brien and colleagues found an average time savings of 3.8 minutes with RLS transport, but only 5.3% of patients transported with RLS had any time-critical interventions performed during their ED stay.[15] Most (81%) patients transported with RLS had no interventions performed at all. [12] Marques-Baptiste and colleagues found that only 4.5% of patients transported with RLS to their level I trauma center had a time-critical intervention at any time during their ED stay, and no patients had a time-critical intervention performed within the 2.6 minutes saved by using RLS transport. [12]

We were surprised by the relatively low proportion of PLSI utilized on responses dispatched as cardiac arrest. It is likely that this is explained by the imprecise and conservative nature of dispatch protocols erring on the side of identifying a call as a cardiac arrest, even when that cannot be confirmed by call-takers. Also, some dispatch centers may dispatch responses for obvious death as cardiac arrest, for which no resuscitative interventions are indicated. Finally, patients in arrest may have advanced directives requesting that no resuscitation be attempted. These suppositions are supported by our sensitivity analysis of all responses with a call nature of cardiac arrest. Only 54.2% were found to be cardiac arrest on arrival and some portion of these likely had no attempts at resuscitation, perhaps because of obvious death or presence of do not attempt resuscitation orders. The proportion of responses with a call nature of cardiac arrest with PLSI performed at any time increased to 70% when limited only to those patients found to actually have had cardiac arrest.

It could be argued that so few PLSI are seen with RLS response because the patient's condition was stabilized by other EMS interventions which could have been facilitated by shorter RLS response times. However, we found that 93.4% of 911 RLS responses with patient contact had no time-critical interventions at all. Also, we found no difference in the rate of PLSI across response time quartiles, indicating that encounters with shorter response times were no less likely to receive PLSI than those with longer response times. In fact, the rate of PLSI actually trended downward with increasing response time, although not significantly so.

Given the increased risk for collisions and resulting injuries to patients, EMS clinicians, and the public, it seems prudent to use methodologies to better target RLS use. While several systems exist to assist call takers in better identifying medical emergencies[19–22] these are primarily aimed at determining which resources to send to a 911 call; the determination of *how* these resources respond is left to the discretion of each agency. National organizations have recognized the need for more targeted use of RLS.[16]

Our work suggests individual agencies could use their own data to determine which call natures in their system result in very low rates of PLSI and use those data to reduce RLS use without sacrificing patient care. Although our data confirm that PLSI is rare, the call natures and PLSI in our analysis come from national data and divergent EMS systems. Individual agencies will have unique dispatch protocols and treatment options, and thus their rates of PLSI for specific call natures will vary from what we report here. Agencies (and the communities they serve) will also want to establish their own PLSI thresholds for RLS response. As an example, an agency might decide to respond with RLS to all call natures with a PLSI rate, determined using their own call nature and treatment data, above, say, 5%. This would allow a systematic approach to deciding when RLS use was worth the increased risk. Using our data as an example, a threshold of 5% PLSI would result in 2,046,370 RLS responses, a 47% reduction from the 3,843,123 RLS responses we saw in our data. Likewise, a 10% threshold would result in 1,458,766 RLS responses, a 62% decrease in RLS use. Our results, however, cannot suggest a specific threshold for RLS response. Future work should evaluate the impact of making such changes in RLS response.

<u>Limitations.</u>

Our work has several important limitations. The dataset we used may not be representative of the overall EMS community. It is a very large dataset including multiple agencies of various types in all regions of the US, but it is possible that agencies not using ESO as their EHR vendor may differ in unknown ways from those that do. Our process for determining the list of PLSI was subjective. We used a consensus process based on a common definition, but it is likely that others may have chosen to include or exclude different interventions. As an example, we chose not to list oxygen as a PLSI. Our rationale was that life-saving oxygen would likely have been administered with an adjunct such as BVM or intubation, which were included. We also did not include assessments, such as obtaining a 12 lead ECG or evaluating blood glucose as PLSI because these assessments provide no therapeutic value by themselves; we do, however, include the interventions that result from those assessments, such as a STEMI Alert or glucose administration. We did not initially have 100% agreement on interventions that constituted

PLSI. All authors reviewed those cases without initial consensus. The interventions without initial consensus included several benzodiazepines, hydroxycobalamine, verapamil, and glucose. All authors agreed on each item ultimately both included and excluded in the list of PLSI used in the analysis. Others might apply a different standard, which could either increase or decrease the rate of PLSI depending on whether they use a more or less liberal definition.

To address the probable variation in PLSI determination from agency to agency, we intentionally chose a very liberal definition of what might be considered a potentially life-saving intervention. We did this to make our findings as broadly applicable as possible. We do, however, recognize that our findings likely overstate the proportion of calls with true life-saving interventions. We did not match interventions with their indications, either in our initial classification of PLSI or in our evaluation of responses resulting in PLSI. Because of this, it is likely that some of the PLSI we chose to include might have actually been given for non-life-threatening conditions. For example, we included midazolam as a PLSI because of its potential use in status epilepticus but recognize that it may have also been administered for anxiety or back pain. This would inflate the rate of PLSI as defined in our study. Also, we specifically evaluated PLSI—with the emphasis on the P for potential; even with outcome data, it would be very difficult to ascribe actual life-saving to most individual interventions. Finally, our outcome of interest was the performance of a PLSI. Some patients might have had an intervention we classified as a PLSI for a non-life-saving indication. On the other hand, some patients might have had an indication for a PLSI but not received it; either as an omission in care or because that particular PLSI was not available for the responding EMS agency. This would be particularly true for a BLS-only system without access to the full range of PLSI. This reinforces the need for system-specific analyses to guide response modes: the call natures that result in PLSI likely differ from system to system, especially between ALS and BLS agencies.

We stratified PLSI by call nature rather than by chief complaint or provider impression. We did this because call nature is the information known at the time of the decision to use or not use RLS. However, the data set does not indicate how dispatchers select a given call nature, or whether individual agencies use specific dispatch protocol systems.

It is possible that arriving on scene sooner through the use of RLS may have mitigated the need for PLSI. We addressed this possibility with a sensitivity analysis looking at the rate of PLSI across response time quartiles. The rate of PLSI actually trended downward with increasing response time, suggesting that any time saved with the use of RLS did not mitigate the use of PLSI.

All interventions were self-documented by providers. Any inaccuracies or omissions in their documentation would impact our results. We did not exclude BLS agencies from our analysis. We recognize that these agencies have fewer PLSI available to them than ALS agencies, but felt that there were sufficient BLS interventions (CPR, bag mask ventilations) that were potentially lifesaving to include them in our analysis.

RLS Yield

Conclusion

In this large national dataset, RLS responses were very common (85.8%) yet PLSI were infrequent (6.9%). Using our methodology, when applied to local data, may help EMS leaders craft agency-specific, targeted RLS response strategies.

Disclosure of Interests

The authors have no conflicts of interest to disclose.

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Tables

Table 1: Description of Dataset

Number unique agencies	1,187	
Level of Care		
BLS	299,634 (7.8%)	
ALS	3,012,057 (78.4%)	
Unknown	531,432 (13.8%)	
Transport Priority		
RLS	487,677 (12.7%)	
No RLS	3,355,446 (87.3%)	
Response Intervals – median (Interquartile Range)		
Response	6.7 (4.7, 9.8)	
Chute	1.0 (0.4,1.8)	
Rolling	6 (4,9)	
Access	1 (1,2)	
Scene	15 (11, 21)	
Transport	12 (8,19)	
Total Patient Time	27 (20, 36)	

Table 2. Proportion of 911 Calls with a Red Lights & Sirens Response and Potentially Life Saving Intervention, by Documented Call Nature

Call Nature	Total Number of Responses*	RLS Responses n (%)	Included Responses**	PLSI*** N (%)
Cardiac Arrest	75,623	72,380 (95.7%)	53,965	24,277 (44.99%)
Diabetic Problem	88,119	79,085 (89.7%)	69,824	25,854 (37.03%)
Air Medical Transport	1,465	1,308 (89.3%)	1,008	342 (33.93%)
Respiratory Arrest	123	115 (93.5%)	93	29 (31.18%)
Drowning/SCUBA Accident	2,183	2,097 (96.1%)	1,327	301 (22.68%)
Stab/Gunshot Wound	19,371	18,603 (96.0%)	12,633	2,589 (20.49%)
Overdose/Poisoning	114,938	103,925 (90.4%)	80,976	15,819 (19.54%)
Unconscious/Fainting	206,281	196,010 (95.0%)	159,735	22,072 (13.82%)
Stroke/CVA	101,245	98,477 (97.3%)	89,749	11,903 (13.26%)
Convulsions/Seizure	167,362	157,932 (94.4%)	139,651	17,442 (12.49%)
Unknown/Man Down	763,779	637,825 (83.5%)	95,509	11,194 (11.72%)
Altered Mental Status	65,158	59,231 (90.9%)	51,620	6,021 (11.66%)
Allergic Reaction/Stings	35,793	31,778 (88.8%)	27,665	2,987 (10.80%)
Breathing Problem	553,334	535,620 (96.8%)	478,218	43,447 (9.09%)
Auto vs. Pedestrian	441	394 (89.3%)	326	28 (8.59%)
Choking	14,878	13,533 (91.0%)	9,871	682 (6.91%)
Industrial Accident	1,507	1,354 (89.8%)	858	58 (6.76%)
Boating Accident	377	355 (94.2%)	225	15 (6.67%)
Pandemic/Epidemic/Outbreak	115	102 (88.7%)	76	5 (6.58%)
Electrocution		920 (90.6%)		45 (5.97%)

	1,016		754	
Transfer	51,293	35,326 (68.9%)	33,366	1,806 (5.41%)
Fainting	5,432	4,852 (89.3%)	4,252	193 (4.54%)
Burns	7,013	6,040 (86.1%)	4,779	209 (4.37%)
Heart Problems	33,458	31,582 (94.4%)	28,291	1,184 (4.19%)
Fire	28,093	23,516 (83.7%)	2,886	116 (4.02%)
Standby	17,038	10,269 (60.3%)	984	39 (3.96%)
Sick Person	1,204,177	978,725 (81.3%)	850,390	32,259 (3.79%)
Traumatic Injury	134,538	109,647 (81.5%)	94,732	3,587 (3.79%)
Traffic Accident	531,115	493,858 (93.0%)	371,088	13,879 (3.74%)
Psychiatric Problem	158,308	105,515 (66.7%)	81,405	2,912 (3.58%)
Assault - Sexual	117	75 (64.1%)	61	2 (3.28%)
Heat/Cold Exposure	10,054	8,614 (85.7%)	7,263	218 (3.00%)
Medical Alarm	51,168	42,235 (82.5%)	12,125	342 (2.82%)
Chest Pain	355,314	343,663 (96.7%)	313,194	8,597 (2.74%)
Pregnancy/Childbirth	30,751	28,444 (92.5%)	25,525	691 (2.71%)
Fall	526,935	413,951 (78.6%)	348,095	8,659 (2.49%)
Well Person Check	20,983	13,202 (62.9%)	8,521	211 (2.48%)
Hemorrhage/Laceration	75,075	63,477 (84.6%)	55,546	1,280 (2.30%)
Inhalation/HazMat	4,203	3,326 (79.1%)	1,910	42 (2.20%)
Other	153,120	122,154 (79.8%)	95,591	2,063 (2.16%)
Assault	106,182	84,287 (79.4%)	61,544	1,092 (1.77%)

EMS Special Service	3,133	1,832 (58.5%)	969	16 (1.65%)
Admission	592	420 (70.9%)	366	6 (1.64%)
Headache	25,514	20,970 (82.2%)	18,994	284 (1.50%)
Medical Transport	2,152	936 (43.5%)	828	12 (1.45%)
Fever	419	262 (62.5%)	241	3 (1.24%)
Animal Bite	9,518	7,706 (81.0%)	6,247	76 (1.22%)
Back Pain	52,913	38,348 (72.5%)	34,870	331 (0.95%)
Assist Invalid	32,240	14,540 (45.1%)	7,338	67 (0.91%)
Abdominal Pain	128,952	104,297 (80.9%)	94,917	756 (0.80%)
Eye Problem	4,681	3,131 (66.9%)	2,702	18 (0.67%)
Mass Casualty Incident	23	22 (95.7%)	20	0 (0.00%)

* Includes responses with and without Red Lights & Sirens
** Includes only those Responses with Red Lights & Sirens with Call Natures and Patient Contact Times.
*** Proportion of Responses with Red Lights & Sirens with Call Natures and Patient Contact Times who have a Potentially Life Saving Intervention

Table 3. 10 Most Frequent Potentially Life Saving Interventions

Treatment	Number of Patients Receiving at least One Administration	Total Number of Administrations*
Glucose	69,036	79,676
BLS Airway	62,898	87,118
Naloxone	56,351	74,757
Epinephrine	47,128	157,282
Midazolam	39,480	52,547
Intubation	35,616	45,250
CPR	33,659	49,039
NIPPV	32,740	33,595
Suction	29,256	36,017
Trauma Alert	20,365	20,494

*Includes multiple treatment administrations per patient