Is Use of Warning Lights and Sirens Associated With Increased Risk of Ambulance Crashes? A Contemporary Analysis Using National EMS Information System (NEMSIS) Data

Brooke L. Watanabe, MD*; Gregory S. Patterson, DO; James M. Kempema, MD; Orlando Magallanes, MD; Lawrence H. Brown, PhD

*Corresponding Author. E-mail: bwatanabe@ascension.org.

Study objective: We compare reported crash rates for US ambulances responding to or transporting patients from a 911 emergency scene with or without lights and sirens. Our null hypothesis is that there will be no difference in the rate of ambulance crashes whether lights and sirens are used.

Methods: For this retrospective cohort study, we used the 2016 National EMS Information System data set to identify 911 scene responses and subsequent patient transports by transport-capable emergency medical services (EMS) units. We used the system's "response mode to scene" and "transport mode from scene" fields to determine lights and sirens use. We used the "type of response delay" and "type of transport delay" fields to identify responses and transports that were delayed because of a crash involving the ambulance. We calculated the rate of crash-related delays per 100,000 responses or transports and used multivariable logistic regression with clustered (by agency) standard errors to calculate adjusted odds ratios (AORs) (with 95% confidence intervals [CIs]) for the association between crash-related delays and lights and sirens use for responses and transports separately.

Results: Among 19 million included 911 scene responses, the response phase crash rate was 4.6 of 100,000 without lights and sirens and 5.4 of 100,000 with lights and sirens (AOR 1.5; 95% CI 1.2 to 1.9). For the transport phase, the crash rate was 7.0 of 100,000 without lights and sirens and 17.1 of 100,000 with lights and sirens (AOR 2.9; 95% CI 2.2 to 3.9). Excluding responses and transports with only partial lights and sirens use did not meaningfully alter the results (response AOR 1.5, 95% CI 1.2 to 1.9; transport AOR 2.8, 95% CI 2.1 to 3.8).

Conclusion: Ambulance use of lights and sirens is associated with increased risk of ambulance crashes. The association is greatest during the transport phase. EMS providers should weigh these risks against any potential time savings associated with lights and sirens use. [Ann Emerg Med. 2018;■:1-9.]

Please see page XX for the Editor's Capsule Summary of this article.

0196-0644/$-see front matter

https://doi.org/10.1016/j.annemergmed.2018.09.032

SEE EDITORIAL, P. XXX.

INTRODUCTION

Lights and sirens are required equipment for emergency ambulances and are used "to warn other drivers…and request the right-of-way,"[1] presumably expediting ambulance travel. Previous studies, however, have shown only marginal time savings are achieved with lights and sirens response or transport,[2-7] and patient outcomes are not affected by limiting lights and sirens use to only critical clinical circumstances such as unresolved airway obstruction, impending respiratory failure, uncontrolled seizures, or trauma requiring emergency surgery.[6-11]

There are also potential risks associated with lights and sirens use. Injury rates are higher when an ambulance crashes while using lights and sirens,[12-15] and the majority of fatal ambulance crashes involve vehicles operating with lights and sirens.[16-18] However, whether lights and sirens use specifically increases the risk of crashing is less clear. Higher ambulance crash rates have been reported with lights and sirens use, but these analyses were either purely descriptive or did not achieve statistical significance.[14,15,19-21]

To our knowledge, no nationwide analysis has explored the association between lights and sirens use and the risk of an ambulance crash in the United States. Furthermore, most of the existing data predate strategies and

Editor's Capsule Summary

What is already known on this topic

Despite inherent risk, lights and sirens use provides only marginal improvement in time and outcome.

What question this study addressed

This retrospective national emergency medical services (EMS) database analysis evaluated the association between lights and sirens use and ambulance crash risk.

What this study adds to our knowledge

In this 19-million-run database, the overall ambulance crash risk was 12.4 of 100,000 runs. EMS scene response risk was 4.6 of 100,000 without and 5.4 of 100,000 with lights and sirens. The risk during transport was 7.0 of 100,000 without and 17.1 of 100,000 with lights and sirens.

How this is relevant to clinical practice

Although the absolute ambulance crash risk remains small, use of lights and sirens is associated with increased relative risk, particularly during transport. EMS directors should carefully evaluate their lights and sirens use policies.

technologies—such as advanced priority dispatch algorithms, traffic signal preemption systems, and real-time traffic mapping—that might influence both lights and sirens use and traffic risks. The purpose of this study was to provide a contemporary, nationwide comparison of reported crash rates for US ambulances responding to or transporting patients from a 911 emergency scene with or without lights and sirens.

MATERIALS AND METHODS

Study Design and Setting

For this retrospective cross-sectional study, we analyzed data from the 2016 National EMS Information System (NEMSIS) public-release research data set, supplemented with additional masked agency data provided strictly for multivariable covariance modeling (not reporting). The data set includes nearly 30 million emergency medical services (EMS) activations submitted by 9,993 EMS agencies serving 49 states and territories.[22] It is a fully deidentified, Health Insurance Portability and Accountability Act–compliant data set.[23] The University of Texas–Austin institutional review board administratively affirmed that this analysis does not constitute human subjects research.

Table 1 shows the NEMSIS elements used in this study.

Our primary analysis included all dispatches of a transport-capable ground EMS vehicle to a 911 emergency scene (ambulance runs). For each run, we evaluated response to the scene and transport from the scene separately because some runs do not result in transport. We excluded interfacility transfers, intercepts, medical transports, and standbys; responses by nontransport or rescue vehicles, mutual aid activations, and supervisor responses; and events documented as responses or transports by rotor-wing or fixed-wing air-medical services.

NEMSIS includes information about each EMS vehicle's lights and sirens use. As shown in Table 1, NEMSIS allows entries for lights and sirens use throughout the entire response phase or transport phase, as well as "downgrades" from or "upgrades" to lights and sirens during either phase. We categorized lights and sirens use throughout response or transport as "full lights and sirens"; we also combined full lights and sirens with downgrades and upgrades into a single category of "any lights and sirens." Responses and transports documented as "no lights and sirens" served as the control group for our analyses.[23] Responses and transports with missing lights and sirens data were excluded from the primary analyses but included in subsequent sensitivity analyses (described below).

Outcome Measures

For each activation, NEMSIS reports response and transport delays, including delays resulting from crashes involving the EMS vehicle. We used reported crash-related delays as a proxy measure of EMS vehicle crashes, accepting that minor crashes that did not result in a delay would go uncounted. In rare circumstances (n=41) in which crash-related delays were reported for both the response and transport phase of a single run, we presumed a response phase crash had a carryover effect that also resulted in transport delay, rather than presuming 2 crashes occurred during a single run.

We considered several potential agency- and run-level covariates: at the agency level, we determined agency "response volume" by summing the included responses for each agency and then placing agencies into 5 groups based on response volume quintiles. We determined each agency's rate of lights and sirens use for included responses and transports separately and then placed agencies into 5 groups based on agency-specific lights and sirens use quintiles. NEMSIS reports agency level of service as the highest level of provider routinely available, regardless of whether that level of provider is dispatched with every response. We

Table 1. NEMSIS data elements used in this analysis.

NEMSIS Element	Use	Codes/Data Used
E02_04: type of service requested	Inclusion criteria	30: 911 response (scene)
E02_05: primary role of unit	Inclusion criteria	75: transport
E20_10: patient disposition	Inclusion criteria (transport)	4850: treated, transported by EMS
E07_34: CMS service level	Exclusion criteria	1025: fixed wing (airplane)
		1030: rotary wing (helicopter)
E02_20: response mode to scene	Exposure (full L&S)	390: lights and siren
	Exposure (any L&S)	380: initial lights and siren, downgraded to no lights and siren
		385: initial no lights and siren, upgraded to lights and siren
		390: lights and siren
	Reference (no L&S)	395: no lights and siren
E20_14: transport mode from scene	Exposure (full L&S)	4965: lights and siren
	Exposure (any L&S)	4955: initial lights and siren, downgraded to no lights and siren
		4960: initial no lights and siren, upgraded to lights and siren
		4965: lights and siren
	Reference (no L&S)	4970: no lights and siren
E02_07: type of response delay	Outcome measure	175: vehicle crash
E02_09: type of transport delay	Outcome measure	315: vehicle crash
E05_05: unit en route date/time	Multivariable adjustment	6 AM–6:59 PM daytime 5 PM–11:59 PM evening
		Midnight–6 AM overnight
E05_09: depart scene date/time	Multivariable adjustment	6 AM–6:59 PM daytime 5 PM–11:59 PM evening
		Midnight–6 AM overnight
Urbanicity	Multivariable adjustment	Urban, suburban, rural, wilderness
D01_07: level of service	Multivariable adjustment	6090: EMT-basic or 6120: first responder 6100: intermediate 6110: EMT-paramedic, 6111: nurse or 6112: physician
		Other levels
D01_08: organization type	Multivariable adjustment	5810: community, nonprofit or 5860 tribal
		5820: fire
		5830: government, nonfire
		5840: hospital
		5850: private, nonhospital
D01_09: organization status	Multivariable adjustment	5870: mixed
		5880: nonvolunteer
		5890: volunteer

CMS, Centers for Medicare and Medicaid Services; *L&S*, lights and sirens.

condensed level of service into 4 categories: first responder and EMT-basic, EMT-intermediate, EMT-paramedic or higher, and other. That is, we assumed that agencies with nurses or physicians available to routinely respond would most likely operate at the paramedic level. NEMSIS records agency type in 6 mutually exclusive categories (community, nonprofit; fire department; governmental, nonfire; hospital; private, nonhospital; and tribal). We analyzed each agency type separately except community and tribal, which we combined as requested by NEMSIS. Finally, NEMSIS records agency staffing in 3 mutually exclusive categories: volunteer, nonvolunteer, and mixed.[23]

At the run level, NEMSIS records detailed time data for each event. We used the en route and depart-scene times to stratify responses and transports into 3 time-of-day subgroups: daytime, including morning and afternoon commute times (6 AM to 6:59 PM); evening (7 PM to 11:59 PM); and overnight (midnight to 5:59 AM). NEMSIS stratifies scene locations into 4 urbanicity groups based on US Department of Agriculture Urban Influence Codes: urban, suburban, rural and wilderness.[23]

Primary Data Analysis

We report the total number of ambulance 911 scene responses and subsequent transports, as well as the number of those responses and transports experiencing a crash-related delay. We calculated the rate of crash-related delays per 100,000 responses or transports.

We conducted multivariable logistic regression assessing the association between lights and sirens use and crash-related delays. Because the large sample size produced statistically significant bivariate associations between lights and sirens use and every potential covariate, we included in the models only those agency- and run-level characteristics for which bivariate analyses revealed a 5% (or greater) difference in the rate of either response or transport lights and sirens use (Table 2). Ideally, other unmeasured within-agency factors that might confound the relationship between lights and sirens use and crashes (eg, local traffic/road conditions, availability of traffic signal preemption) would be addressed with mixed-effects modeling to adjust for clustering of events within agencies.[24] In this case, with less than 3% of more than 6,600 agencies having more than one event, such modeling was computationally infeasible. Instead, we conducted the regression modeling with clustered (by agency) standard errors, which produce wider, more conservative confidence intervals (CIs). We included agency response volume and agency-specific lights and sirens use (in quintiles) as covariates in the regression models, using the middle quintile as the reference category, to account for unmeasured within-agency factors that could potentially confound any association between lights and sirens use and crashes. We used the Hosmer-Lemeshow test to assess the models' goodness of fit.

In secondary analyses, we repeated the multivariable logistic regression modeling, but stratified across each response volume and lights and sirens use quintile. We also repeated the multivariable analyses stratified by each agency- and run-level characteristic separately.

Finally, we also conducted several sensitivity analyses: (1) including crash-related delays with missing lights and sirens data, assuming they represented non–lights and sirens events; (2) excluding agencies with very low (<1,000) response volumes; (3) excluding agencies with either very low or very high (>200,000) response volumes; and (4) excluding data for a single agency with a high rate of transport phase lights and sirens use (89%) and a disproportionate (nearly 10-fold) number of reported transport phase crash-related delays.

Table 2. Agency characteristics, run characteristics, and lights and sirens use among the included responses and transports.

Characteristics	Runs, N	L&S Use, % Response	L&S Use, % Transport
Agency annual response volume, quintile*†			
1 (<3,860)	4,093,913	75.8	27.7
2 (3,861–12,070)	4,097,514	75.4	21.6
3 (12,071–35,000)	4,119,824	75.3	22.0
4 (35,001–96,250)	4,144,253	79.9	19.5
5 (>96,250)	4,010,352	76.3	24.2
Agency level of service			
Paramedic (+/− MD, RN)†	17,514,730	76.0	22.2
Intermediate	346,415	78.9	30.3
Basic EMT/first responder	986,705	78.4	31.7
Other levels†	1,615,768	83.3	26.1
Agency type of service			
Community, nonprofit, or tribal†	2,462,481	65.6	19.9
Fire†	6,203,140	86.7	35.3
Governmental	3,867,835	75.8	19.2
Hospital based	3,197,592	74.1	17.7
Private, for profit	4,734,808	71.7	17.0
Agency L&S use, quintile, %*†			
1 (resp: <48; trans: <4)	3,940,346	45.9	3.5
2 (resp: 48–64; trans: 4–7)	3,930,531	67.1	7.1
3 (resp: 65–79; trans: 8–14)	3,962,351	79.5	11.2
4 (resp: 80–96; trans: 15–37)	3,982,436	91.5	22.9
5 (resp: >96; trans: >37)	3,852,754	99.0	74.4
Agency staffing			
Nonvolunteer	16,200,077	75.9	22.4
Mixed	3,690,424	79.0	24.1
All volunteer†	575,355	80.6	33.9
Run location			
Urban†	16,518,013	76.7	23.4
Suburban	1,422,366	75.1	17.5
Rural	1,506,492	75.0	21.2
Wilderness†	397,026	72.8	26.7
Run dispatch time of day			
6 AM–6:59 PM	12,451,837	76.5	21.7
7 PM–11:59 PM	4,606,688	76.7	23.7
Midnight–5:59 AM†	3,827,490	76.9	26.3

resp, Response phase; *trans*, transport phase.
*911 Scene responses are by transport units only; quintile values are rounded for presentation.
†Covariates included in the multivariable analyses.

For our primary analyses, we report both unadjusted odds ratios and adjusted odds ratios (AORs) (with 95% CIs) for the association between crash-related delays and any lights and sirens use or full lights and sirens use. Given the consistency of the results, we report only the AORs for any lights and sirens use for our secondary and sensitivity analyses.

All analyses were conducted in Stata (version 11.2; StataCorp, College Station, TX). The data commands for building the data set and executing the analysis are available from the authors on request.

RESULTS

The 2016 NEMSIS data set includes 20,465,856 dispatches of a transport-capable ground EMS vehicle to a 911 emergency scene. There were 2,539 crash-related delays among these runs, for an overall rate of 12.4 crashes per 100,000 ambulance runs.

Table 2 provides a summary of the agency- and run-level characteristics and shows response and transport phase lights and sirens use across those characteristics. Table 3 shows the primary results. Lights and sirens data were available for 19,040,095 responses (93%), with 1,000 of those responses experiencing a crash-related delay (5.3/100,000 responses). The crash rate for responses with any lights and sirens (AOR 1.5; 95% CI 1.2 to 1.9) and responses with full lights and sirens (AOR 1.5; 95% CI 1.2 to 1.9) was greater than the crash rate for responses with no lights and sirens in the unadjusted and the clustered multivariable analyses. The absolute difference in response phase crash rates with and without lights and sirens was 0.8 of 100,000 responses (95% CI 0.1 to 1.6).

There were 14,549,776 subsequent transports from the 911 scene, and lights and sirens data were available for 13,892,345 of those transports (96%). Crash-related delays occurred during 1,289 transports (9.3/100,000 transports). Again, the crash rate for transports with any lights and sirens (AOR 2.9; 95% CI 2.2 to 3.9) and full lights and sirens (AOR 2.8; 95% CI 2.1 to 3.8) was greater than the crash rate for transports with no lights and sirens in the unadjusted and the clustered multivariable analyses. The absolute difference in transport phase crash rates with and without lights and sirens was 10.1 of 100,000 transports (95% CI 8.6 to 11.6).

Table 4 shows the associations between lights and sirens use and crash-related delays across the response volume and lights and sirens use quintiles. The response-phase effect was variable, with several AOR CIs overlapping 1. The transport-phase effect, however, persisted across all response volume and lights and sirens use quintiles. The Figure shows the analyses stratified by run phase and each agency- and run-level characteristic, again demonstrating the persistent effect during the transport phase.

There were 1,425,761 responses and 657,431 transports with missing lights and sirens data, which resulted in 37 and 21 crash-related delays, respectively. The crash rates for responses (2.6/100,000) and transports (3.2/100,000) with missing lights and sirens data were lower than for the overall data. Table 5 shows the results of the sensitivity analyses, including an analysis assuming that crash-related delays with missing lights and sirens data represented non–lights and sirens events. None of the sensitivity analyses produced results markedly different from those of the primary analyses.

LIMITATIONS

We used data from NEMSIS, which is not designed as a representative sample of EMS events. NEMSIS does, however, contain data from a large number of US EMS agencies from 49 states and territories.[22] Analyses using NEMSIS rely on the accuracy and completeness of documentation by field personnel. There may be inconsistencies in how EMS agencies or individual providers

Table 3. Crash-related delays and lights and siren* use among ambulance 911 scene responses and subsequent transports.

Phase/Mode	N	Crashes	Rate/100,000	OR (95% CI)	AOR (95% CI)
Response phase					
No L&S	4,468,292	207	4.6	1 [Reference]	1 [Reference]
Any L&S	14,571,803	793	5.4	1.18 (1.01–1.37)	1.50 (1.19–1.90)
Full L&S	14,063,826	779	5.5	1.20 (1.03–1.39)	1.53 (1.21–1.94)
Transport phase					
No L&S	10,700,943	744	7.0	1 [Reference]	1 [Reference]
Any L&S	3,191,402	545	17.1	2.46 (2.20–2.74)	2.90 (2.18–3.87)
Full L&S	2,990,237	494	16.5	2.38 (2.12–2.66)	2.84 (2.12–3.80)

OR, Odds ratio.
*Full L&S means L&S use throughout the phase; any L&S includes responses and transports with L&S use in any part of the phase (ie, full L&S or upgraded to L&S or downgraded from L&S). AOR is adjusted for agency response volume, agency level of service, agency type of service, agency L&S use, agency staffing, run location, and time of day.

Table 4. Association between any lights and sirens use and ambulance crashes, stratified by agency response volume and agency lights and sirens use.

Analysis	AOR (95% CI)	
	Response	Transport
Stratified by response volume*		
<3,860	1.3 (0.9–1.7)	2.5 (1.8–3.4)
3,861–12,070	3.2 (2.0–5.2)	2.2 (1.4–3.4)
12,071–35,000	2.2 (1.3–3.7)	4.0 (2.6–6.0)
35,001–96,250	1.1 (0.5–2.1)	2.6 (1.4–4.8)
>96,250	0.9 (0.4–2.4)	6.6 (3.4–12.8)
Stratified by L&S use, %*		
Resp: <48; trans: <4	1.5 (1.1–2.2)	5.7 (4.0–8.2)
Resp: 48–64; trans: 4–7	1.3 (0.9–2.0)	2.7 (1.7–4.2)
Resp: 65–79; trans: 8–14	2.6 (1.5–4.5)	3.9 (2.7–5.9)
Resp: 80–96; trans: 15–37	1.0 (0.6–1.7)	2.0 (1.3–3.2)
Resp: >96; trans: >37	0.6 (0.2–1.7)	1.9 (1.2–3.2)

*Quintile values are rounded for presentation. Volume strata AOR is adjusted for agency level of service, agency type of service, agency L&S use, agency staffing, run location, and run time of day. L&S use strata AOR is adjusted for agency response volume, agency level of service, agency type of service, agency staffing, run location, and time of day.

record lights and sirens use or crash-related delays, but we have no reason to believe there would be a systematic association between reporting inconsistencies for those 2 variables. Our reliance on reported crash-related delays does exclude minor crashes that did not result in delay, as well as any unreported crashes. If unreported crashes are for some reason less likely to involve lights and sirens use, or if reporting of lights and sirens use is inaccurate (eg, falsified to avoid civil or criminal liability), that would introduce some bias into our analysis. Such practices, however, would have to be widespread to meaningfully influence our results. We cannot determine the temporal relationship between upgrades to or downgrades from lights and sirens and any reported crash-related delays. It is possible that some upgrades to lights and sirens occurred after a crash or that some crashes occurred after a downgrade to non–lights and sirens, which could introduce bias into our analyses of any lights and sirens. Our full lights and sirens analyses avoid this potential bias, and there was no meaningful difference in the results generated by the 2 approaches. The data precluded traditional mixed-effects modeling to adjust for clustering of events within agencies, but our use of clustered standard errors and stratified analyses provides a conservative view of the data. Although we have included agency- and run-specific covariates in our multivariable models, the NEMSIS data did not allow us to adjust for other potential confounding factors such as weather, traffic conditions, lighting conditions, or travel distances. Finally, the data set did not allow us to account for secondary crashes or injuries involving pedestrians or passengers in other vehicles, including "wake effect" crashes caused by—but not involving—ambulances as they disrupt traffic.[25]

DISCUSSION

In this contemporary assessment of lights and sirens use and ambulance crashes on a national level, we found that lights and sirens use was associated with increased crash rates compared with no lights and sirens use. We believe these data can help guide EMS agencies with lights and sirens policy setting and EMS providers in lights and sirens use decisionmaking.

Lights and sirens were used for 77% of responses but only 23% of transports. The relationship between lights and sirens use and crashes held true for both the response and transport phases of EMS runs, but with some distinctions. During the response phase, there was a statistically significant increase in crashes for ambulances traveling with lights and sirens, but the effect was inconsistent in the stratified analyses, and the crude difference in response phase crash rates—less than 1 crash per 100,000 responses—might not be practically meaningful. Although lights and sirens use appeared more judicious during transports, the relationship between it and crashes was more pronounced. The rate of transport-phase crashes more than doubled when lights and sirens were used: the absolute increase in crashes is estimated to be between 8.6 and 11.6 additional crashes per 100,000 transports, or approximately 1 additional crash per 10,000 transports. Certainly, ambulance crashes overall are rare ($\approx$12/100,000 runs). Any individual EMS agency may not experience a crash—or the increased risk of crashing with lights and sirens use—during the course of a single year or, for smaller agencies, even multiple years. On a national scale, however, the increased risk of crashing when lights and sirens are used is significant, particularly during the transport phase of a run.

We can only hypothesize about the reasons for the different effects of lights and sirens in the response and transport phases. During responses, 2 providers are typically seated in the front of the ambulance and share the cognitive load required to operate the ambulance (eg, using the radio, activating the siren, watching for traffic risks). During transport, the driver is typically alone in the front. Also, lights and sirens use during transport might indicate a higher-acuity patient, potentially leading to faster driving or

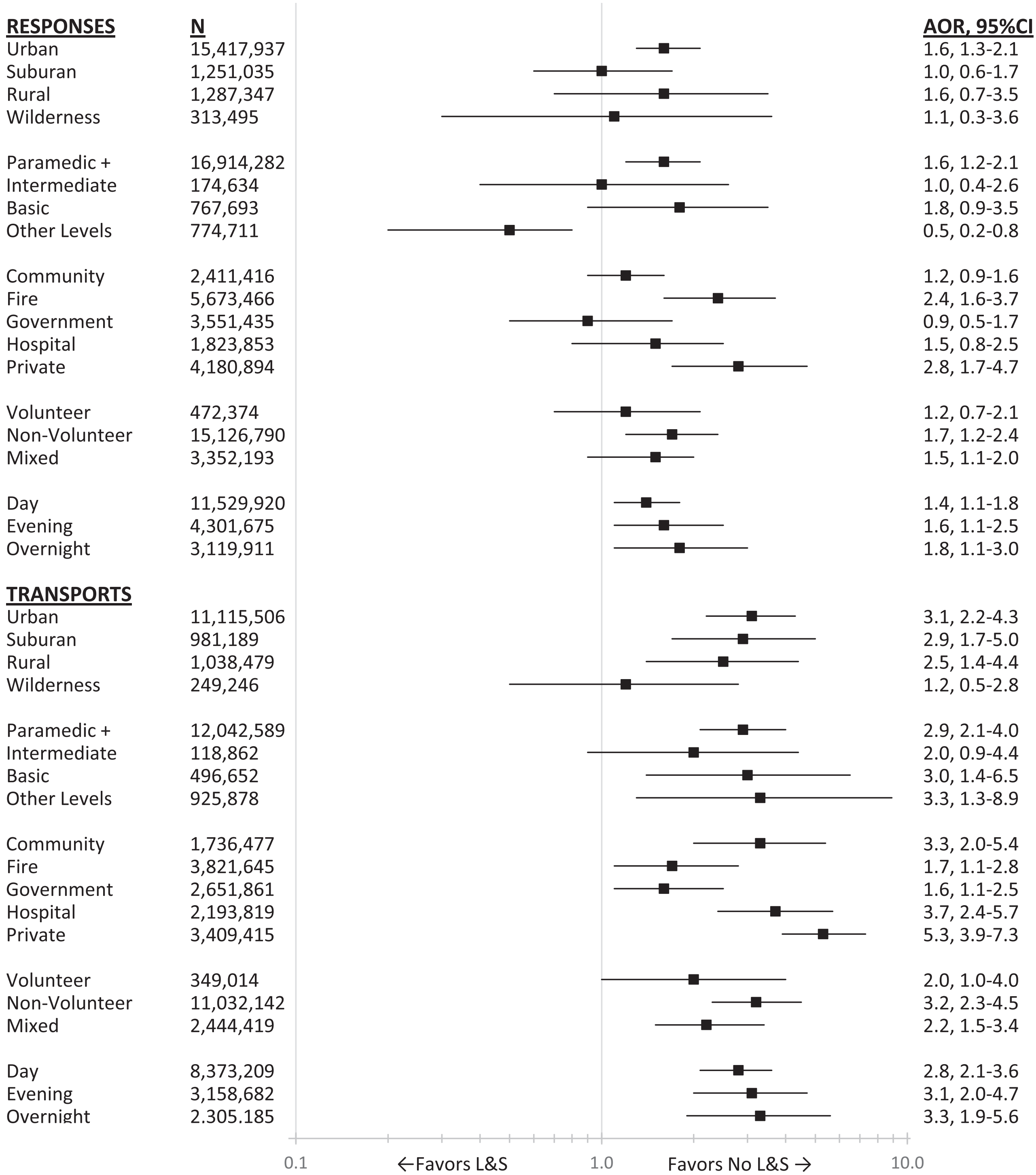

Figure. Association between lights and sirens use and crash-related delays, stratified by run phase and agency- and run-level characteristics.

increased driver distractions because of activities in the cabin. Further work is needed to understand the differential effects of lights and sirens use in the response and transport phases of ambulance runs, and to determine the role (if any) that patient acuity plays in that difference.

To our knowledge, our study is the first to definitively link lights and sirens use with ambulance crashes. A few studies have reported higher crude crash rates with lights and sirens, but they did not achieve statistical significance.[14,15,19] A recent analysis from Iowa found no

Table 5. Sensitivity analyses for the association between any lights and sirens use and ambulance crashes.

Analysis	AOR (95% CI) Response	Transport
Assuming crashes with L&S missing=L&S no	1.4 (1.1–1.7)	2.7 (2.1–3.7)
Excluding low-volume (volume <1,000*) agencies	1.5 (1.2–2.0)	3.0 (2.2–4.1)
Excluding low- and high-volume (volume ≥200,000*) agencies	1.5 (1.2–2.0)	3.0 (2.2–4.1)
Excluding 1 agency with disproportionate transport phase crashes	NA	2.7 (2.1–3.6)

NA, Not applicable.
*911 Scene responses are by transport units only. Quintile values are rounded for presentation. AOR is adjusted for agency response volume, agency level of service, agency type of service, agency L&S use, agency staffing, run location, and time of day.

significant association between lights and sirens use and crashes (odds ratio=1.1) but did not differentiate between EMS and fire department vehicles.[21] The relative rarity of ambulance crashes hampers single-system analyses: smaller systems with low response volumes could go several years without a crash, even though the underlying crash rate and association with lights and sirens use could be the same as in larger systems. Even relatively large systems could have too few crashes to detect any effect of lights and sirens use, and data from extremely large systems with high response volumes are not necessarily generalizable to other systems. By analyzing data from the large number of heterogenous agencies included in the NEMSIS data set, we were able to produce a global estimate of the association between lights and sirens use and ambulance crashes in the United States.

We were specifically interested in the association between lights and sirens use and ambulance crashes, so we analyzed data only for transport units responding to or transporting from 911 emergency scenes. The concerns about lights and sirens use, however, extend to other EMS (and non-EMS) vehicles and other types of responses. For example, the crude association between lights and sirens use and crashes is similar for mutual aid responses (Table 6), but they represent a very small proportion of the events included in the NEMSIS data set. Including them in our analyses would not alter our results.

Table 6. Crash-related delays and lights and siren use among mutual aid responses.

Mode	N	Crashes	Rate/100,000	OR (95% CI)
No L&S	14,894	2	13.4	1 [Reference]
Any L&S	35,253	8	22.7	1.69 (0.36–7.96)
Full L&S	34,565	7	20.3	1.51 (0.31–7.26)

We used reported crash-related delays as a proxy measure for crashes, but we do not have data on the severity of the crashes in terms of physical damage, injuries, or fatalities. Previous studies, however, have reported higher injury rates when ambulance crashes occur while lights and sirens are used[12-15,19] and that a majority of fatal ambulance crashes involve lights and sirens use.[16-18] One central consistent finding in previous studies is the importance of restraint devices in reducing injuries and fatalities among ambulance occupants, regardless of lights and sirens use.[12,13,17,18,26] We also do not have data on the duration of the reported delays. Beyond crash severity, system policies and local or state reporting requirements might exacerbate the duration of crash-related delays, even for minor crashes. Whether or how those delays affect patient outcomes, patient satisfaction of system operations requires further study.

The time saved with lights and sirens response or transport, reported at approximately 1 to 3 minutes,[2-7] is probably beneficial in only a very few clinical circumstances. Cardiac arrest, airway obstruction or compromise, respiratory insufficiency, severe trauma, uncontrolled hemorrhage, and true obstetric emergencies have been proposed as conditions that might benefit from lights and sirens response and lights and sirens transport if the condition cannot be resolved by the EMS providers on scene.[6-11] Out-of-hospital time may also be critical for stroke, ST-segment elevation myocardial infarction, and other conditions with narrow therapeutic windows. Further research is necessary to quantify the trade-off between the risk of crashing and any clinical benefit of faster transport. The low rates of transport phase lights and sirens use in our study suggests most EMS systems and EMS providers are attempting to balance the risks associated with lights and sirens transport against any potential time savings from lights and sirens use, but there remains room for improvement. The high rates of response-phase lights and sirens use likely reflects the uncertainty associated with what 911 callers report to dispatchers and highlights the need for better methods of identifying calls for true emergencies. In some communities, reducing lights and sirens use might also require some management of public expectations.

Ambulance use of lights and sirens is associated with increased risk of ambulance crashes, particularly during the transport phase. EMS systems and providers should weigh this risk against any potential time savings associated with lights and sirens use.

Supervising editor: Matthew D. Sztajnkrycer, MD, PhD

Author affiliations: From the Emergency Medicine Residency Program, Department of Surgery and Perioperative Care, Dell Medical School at the University of Texas, Austin, TX.

Author contributions: BLW, GSP, and LHB conceived and designed the study, obtained and managed the data, and drafted the article. LHB provided statistical advice on study design and analyzed the data. All authors reviewed and interpreted the data and contributed substantially to article revision. LHB takes responsibility for the paper as a whole.

All authors attest to meeting the four ICMJE.org authorship criteria: (1) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND (2) Drafting the work or revising it critically for important intellectual content; AND (3) Final approval of the version to be published; AND (4) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding and support: By *Annals* policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see www.icmje.org). The authors have stated that no such relationships exist.

Publication dates: Received for publication June 21, 2018. Revisions received August 13, 2018, and September 20, 2018. Accepted for publication September 28, 2018.

REFERENCES

1. International Association of Fire Chiefs. Guide to IAFC model policies and procedures for emergency vehicles. Available at: https://sites.iafc.org/files/1SAFEhealthSHS/VehclSafety_IAFCpolAndProceds.pdf. Accessed July 31, 2018.
2. Hunt RC, Brown LH, Cabinum ES, et al. Is ambulance transport time with lights and sirens faster than without? *Ann Emerg Med*. 1995;25:507-511.
3. Brown LH, Whitney CL, Hunt RC, et al. Do warning lights and sirens reduce ambulance response times? *Prehosp Emerg Care*. 2000;4:70-74.
4. Ho J, Casey B. Time saved with use of emergency warning lights and sirens during response to requests for emergency medical aid in an urban environment. *Ann Emerg Med*. 1998;32:585-588.
5. Ho J, Lindquist M. Time saved with the use of emergency warning lights and siren while responding to requests for emergency medical aid in a rural environment. *Prehosp Emerg Care*. 2001;5:159-162.
6. Murray B, Kue R. The use of emergency lights and sirens by ambulances and their effect on patient outcomes and public safety: a comprehensive review of the literature. *Prehosp Disaster Med*. 2017;32:209-216.
7. Marques-Baptista A, Ohman-Strickland P, Baldino KT, et al. Utilization of warning lights and siren based on hospital time-critical interventions. *Prehosp Diaster Med*. 2010;25:335-339.
8. Kupas DF, Dula DJ, Pino BJ. Patient outcomes using medical protocol to limit "lights and siren" transport. *Prehosp Disaster Med*. 1994;9:226-229.
9. Isenberg D, Cone DC, Stiell IG. A simple three-step dispatch rule may reduce lights and sirens responses to motor vehicle crashes. *Emerg Med J*. 2012;29:592-595.
10. Merlin MA, Baldino KT, Lehrfeld DP, et al. Use of limited lights and siren protocol in the prehospital setting vs standard usage. *Am J Emerg Med*. 2012;30:519-525.
11. Burns B, Hansen ML, Valenzuela S, et al. Unnecessary use of red lights and siren in pediatric transport. *Prehosp Emerg Care*. 2016;20:354-361.
12. Auerbach PS, Morris JA, Phillips JB, et al. An analysis of ambulance accidents in Tennessee. *JAMA*. 1987;258:1487-1490.
13. Heick R, Young T, Peek-Asa C. Occupational injuries among emergency medical service providers in the United States. *J Occup Environ Med*. 2009;51:963-968.
14. Saunders CE, Heye CJ. Ambulance collisions in an urban environment. *Prehosp Disaster Med*. 1994;9:118-124.
15. Custalow CB, Gravitz CS. Emergency medical vehicle collisions and potential for preventive intervention. *Prehosp Emerg Care*. 2004;8:175-184.
16. Pirrallo RG, Swor RA. Characteristics of fatal ambulance crashes during emergency and non-emergency operation. *Prehosp Disaster Med*. 1994;9:125-132.
17. Kham CA, Pirrallo RG, Kuhn EM. Characteristics of fatal ambulance crashes in the United States: an 11-year retrospective analysis. *Prehosp Emerg Care*. 2001;5:261-269.
18. Becker LR, Zaloshnja E, Levick N, et al. Relative risk of injury and death in ambulances and other emergency vehicles. *Accid Anal Prev*. 2003;35:941-948.
19. Biggers WA, Zachariah BS, Pepe PE. Emergency medical vehicle collisions in an urban system. *Prehosp Disaster Med*. 1996;11:195-201.
20. Sanddal TL, Sanddal ND, Ward N, et al. Ambulance crash characteristics in the US defined by the popular press: a retrospective analysis. *Emerg Med Int*. 2010;2010:525979.
21. Missikpode C, Peek-Asa C, Young T, et al. Does crash risk increase when emergency vehicles are driving with lights and sirens? *Accid Anal Prev*. 2018;113:257-262.
22. National EMS Information System. The 2016 NEMSIS public-release research dataset is available to you. Available at: https://nemsis.org/using-ems-data/request-research-data/. Accessed May 22, 2018.
23. National EMS Information System. NEMSIS user manual, national EMS database, NEMSIS research data set V2.2.1 and V3.3.4. Available at: https://nemsis.org/wp-content/uploads/2018/02/NEMSIS-RDS-221-2016-User-Manual.pdf. Accessed May 22, 2018.
24. Wears RL. Advanced statistics: statistical methods for analyzing cluster and cluster-randomized data. *Acad Emerg Med*. 2002;9:330-341.
25. Clawson JJ, Martin RL, Cady GA, et al. The wake effect: emergency vehicle–related collision. *Prehosp Disaster Med*. 1997;12:274-277.
26. Weiss SJ, Ellis R, Ernst AA, et al. A comparison of rural and urban ambulance crashes. *Am J Emerg Med*. 2001;19:52-56.