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Lights and Siren Use by Emergency Medical Services (EMS): Above All Do No Harm

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Disclosures

The author has no financial conflict of interest with any company or organization related to the topics within this report. The author serves as an unpaid member of the Institutional Research Review Committee of the International Academy of Emergency Dispatch, Salt Lake City, UT.

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List of Frequently Used Abbreviations

ACEP	American College of Emergency Physicians
dB	Decibel
DRLs	Daytime Running Lights
EMD	Emergency Medical Dispatch or Dispatcher
EMS	Emergency Medical Services
EMSVOs	EMS Vehicle Operators
NEMSIS	National EMS Information System
L&S	Lights and Siren
NAEMSP	National Association of EMS Physicians
NHTSA	National Highway Traffic Safety Administration
USFA	U. S. Fire Administration

Executive Summary

Primum non nocere – first do no harm. This principle of medical care helps to guide medical decisions by reminding healthcare providers that while attempting to provide treatments to improve a patient's outcome, there are risks that can cause harm. Providing healthcare requires a constant assessment of the impact of certain interventions on patient outcome while balancing that with the risks associated with the intervention. The primary role of Emergency Medical Services (EMS) providers and agencies is to deliver healthcare, often for medical emergencies, and weighing the risks and benefits of all aspects of delivering care – including the risks and benefits of the treatment of lights and siren (L&S) use – should be part of this practice of medicine.

Another tenant of medicine is that treatments that have a known risk should be delivered in the lowest possible effective dose. This applies to chemotherapy that may be life-saving but has also may have a high risk of serious side effects. In radiology, the ALARA principle attempts to reduce radiation exposure from x-rays and CT scans to doses that are "as low as reasonably achievable" to make diagnoses while minimizing the hazards of radiation. We can apply this same medical principle to the use of L&S. There are some situations where the "medical treatment" of L&S use can improve patient outcome by the time that it saves, but there is a risk when L&S lead to EMS vehicle crashes, provider or patient injury, EMS provider hearing loss, or worsened patient condition due to anxiety and stress. It is even possible that excessive use of L&S by an EMS agency causes some patients with legitimate emergencies to choose private vehicle transportation to the hospital rather than calling 911 due to the sirens and attention.

This report begins by exploring the traditional reasons for L&S use by EMS. Data from most EMS incidents in the United States is provided to the National EMS Information System (NEMSIS)[1] by EMS agencies. This report uses the NEMSIS data from 2015 to gain a perspective on the current use of L&S, during both response to 911 scene incidents and transport of these patients to a medical facility. The Uniform Vehicle Code[2] attributes related to emergency vehicle operations will be reviewed, and examples of variations in the laws and regulations for L&S use by EMS are discussed.

The discussion section will review the evidence and expert opinion from both scientific studies and non-peer reviewed journals related to L&S use. This discussion includes topics of effectiveness of emergency warning lights, vehicle conspicuity, and the effectiveness of sirens and traffic light preemption systems. L&S are useful in gaining attention when "requesting the right of way", but neither warning lights nor siren are

[1] The National EMS Information System, NEMSIS, provides the framework for collecting, sharing, and storing standardized EMS data for states across the nation. Currently, more than 90% of the states and U. S. territories have a NEMSIS-compliant data system with varying degrees of sophistication.
[2] The Uniform Vehicle Code is the set of U. S. traffic laws prepared and compiled by the National Committee of Uniform Traffic Laws and Ordinances (NCUTLO). NCUTLO is a private, non-profit organization. Most of the members of NCUTLO are state governments and related organizations.

always effective. EMS vehicle operators (EMSVOs) must always assume that the motoring public and pedestrians do not see or hear the EMS vehicle.

The time saved by using L&S during response and transport has been evaluated by several studies. These all show that a relatively short amount of time is saved by L&S use. While this may be of clinical importance to patient outcome in critical time-sensitive conditions like cardiac arrest, the consensus among the researchers in this field is that the time is not significant in most of the responses or transports.

In addition to the amount of time saved with L&S transport, an equally important discussion is whether that time is clinically important to patient outcome. For most conditions, EMS professionals can provide appropriate care to reduce the importance of saving a few minutes by L&S transport. While we do not fully understand the potential negative physiologic effects from L&S use, any EMS vehicle crash that occurs when exercising the privileges of L&S is detrimental to the health of both EMS providers and their patients.

Each section includes many considerations and recommendations for states, jurisdictions, EMS agencies, and EMSVOs. These recommendations are organized and concentrated in the final section of the report. While there are many recommendations related to agency policy, vehicle design, L&S use, and EMS vehicle driving, the most important suggestions are probably the suggestion that every agency analyze the potential time benefits and risks of L&S use in their community. Each agency should measure their L&S use during response and transport, and quality improvement processes should be used to reduce the use of L&S response and transport to the minimum effective rate. Justification is given for using benchmark targets of reducing L&S use during response to less than 50% and during transport to less than 5%. These would likely improve patient and provider safety without risking detrimental patient outcomes in most EMS agencies. The collaboration of the EMS agency medical director and EMS agency leadership/management is essential in overseeing the quality of emergency medical dispatch (EMD) and clinical care that is required to attain these safety goals.

The report ends with an annotated comprehensive bibliography of articles and references related to L&S use on EMS vehicles. The bibliography is purposefully broad and is organized by topic to serve as a resource for individuals that seek to delve more deeply into specific issues or to gain a better understanding of the L&S science and expert opinions. Hopefully, the annotated bibliography will be helpful to EMS agency leaders that are constructing L&S policy and working to change the culture of safety within their organizations.

Section 1 Introduction

Emergency warning lights and siren (L&S) are standard components of EMS vehicles, and these devices have historically been used to decrease times for response of EMS providers to the scene and for transport of patients to more definitive care. Additionally, emergency warning lights have traditionally been used to make EMS vehicles more visible when parked at a scene. Unlike many aspects of providing medical care, there is a culture and emotional component of L&S use that seems to evade reason and trigger a defensive response from some – discussing or providing feedback about L&S use is taken by some as questioning the core of EMS – and this must be recognized by administrators, managers and medical directors who take a clinical approach to the use of L&S as part of the care delivered by EMS agencies and providers.

The purpose of this report is to review the use of L&S during EMS vehicle operations, including the impact of L&S use on effectiveness in saving time, safety, public perception, and medical outcomes. When possible, the published literature related to L&S use will be presented and used to justify statements. When research-based evidence does not exist, research gaps will be recognized and opinions of subject matter experts will also be considered.

As with many aspects of providing healthcare, including EMS, the traditional use of some interventions has persisted based upon the dogma and inertia of past practice, rather than objective evidence for effectiveness or better outcomes. Although many EMS agencies have changed their approaches to L&S use over the last forty years, there are still agencies that respond to all 911 requests for EMS with L&S use, and there are still some agencies that transport nearly all of their patients with the use of L&S. Historically, many reasons have been cited for the routine use of L&S during EMS vehicle responses and transportation of patients. While quotations are used to accentuate the emotional aspect of discussing L&S, myths and facts must be separated from tradition and emotion when discussing this topic. Some common reasons for L&S use include:

- “Saves time.”
- Contract requirements – “Our agency’s contract requires that we arrive in 8 minutes or less, and L&S are essential to meeting these standards and avoiding financial penalties.”
- Medical emergency – “EMS providers don’t diagnose, any patient can worsen”, “we are *emergency* medical services, if someone called 911, it is an emergency”, or “time is muscle/brain.”
- Public expectations – “Patients and families expect us to arrive with L&S”, or “we will get complaints from patients and families if we don’t use L&S”.
- EMS provider retention – “Our agency will lose providers if they don’t get to drive with L&S,” or “EMS attracts adrenaline junkies, and L&S is part of the attraction to the job.”

- Insurance requirements – although completely unfounded and not heard as often recently, “our insurance company requires that we respond and transport with L&S for safety.”

During the early years of EMS, agencies followed the traditional responses of the fire service, and responded to every call for help from the public with an L&S response. In the early fire analogy, a small fire in a wastebasket can spread to involve several rooms within a couple minutes. Transportation to the hospital was also traditionally done with L&S, irrespective of the nature of the medical issue. During the early years, EMS providers had minimal “first aid” training. It was not considered to be within the provider’s scope to determine whether a patient was stable, and it was presumed that every patient may deteriorate and should get to the hospital as soon as possible. In fact, during these early days, the ambulance attendants often rode in the front of the vehicle and rapid transport was the primary intervention provided by the service. While there are still EMS agencies that respond with L&S to every emergency call and transport every patient with L&S, in the last forty (40) years most EMS agencies have changed this paradigm, to varying degrees. In fact, some EMS agencies in the U.S. now respond to most 911 initiated responses without the use of L&S and almost never use L&S during patient transport.

A central theme or approach in this report will be that L&S use is a medical therapy. Like all therapies, it has potential benefits and potential risks, and the “first do no harm” principle should be paramount when weighing those risks and benefits. This report uses the “lowest effective dose” concept from other specialties of medicine in attempting to identify the situations where L&S response or transport may benefit patient outcome, without overusing the treatment and subjecting the patient or EMS providers to unnecessary risks of injury or death.

The report begins by using L&S use data from the NEMSIS database to better understand the current reported use of L&S on EMS vehicles. An annotated bibliography will be used to summarize the findings of key scientific studies and literature related to EMS L&S use. The discussion section will synthesize available literature and information from subject matter experts and other sources related to safety of L&S use, L&S effectiveness, public perception, and medical outcomes. Finally, the report concludes with a list of possible interventions, performance measures, and best practices that EMS agency managers and medical directors should consider when reviewing and establishing policy regarding L&S use in their systems.

Section 2 Current Use of Lights & Siren in the U. S.

Information collected within EMS patient care reports can be valuable in understanding various aspects of EMS performance across the U.S., including the use of lights and siren during response and transport. The NEMSIS collects standardized data elements related to EMS response and patient care from EMS agencies across the U.S. Wang, et al analyzed the 2010 NEMSIS Public-Release Research Data Set version 1.0, which included data from 29 states and almost 10 million EMS responses. They estimated that in 2010, the NEMSIS dataset included EMS responses covering 34 percent of the U.S. population. (Wang, 2013) Using the same methodology, the NEMSIS Technical Assistance Center[3] estimates that the 2015 NEMSIS dataset includes 78 to 82 percent of the EMS calls in the U.S.[4]

For this report, the NEMSIS Technical Assistance Center provided in-depth information related to various aspects of L&S use among EMS agencies within states that reported data to NEMSIS for the year 2015 – the most current year of complete data available for this document. Data included information from EMS emergency responses, including reports using the call type code of "911 Response (Scene)", and excluding reports with data codes for "Interfacility Transfer", "Mutual Aid", "Intercept", and "Standby". L&S were considered to have been used during responses based upon selection of response mode NEMSIS code for "Lights and sirens", "Initial lights and sirens, downgraded to no lights or sirens", or "Initial no lights or sirens, upgraded to lights and sirens" – this distinguishes between L&S used at any time during the response or transport versus no L&S use. For mode during transport, we used the same L&S modes that we did for response, and we combined cases where the provider chose the unrelated NEMSIS transport mode codes of "not applicable", "not reporting", "not recorded", and "not known".

During 2015, the NEMSIS data set included 15,729,516 responses in the category of 911 Response (scene) with transport to a medical facility. Of these, 12,033,680 responses (76.5%) used L&S at some point during the response and 3,695,836 responses (23.5%) did not use L&S. This number of EMS emergency responses that were conducted without the use of L&S likely represents the effect of emergency medical dispatch (EMD) call screening and prioritization that assigns non-L&S response mode to some EMS emergency responses. It is important to separate the concept of a legitimate EMS medical emergency from the use of L&S during the response or transport – they are not synonymous. In comparing the use of L&S during 911 responses each year from 2010 through 2015, there was minimal variation in L&S use during response, with the average L&S response each year ranging from 76.0% to 77.5% across these six years. Although the number of states and EMS agencies submitting data to NEMSIS increased dramatically between 2010 and 2015, there was

[3] The NEMSIS Technical Assistance Center is the resource center for NEMSIS and provides technical assistance to states, territories and local jurisdictions on collecting EMS data and providing that data to NEMSIS. For more information on NEMSIS and the Center, please visit www.nemsis.org .

[4] Personal communication, N. Clay Mann, NEMSIS Technical Assistance Center, 2017.

negligible change in the responses with L&S used at some time during response and in responses with no L&S use, as shown in Table A.

TABLE A
Reported use of L&S during *response* for EMS calls where the call type was a 911 response and the patient was transported by the EMS agency, 2010 and 2015 (NEMSIS).

Reported Use of L&S	2010		2015	
	No. of Calls	Percent (%)	No. of Calls	Percent (%)
No Lights or Siren	1,096,923	22.5	3,695,836	23.5
L&S	3,627,504	74.4	11,640,479	74.0
Initial Use of L&S, Downgraded to No Lights or Siren	117,563	2.4	251,043	1.6
Initial Use of No L&S, Upgraded to L&S	32,071	0.7	142,158	0.9
All	4,874,061	100%	15,729,516	100%

While L&S were used at some point during the response to 76.5% of 911 responses that included transport in 2015, it is encouraging that L&S were reported to be used at some point during only 22.7% of patient transport in those same incidents, as shown in Table B. Although the focus of this report is L&S use in the U.S., the literature has other examples of restricting L&S use during transport to only a portion of EMS responses. For example, a relatively low statewide L&S transport rate of 16.6% was found in Vaud, Switzerland. (Dami, 2014)

TABLE B
Reported use of L&S during *transport* for EMS calls where the call type was a 911 response and the patient was transported by the EMS agency, 2010 and 2015 (NEMSIS).

Reported Use of L&S	2010		2015	
	No. of Calls	Percent (%)	No. of Calls	Percent (%)
No Lights or Siren	3,041,662	62.4	11,527,384	73.3
L&S	1,322,801	27.1	3.401.124	21.6
Initial Use of L&S, Downgraded to No Lights or Siren	68,185	1.4	91,240	0.6
Initial Use of No L&S, Upgraded to L&S	34,940	0.7	85,223	0.5
Not Known, Not Reported, Not Recorded, Not Applicable, or Not Available	406,473	8.4	624,545	4.0
All	4,874,061	100%	15,729,516	100%

It is interesting to consider that these data from 2010 and 2015 span a period of national concentration on EMS patient and provider safety. Findings from the National Highway Traffic Safety Administration/American College of Emergency Physicians' (NHTSA/ACEP) Culture of Safety in EMS project was released in December 2013. It appears that between 2010 and 2015, the EMS safety culture in the U.S. was associated with a decreasing use of L&S during patient transport, but the consistency in L&S use during response appears to indicate little change in the response component of L&S use.

Looking further back in EMS history, although some of the standardized data elements were modified from the early NHTSA EMS data elements to the later NEMSIS data elements, there is some evidence that there has been a significant decrease in the use of L&S during transport between the early 1990's and these data from 2015. A 1991 analysis of EMS NHTSA data elements in Pennsylvania revealed that the majority of patients (56.6%) were transported using L&S mode at that time. Specifically, there were 223,607 transports reported with L&S mode from 394,980 EMS calls reporting L&S response to scene and patient transport to a medical facility. Of the patients transported with L&S, 42,485 (19%) were coded as life-threatening and 36,760 (16%) were coded as minor. Additionally, 189,394 (85%) were subjectively reported as improved or stable on arrival to the facility, and only 5,280 (2.4%) were noted to be worse on arrival to the facility.[5]

To understand variation in L&S use, the NEMSIS Technical Assistance Center also provided data regarding L&S use during response and transport by urbanicity, across geographic regions, and by fractile differences among individual reporting EMS agencies. It is possible that traffic congestion is responsible for some factor of any differences in urbanicity. Differences in geographic regions may be due to the culture of EMS agencies in these regions, but may also be influenced by state-specific regulations or policies. Fractile differences in use of L&S by individual EMS agencies are most likely due to cultures and traditions within agencies, medical oversight, and philosophies of providers or managers in the agencies.

The Office of Management and Budget/U. S. Department of Agriculture (OMB/USDA) Urban Influence Codes were used to separate the NEMSIS data by incident locations into categories of urban, suburban, rural, and wilderness. It might seem intuitive that urbanicity would be associated with substantial variation in L&S use during response and transport, but when analyzing the EMS 911 responses in 2015 for urbanicity, the variations are only modest and somewhat surprising. During response, L&S use varied by only 1.8% across the urbanicity categories, ranging from 74.8% (suburban) to 76.6% (urban), as shown in Table C. Meanwhile, the variation of L&S use during transport was broader with a difference of 10.3% across categories, ranging from 17.6% (suburban) to 27.9% (wilderness), as shown in Table D. With urban traffic congestion, it can be

[5] Personal communication, Patrick Moran, Commonwealth of Pennsylvania Department of Health, January 27, 1993.

hypothesized that the urban use of L&S during transport would be higher than that in the rural setting, but with this reasoning, it is peculiar that suburban use of L&S was the lowest and wilderness was the highest. This may indicate that cultural or traditional use of L&S is a factor when considering urbanicity, since counties classified as wilderness have few towns and the least traffic.

TABLE C
Reported use of L&S during *response* for EMS calls where the call type was a 911 response and the patient was transported by the EMS agency, by urbanicity[6] of the county in which the EMS incident occurred, 2015 (NEMSIS).

Reported Use of L&S	Rural		Suburban		Urban		Wilderness	
	No. of Calls	Percent (%)	No. of Calls	Percent (%)	No. of Calls	Percent (%)	No. of Calls	Percent (%)
No Lights or Siren	295,166	24.4	298,528	25.2	2,931,259	23.4	84,987	24.9
L&S	871,803	72.0	862,110	72.8	9,270,462	74.2	250,064	73.4
Initial Use of L&S, Downgraded to No Lights or Siren	41,528	3.4	19,813	1.7	164,836	1.3	4,528	1.3
Initial Use of No L&S, Upgraded to L&S	2,602	0.2	3,963	**0.3**	131,169	0.7	142,158	0.9
All	1,211,099	100%	1,184,414	100%	12,497,726	100%	340,762	100%

TABLE D
Reported use of L&S during *transport* for EMS calls where the call type was a 911 response and the patient was transported by the EMS agency, by urbanicity[7] of the county in which the EMS incident occurred, 2015 (NEMSIS).

Reported Use of Lights and Siren	Rural		Suburban		Urban		Wilderness	
	No. of Calls	Percent (%)	No. of Calls	Percent (%)	No. of Calls	Percent (%)	No. of Calls	Percent (%)
No Lights or Siren	917,232	75.7	955,479	80.7	9,045,461	72.4	234,235	68.7
L&S	254,253	21.0	196,135	16.6	2,755,852	22.1	90,155	26.5
Initial Use of L&S, Downgraded to No Lights or Siren	7,346	0.6	5,514	0.5	70,250	0.6	3,280	1.0
Initial Use of No L&S, Upgraded to L&S	4,235	0.4	5,982	0.5	70,354	0.6	1,385	0.4
Not Known, Not Reported, Not Recorded, Not Applicable, or Not Available	28,033	2.3	21,304	1.8	555,809	4.4	11,707	3.4
All	1,211,099	100%	1,184,414	100%	12,497,726	100%	340,762	100%

[6] Urbanicity using OMB/USDA Urban Influence Codes.
[7] Urbanicity using OMB/USDA Urban Influence Codes.

The NEMSIS data was also analyzed for variation of L&S use during response among U.S. Census regions and divisions. Across the U.S. Census divisions, the use of L&S during response to 911 responses with patient transport varies by 14.8%, ranging from 69.8% (Middle Atlantic division – New Jersey, New York, and Pennsylvania) to 84.6% (East South Central division – Alabama, Kentucky, Mississippi, and Tennessee), as shown in Table E. While cultural variation and tradition in various regions/divisions is probably responsible for much of these differences, regulations related to L&S use and state guidelines or protocols may also have an influence.

Across the U.S. Census divisions, the L&S use during transport of these cases is shown in Table F. During 911 responses with patient transports, the rate of L&S use varies by at least 20.8%, ranging from a low of 12.7% (West South Central division – Arkansas, Louisiana, Oklahoma, Texas) to a high of 33.5% (East North Central – Indiana, Illinois, Michigan, Ohio, Wisconsin). The Mountain census division was not included in this statement, because over 20% of the incidents in this division were listed in the "not known, not recorded, not reported, not applicable, or not available" categories within NEMSIS.

In considering these NEMSIS data, the U.S. territories (American Samoa, Guam, Northern Mariana Islands, Puerto Rico, Virgin Islands) are listed separately as U.S. Territories in Tables E and F. The U.S. territories are not included in any of the U.S. Census regions or divisions, but interestingly, the use of L&S in the territories is an outlier within NEMSIS data, with the highest L&S use reported during both 911 response (91.3%) and during transport (52.9%). The smaller numbers of NEMSIS incidents reported from the territories and other confounders make it difficult to suggest why the U.S. territories may have the highest use of L&S.

TABLE E
Reported use of L&S during *response* for EMS calls where the call type was a 911 response and the patient was transported by the EMS agency by U. S. Census Division, 2015 (NEMSIS).[8]

Reported Use of L&S	East North Central		East South Central		Middle Atlantic		Mountain		New England		Pacific	
	No. of Calls	Percent (%)	No. of Calls	Percent (%)	No. of Calls	Percent (%)	No. of Calls	Percent (%)	No. of Calls	Percent (%)	No. of Calls	Percent (%)
No Lights or Siren	501,436	23.3	136,437	15.4	930,486	30.2	314,674	28.7	198,916	25.7	259,125	22.9
L&S	1,575,330	73.3	722,922	81.8	2,105,659	68.4	714,914	65.2	553,468	71.5	826,678	72.9
Initial L&S, Downgraded to No Lights or Siren	63,774	3.0	22,217	2.5	21,653	0.7	37,404	3.4	17,852	2.3	6,918	0.6
Initial No Lights or Siren, Upgraded to L&S	9,659	0.5	2,494	0.3	18,850	0.6	28,956	2.6	3,722	0.5	41,111	3.6
All	2,150,199	100%	884,070	100%	3,076,648	100%	1,095,948	100%	773,958	100%	1,133,832	100%.

[8] Percentages may not add to 100% due to rounding.

TABLE E (Continued)
Reported use of L&S during *response* for EMS calls where the call type was a 911 response and the patient was transported by the EMS agency by U. S. Census Division, 2015 (NEMSIS).[9]

Reported Use of Lights and Siren	South Atlantic		U. S. Territories		West North Central		West South Central		All	
	No. of Calls	Percent (%)	No. of Calls	Percent (%)	No. of Calls	Percent (%)	No. of Calls	Percent (%)	No. of Calls	Percent (%)
No Lights or Siren	870,644	18.3	1,420	8.7	301,753	29.0	180,945	22.7	3,623,836	23.1
L&S	3,815,084	80.2	14734	90.3	716,217	68.7	595,473	74.5	11,640479	74.3
Initial L&S, Downgraded to No Lights or Siren	46,133	1.0	145	0.9	16,068	1.5	18,879	2.4	251,043	1.6
Initial No Lights or Siren, Upgraded to L&S	25,832	0.5	21	0.1	7,910	0.8	3,603	0.5	142,158	0.9
All	4,757,693	100%	16,320	100%	1,041,948	100%	798,900	100%	15,729,516	100%

[9] Percentages may not add to 100% due to rounding.

TABLE F
Reported use of L&S during ***transport*** for EMS calls where the call type was a 911 response and the patient was transported by the EMS agency by U. S. Census District, 2015 (NEMSIS).[10]

Reported Use of L&S	East North Central		East South Central		Middle Atlantic		Mountain		New England		Pacific	
	No. of Calls	Percent (%)	No. of Calls	Percent (%)	No. of Calls	Percent (%)	No. of Calls	Percent (%)	No. of Calls	Percent (%)	No. of Calls	Percent (%)
No Lights or Siren	1,325,790	61.7	682,227	77.2	2,317,228	75.3	783,134	71.5	506,676	65.5	925,626	81.6
L&S	692,653	32.2	171,968	19.5	687,745	22.4	87,029	7.9	244,281	31.6	140,046	12.4
Initial L&S, Downgraded to No Lights or Siren	18,431	0.9	6,430	0.7	26,357	0.9	2,664	0.2	5,148	0.7	2,256	0.2
Initial No Lights or Siren, Upgraded to L&S	8,292	0.4	2,203	0.3	5,596	0.2	2,603	0.2	4,504	0.6	3,518	0.3
Not Known, Not Recorded, Not Reported, Not Applicable, or Not Available	105,033	4.9	21,242	2.4	39,722	1.3	220,518	20.1	13,349	1.7	62,386	5.5
All	2,150,199	100%	884,070	100%	3,076,648	100%	1,095,948	100%	773,958	100%	1,133,832	100%

TABLE F (Continued)
Reported use of L&S during ***transport*** for EMS calls where the call type was a 911 response and the patient was transported by the EMS agency by U. S. Census District, 2015 (NEMSIS).[11]

Reported Use of L&S	South Atlantic		U. S. Territories		West North Central		West South Central		All	
	No. of Calls	Percent (%)	No. of Calls	Percent (%)	No. of Calls	Percent (%)	No. of Calls	Percent (%)	No. of Calls	Percent (%)
No Lights or Siren	3,441,762	72.3	7,397	45.3	841,887	80.8	695,697	87.1	11,527,384	73.3
L&S	1,125,480	23.7	7,875	48.3	151,975	14.6	92,072	11.5	3,401,124	21.6
Initial L&S, Downgraded to No Lights or Siren	20,586	0.4	718	4,4	5,671	0.5	2,979	0.4	91,240	0.6
Initial No Lights or Siren, Upgraded to L&S	33,628	0.7	35	0.2	18,635	1.8	6,199	0.8	85,223	1.5
Not Known, Not Recorded, Not Reported, Not Applicable, or Not Available	136,227	2.9	295	1.8	23,780	2.3	1,993	0.1	624,545	4.0
All	4,757,693	100%	16,320	100%	1,041,948	100%	798,900	100%	15,729,516	100%

[10] Percentages may not add to 100% due to rounding.

[11] Percentages may not add to 100% due to rounding.

In considering the factors related to variations in L&S use, of most interest is the very wide difference in L&S use reported during both response and transport between individual EMS agencies. It is likely that these wide fractile differences in L&S use by EMS agency are heavily influenced by safety culture, emergency medical dispatch systems, EMS agency policies and driver training, and other factors within EMS agencies.

As shown in Table G, the fractile results show that while almost half of EMS agencies respond to over 90% of 911 responses with L&S, only 16.9% of agencies respond to at least half of their calls without the use of L&S. Likewise, from Table H, almost 10% of EMS agencies report using L&S for nearly all (over 90%) of their transports of patients from 911 responses, while over half of agencies report using L&S for less than 20% of their transports.

TABLE G Fractile presentation of reported use of L&S during ***response***, as a % of all 911 responses by individual EMS agencies, 2015				
L & S Ratio	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
0	310	3.4	310	3.4
0-10%	198	2.2	508	5.6
10%-20%	169	1.8	677	7.4
20%-30%	224	2.5	901	9.9
30%-40%	283	3.1	1184	13.0
40%-50%	357	3.9	1541	16.9
50%-60%	585	6.4	2126	23.3
60%-70%	780	8.5	2906	31.8
70%-80%	896	9.8	3802	41.6
80%-90%	1,121	12.3	4923	53.9
90%-100%	2,921	31.9	7844	85.8
100%	1,300	14.2	9144	100%

FIGURE 1

Graphical presentation of reported use of L&S during ***response*** as a % of all 911 responses by individual EMS agencies (n=9144 agencies) in 2015.

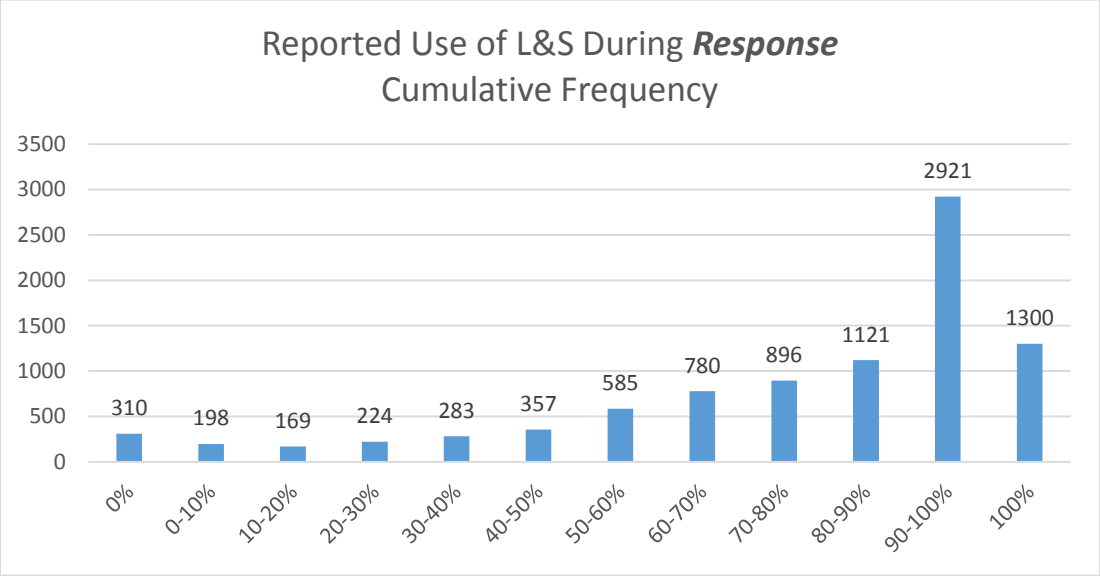
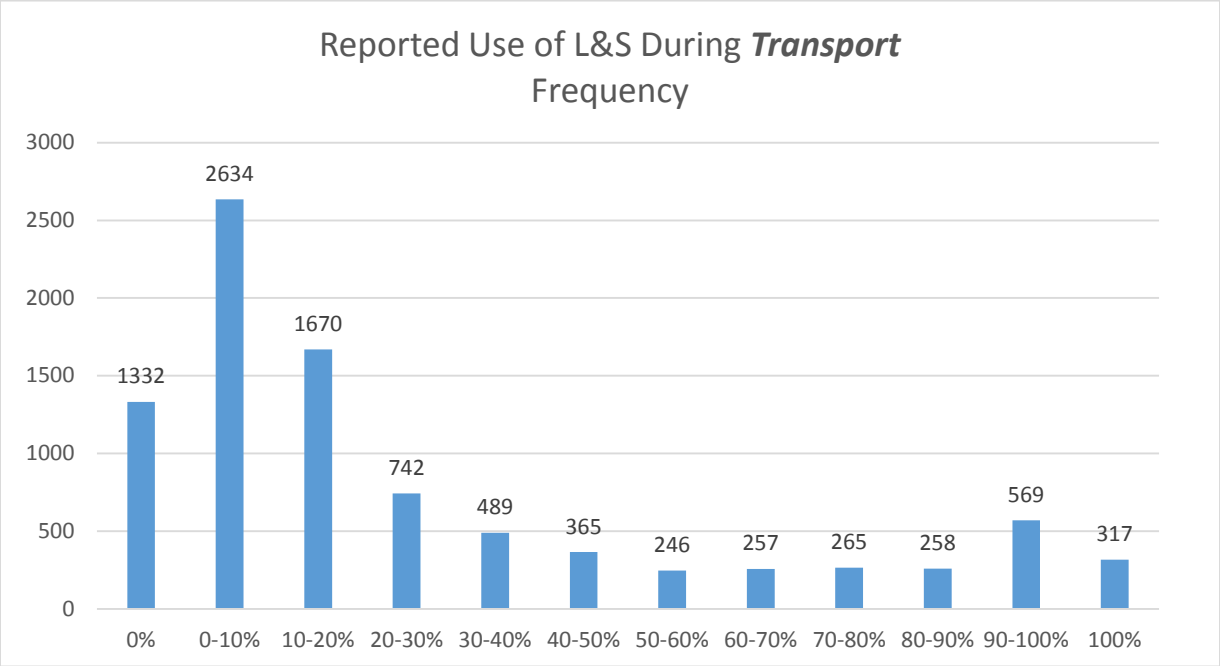


TABLE H
Fractile presentation of reported use of L&S during *transport*, as a % of all 911 responses with patient transport to a medical facility by individual EMS agencies (n=9144 agencies) in 2015.

L & S Ratio	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	1,332	14.6	1,332	14.6
0-10%	2,634	28.8	3,966	43.4
10%-20%	1,670	18.3	5,636	61.6
20%-30%	742	8.1	6,378	69.8
30%-40%	489	5.3	6,867	75.1
40%-50%	365	4.0	7,232	79.1
50%-60%	246	2.7	7,478	81.8
60%-70%	257	2.8	7,735	84.6
70%-80%	265	2.9	8,000	87.5
80%-90%	258	2.8	8,258	90.3
90%-100%	569	6.2	8,827	96.5
100%	317	3.5	9,144	100

FIGURE 2
Graphical Presentation of reported use of L&S during ***transport*** as a % of all 911 responses by individual EMS agencies (n=9144 agencies) in 2015.



Section 3 Review of State Laws Regarding Lights and Siren Use by EMS

In an effort to get medical care to patients with medical emergencies and to get patients with emergent medical conditions to a hospital as quickly as possible, state laws and regulations permit ambulances and other EMS vehicles using warning L&S, some privileges that are not legal for the general motoring public. In general, these laws group ambulances and EMS vehicles with other emergency vehicles, including fire and law enforcement vehicles.

Because motor vehicle operations within the U.S. are regulated by each individual state, it is critical that EMS vehicle operators and EMS agency managers are familiar with their state statutes and regulations. This report contains general recommendations for the safe use of L&S, but in all cases, EMS vehicle operators should operate their vehicles consistent with their state's statutes and regulations. EMS agencies should ensure that the EMS vehicle operators within their agency have been educated regarding State laws regarding L&S use.

Although they vary in each state, specific state laws and regulations are frequently designed around the Uniform Vehicle Code, which provides four general exceptions to motor vehicle rules for drivers of emergency vehicles. These include:

1) Proceeding through a red traffic signal, stop light, or stop sign
2) Driving the wrong way in lanes of opposing traffic or on one-way streets, disregarding directions of movement or turning in specified direction
3) Exceeding the posted speed limit
4) Parking the vehicle in locations that would otherwise not be legal

The Uniform Vehicle Code also guides how other drivers and pedestrians should react on the approach of an emergency vehicle that is operating with L&S. (Solomon 2002)

When considering state laws regarding the use of L&S by EMS vehicles, there are some general principles. These laws generally require that the emergency vehicle driver use due regard or due caution when taking privileges that are only permitted by vehicles using L&S. Like the differences from the Uniform Vehicle Code regarding the exceptions from the motor vehicle code for vehicles using L&S, there are also nuances from state to state related to the definitions of due care, due regard, caution, and reckless disregard that apply to emergency vehicle driving.

A comprehensive list of state laws and regulations related to L&S use by ambulances was published in a book by Solomon and Hill in 2002. This text targets an audience of lawyers by listing each state's statute and examples of case law related to L&S use, but it also includes background information about emergency vehicle visibility and L&S effectiveness. (Solomon 2002)

Although a comprehensive review of all state laws for EMS vehicles is beyond the scope of this report, some examples help to illustrate differences in state laws and variations from the Uniform Vehicle Code language for L&S use on EMS vehicles.

- The Uniform Vehicle Code does not require that emergency vehicles using L&S stop at a red traffic signal, red light, or stop sign, but several states, including Alaska, Massachusetts, New Jersey, and Pennsylvania require a “full stop” at these traffic signals before proceeding through the intersection. Pennsylvania is unique in this regard, because it may be the only state that has differing requirements for ambulances and fire vehicles.
- Although most states include the Uniform Vehicle Code privilege of exceeding the posted speed limit, there is variation in whether this permitted or limitations on speed. For example, Pennsylvania does not permit ambulances to exceed the posted speed limit, and Nevada only permits exceeding the speed limit by 15 miles per hour.
- State laws and regulations related to L&S use generally apply to EMS, fire, and police vehicles. Pennsylvania may be the only state that has different rules for ambulances than for fire and police vehicles. In Pennsylvania, ambulances are required to come to a full stop at red traffic signals and stop signs before proceeding, and ambulances are not permitted to exceed the speed limit, while police and fire vehicles are not held to these requirements.
- In most states, the driving privileges afforded to emergency vehicles only apply when the vehicle is using both L&S, but in Montana and Oklahoma, the law only requires the use of lights or siren.
- Most states permit the privileges of L&S driving without restrictions on the type of emergency that apply to EMS vehicles, but some state regulations try to restrict L&S use on EMS vehicles to situations when responding to circumstance that present or are perceived to present a need for immediate medical intervention. Likewise, some states attempt to restrict transport with L&S to situations where there is need for a medical intervention that is beyond the capability of the EMS crew. (Pennsylvania EMS Systems Act regulations, Title 28 Health and Safety, 28 Pa.C.S. section 1027.3(i))

These examples are cited to provide an understanding of the variations in state laws related to EMS vehicle use of L&S, and EMS drivers are responsible for understanding the laws in any state in which they operate an emergency vehicle. Unless stated otherwise, these variations are taken from the survey of state laws by Solomon and Hill, which was published in 2002, and some of the state laws may have changed in the intervening years. (Solomon, 2002)

Ambulances have some unique characteristics when considering emergency driving. The size and weight of an ambulance increases the stopping distance when compared with automobiles, and this leads to additional risks when exceeding the speed limit. For this reason, some experts have recommended that EMS agencies monitor and enforce policies that prohibit their drivers from exceeding the speed limit. When a patient is on board with patient care in progress, the g-forces involved with exceeding the speed limit

create additional risks to patient anxiety, patient care, and EMS provider safety, particularly when providers or the patient are not secured appropriately.

Additionally, since many EMS vehicle crashes related to L&S use occur at intersections, the authors of some EMS vehicle driving recommendations have suggested that EMS agencies enforce policies that require a “full stop” at all stop signs and red traffic signals before proceeding with caution when using L&S.

When state laws permit dangerous practices, this should not be construed as permission to support those practices. EMS agency managers should consider developing and enforcing policies that reduce situations with higher risk of EMS vehicle crash, even if these practices are more restrictive than the state’s regulations for L&S use. Requiring a “full stop” at intersections with a red traffic signal or stop sign and restricting maximum speed to the posted speed limit are two strategies that may decrease risk. The discussion will now specifically focus on the effectiveness and clinical reasoning related to L&S use.

Section 4 Discussion

Use and Usefulness of Emergency Warning Lights and Vehicle Conspicuity

As with sirens, the goals of emergency warning lights are to attract the attention of other drivers and pedestrians to the approaching emergency vehicle as soon as possible and to be easily and distinctly recognized as associated with an emergency vehicle. Additionally, it is important that these warning lights to not overwhelm, partially blind, or paralyze the responses of other drivers and pedestrians. (Solomon 1985)

Emergency warning lights on EMS vehicles frequently involve red flashing lights that presumably serve to make the vehicle more visible during L&S driving and also when parked at a scene. State statutes and regulations usually mandate or restrict the color, type, and location of emergency warning lights on EMS vehicles. Some states require or permit the use of other colors like blue, amber, or combinations of color. While red lights are most common on EMS vehicles, blue lights have the widest variety of emergency uses, from police to volunteers in personal vehicles. Amber lights have the widest range of vehicle uses, from service vehicles to emergency vehicles. Flashing white lights are also often permitted and used. (USFA 2104)

While there are many scientific studies published related to emergency vehicle sirens, there is less evidence related to emergency warning light. The optimal color, flashing sequence, light output, and type of light (halogen, LED, strobe, etc.) are controversial. (DeLorenzo 1992) The 2009 USFA study on Emergency Vehicle Visibility and Conspicuity places more emphasis on passive visibility and conspicuity than on active visibility using warning lights. (USFA 2009) and admits that we need more research on this topic.

The USFA 2014 Emergency Safety Initiative and other authors offer some recommendations related to emergency warning lights. Some common recommendations are that there is a differentiation between light use and effectiveness when “requesting the right of way” while driving to on a response or transport and “when blocking the right of way” in a stationary position at a scene. (USFA 2014)

When “requesting the right of way”, white flashing lights may be effective on the front of a vehicle to get attention. In addition to light color, the flashing pattern and frequency may be important, as brighter lights are better at getting attention, and a rapid flash rate gives more sense of urgency to other drivers. (USFA 2014) Some experts have suggested that lights on each corner of the vehicle that flash in a synchronized way, rather than alternating, are best at drawing attention to the vehicle. (Solomon 1985) Additionally, some have suggested that lights should help to outline the vehicle, not only the patient compartment, but placing flashing “intersection” lights at the front corners of the fenders help to outline the entire vehicle. At least some of the flashing emergency lights should be visible from 360 degrees around the vehicle.

When “blocking the right of way” the vehicle helps to protect the scene, responders that are outside, and the patient. Light types and configurations that are helpful in gaining attention during response may distract a driver or overwhelm other drivers from seeing hazards and people at the scene are dangerous – especially when several emergency vehicles are parked in close proximity to a scene. It seems clear that high intensity lights and uncomfortable glare may make it difficult for another driver to see other hazards at a scene, but the concept that these lights have a phototaxis – or “moth to a flame” effect on drivers has not been proven. White flashing lights are not acceptable in this situation. It may also be best to have most of the high-intensity response lights turned off at a scene. In 1994 the Phoenix Fire Department found that amber lights on stationary vehicles were the least likely to blind other drivers. Amber lights are generally consider a cautionary light and can be used as a secondary light or may be effective on the back of EMS vehicles when “blocking the right of way”.(USFA 2014)

Some agencies use large amber directional signs with programmable messages on the back of a “blocking vehicle” at emergency scenes. These can be very helpful in directing traffic to lanes away from an active scene. Of note, some ambulances are now equipped with smaller amber directional slights that can flash together or in patterns that direct an observer to the left or right. These may have a purpose for warning and directing traffic on a stationary EMS vehicle that is “blocking the right of way”, but EMS agencies and vehicle operators should be cautioned against leaving these flashing amber lights on when not actively blocking a scene. When the vehicle is not in L&S mode, these lights easily confuse following drivers. The analogy is that amber lights are appropriate for a tow truck when towing a vehicle (hazard) behind it, but they are not appropriate all of the time when the tow truck is driving on roadways.

It is worth mentioning the controversy regarding strobe lights and seizures. Some authors have suggested that strobe flashes at particular frequencies can induce a seizure, even in individuals who do not have a known seizure disorder. In 1983, Solomon provided a case review of several cases of seizures at emergency scenes that

were attributed to emergency vehicle strobe lights. (Solomon 1983) Despite these concerns, many experts believe that this relationship with emergency vehicle lights has never been proven. (DeLorenzo 1992)

Another lighting option for EMS agencies to consider is daytime running lights (DRLs). These lights are factory installed on many vehicles to provide white lights in the front of the vehicle during the day. If they are not installed, a similar effect can be obtained by manually turning on the vehicle's headlights. Some suggest that EMS vehicles should have DRLs activated at all times, whether automatic or manual to make the vehicle more visible, especially during low lighting conditions on hazy days and during inclement weather. There is no doubt that in these conditions, it is easier to see a vehicle with DRLs.

DRLs are not without controversy too. These lights have been required on vehicles in Canada and in parts of Europe, and European studies have suggested that they (when installed or used manually) reduce collisions by 4-27%. Studies in the U.S. have had mixed results, with some showing a decrease in collisions, but others not showing the same effect. In a NHTSA study, Wang examined only the installed DRLs by comparing crash rates from a database that identified cars by Vehicle Identification Number. This study was not able to determine if other vehicles may have used DRLs manually by driver headlight use during the day. In the study, daytime two-vehicle crashes were statistically reduced by 5.7% for light trucks and vans, but there was a trend (not statistically significant) for more collisions with motorcycles and pedestrians. (J Wang 2008) Despite the mixed studies, it seems reasonable for EMS agencies to either purchase vehicles with DRLs or set policy for use of headlights during the day.

The purpose of emergency lighting is to draw attention to an emergency vehicle. Since this discussion about lighting is related to vehicle conspicuity, it is worth mentioning the topic of vehicle color and retroflective material, since some of the value of flashing emergency lights may be lost if the vehicle is painted and designed in a way that is visually camouflaging. There is a long history in the fire service of using red colored vehicles. While there are theories, the reason for this practice is not known. In 1972, Federal specifications suggested a primarily white body with an Omaha Orange strip for ambulances, although there was no scientific evidence for this decision. (Solomon 1985)

There has not been consensus in the U.S. regarding best color for EMS vehicles, and individuality, choice and system marketing has led to great variation in vehicle color and exterior design. With that said, the yellow-green spectrum is most visible to the human eye, and this color is recommended for safety vests to increase visibility of providers along roadways. The majority of published information has favored the lime green color for maximum ambulance visibility also. (Saly 1980) (Solomon 1984, 1985, 1990, 1991) Dunkle published his agency's experience in lobbying their insurance company for a 5% decrease in cost of insurance premium on each vehicle painted lime-yellow. Their insurance carrier was convinced that the "articles and reports support the view of a causal relationship between vehicle color and accident rates."(Dunkle 1988)

It has been described that lighter colored automobiles are in less collisions than darker vehicles, and the National Safety Council rated the two-tone colors of red and white (similar to many fire vehicles) as ten out of twelve in safest combinations for vehicles. (Nathan, 1969) Solomon compared the rates of crashes for fire department pumpers in Dallas, Texas, where the vehicles were painted either red/white or lime green/white. This study found that the vehicles painted lime green had lower rates of overall crashes, daytime crashes, intersection crashes, L&S crashes, tow-away crashes, and crashes with injuries. The estimated rate of crashes per million miles travelled was 28.2 for the lime-yellow pumpers and 62.1 for the red pumpers. (Solomon, 1995) This compares with rates of 3.9 for passenger cars, 21.6 for city trucks, and 36.3 for police cars. (Solomon, 2002)

Solomon has reported on a private correspondence with the DuPont Automotive Products – Finishes Department that studied the daylight and nighttime reflectance measures comparing their colors of fire department red (DuPont Imron 674) and lime-yellow (DuPont Imron 7744-1). He reported that the "information indicates that lime-yellow has a peak eye response (grabs the attention) approximately 4.9times greater than fire department red during daylight and approximately 93 times greater at night." (Solomon, 2002)

While lime-green is arguably the most visible color for EMS vehicles and many agencies in the U.S. have adopted this color, there is no national recommendation. Traditional "fire engine red" is lower on the visibility scale, and despite knowledge of higher visibility colors, there are still ambulances painted black or dark blue and some ambulances are even designed with camouflaging pictures or photographs on the side.

Fluorescent colors increase vehicle visibility during daylight hours, but at night retroflective sheeting or striping clearly increases conspicuity. Some recommend increasing visibility and vehicle identification by using retroflective material to outline the vehicle. On the back, fluorescent retroflective sheeting in a "down and away" chevron pattern is used to provide conspicuity at a scene or when blocking the right of way with a vehicle. (USFA 2014)

CONSIDERATIONS

Emergency warning lights and other methods of increasing visibility serve to make an EMS vehicle more easily seen. Emergency warning lights draw attention to the EMS vehicle when "requesting the right-of-way" during emergency response or transport and when "blocking the right-of-way" or drawing attention to a hazard at a scene. Even when not responding or transporting with L&S, it is beneficial for EMS vehicles to be conspicuous and easily seen by the public.

- Principle – Emergency warning lights only attempt to increase the public's awareness of an EMS vehicle. When the vehicle is in motion, emergency warning lights only request the right-of-way, which should never be assumed until verified by other means.
- Emergency warning lights should always be used with audible warning devices/siren when exercising moving privileges permitted only by emergency

vehicles. EMS agencies should consider the following aspects of emergency lighting configurations for “requesting the right-of-way”:
    - Consider flashing white lights or automated flashing headlights on the front of the vehicle
    - Consider flashing red lights (or color required by state law) on all top corners of the ambulance that flash in a synchronous pattern, rather than alternating pattern
    - Consider flashing lights on forward corners of front fenders that serve to outline the front of the vehicle
- When “blocking the right-of-way” at a scene, consider altering the lighting pattern of the vehicle with the goal of drawing attention without blinding or overwhelming other drivers.
    - Do not use headlights or flashing white lights
    - Consider decreasing the number and intensity of flashing lights overall
    - Consider using scene floodlights to illuminate the scene and areas around the vehicle
    - Consider turning off distracting flashing emergency lights if the EMS vehicle is not the primary vehicle “blocking the right-of-way” for traffic
    - Consider using amber warning lights to warn of hazards ahead or amber directional signals to direct traffic away from hazards
- EMS agencies should design EMS vehicles for conspicuity to augment visibility when emergency warning lights are less effective (e.g. during bright sunlight or during darkness).
    - Consider lime-green vehicle color, which has the maximum conspicuity. Alternatively, consider avoiding black, dark blue or dark red for the EMS vehicle’s color, which are least visible
    - Consider avoiding patterns, pictures, and emblems that may be camouflaging
    - Consider using retroflective material to outline the vehicle in darkness
    - Consider applying a fluorescent, outward-downward chevron pattern of retroflective sheeting on the back of the vehicle
- Consider using automatic daytime running lights or a policy of headlight use at all times when vehicle is moving (when operating with or without L&S).

Use and Usefulness of Sirens

There are many acoustic studies of siren effectiveness. (Balastegui 2013, Caelli 1980, Catchpole 2007, Corlis 1976, DeLorenzo 1991, Fidell 1978, Maddern 2011, Potter 1976, Privopoulos 2011, Romeu 2013) Siren effectiveness is dependent upon source characteristics (level, frequency, directionality, and temporal characteristics), propagation (geometric spreading, atmospheric absorption, topography effects, and vehicle insertion loss), background noise (traffic and community noise, vehicle noise, and accessory noise), the human detection process (operator awareness and auditory ability), and the response (reaction time and breaking distance). It is obvious that the battle for siren effectiveness is not likely to be won.

Skeiber published one of the most pragmatic studies of auditory warning device effectiveness for the U.S. Department of Transportation in 1978.

The study concluded that siren warnings were only effective in the following situations:

1) to vehicles traveling in the same direction ahead of the emergency vehicle,
2) to vehicles weaving slowly through dense stationary traffic, or
3) to pedestrians

Some of their additional statements are worth quoting directly. “There is not much chance of warning drivers of those vehicles approaching head on, except under the most ideal situations. There is not sufficient warning to advise vehicles on converging roads. The attenuation of the sound in turning the corner in an urban situation and the forward directivity of existing siren devices, coupled with the typical speed of vehicles, in the rural situation can cause the warning distances to be too short for the receiving vehicle to brake and avoid a collision with an emergency vehicle which maintains speed”. (Skeiber 1978) Although this study was done in 1977, and there have been some advances to sirens, many of these points can be tested with common sense today, if one pays attention to when one first sees an emergency vehicle approaching head on or approaching when travelling at highway speeds – many are amazed at how the vehicle’s siren is not heard until they are very close. Tables I, J, and K present findings from Skeiber on the distances at which sirens are heard in urban, suburban, and rural areas, respectively.

TABLE I
Findings on siren effectiveness distances (in feet), various situations, in *Urban* areas
(as reported in Skeiber 1978)

Siren Type (Open Window, No Radio)	Road Configuration	
	Straight	Crossroad
Electronic Wail	123	39
Electronic Yelp	120	38
Electronic Hi-lo	81	26
Mechanical Wail	146	40

TABLE J Findings on siren effectiveness distances (in feet), various situations, in ***Suburban*** areas (as reported in Skeiber 1978)		
Siren Type (Open Window, No Radio)	**Road Configuration**	
	Straight	**Crossroad**
Electronic Wail	440	>106
Electronic Yelp	426	>106
Electronic Hi-lo	257	78
Mechanical Wail	445	>106

TABLE K Findings on siren effectiveness distances (in feet), various situations, in ***Rural*** areas (as reported in Skeiber 1978)		
Siren Type (Open Window, No Radio)	**Road Configuration**	
	Straight	**Crossroad**
Electronic Wail	33	14
Electronic Yelp	32	12
Electronic Hi-lo	24	<12
Mechanical Wail	33	<12

An updated version of a similar siren effectiveness study was done in 2012 by Monmouth Ocean Hospital Service Corporation (MONOC) ambulance service in Neptune, NJ. Although this operational study of siren propagation is less scientific than the Skeiber study, MONOC used it as an opportunity to release a video public safety campaign to educate EMSVOs (available at: https://www.youtube.com/watch?v=ivHTkZa7z0E).

In the study, they measured the distance at which a driver in a parked vehicle with the engine running could hear the siren of an ambulance approaching at 25 mph with various conditions in the parked vehicle. When the windows were open and other distractions were not present, the noise level in the vehicle was 30 dB, and the occupant could hear all forms (wail, yelp, hi-low, and electronic air horn) of the siren at 1500 feet. When the windows were closed and various distractions were added, the distance at which the occupant could hear the ambulance siren was dramatically reduced – but the wail and yelp modes were most easily heard through the distractions when compared with the hi-low or air horn modes. Most notably, when the windows were closed, radio was loud, and a cell phone conversation was occurring, the noise level in the parked vehicle was 70dB, and the distance at which the siren could be heard fell to between 10 and 283 feet depending upon the siren mode.[12] This is

[12] Personal communication, Monmouth Ocean Hospital Service Corporation (MONOC).

consistent with Skeiber's study where the wail and yelp modes were better detected than the high-low mode also.

TABLE L
Distances at which a vehicle occupant can hear a siren in an approaching ambulance at 25 mph with various distractions.
(MONOC study, Personal Communication)

	Distractors				
Siren Mode	Window	C - Phone	Radio	db level	Distance (ft)
Wail	Open	Off	Off	30	1500
Yelp	Open	Off	Off	30	1500
T 3	Open	Off	Off	30	1500
Air Horn	Open	Off	Off	30	1500
Wail	Closed	Off	Medium	50	555
Yelp	Closed	Off	Medium	50	450
T 3	Closed	Off	Medium	50	280
Air Horn	Closed	Off	Medium	50	215
Wail	Closed	Off	Loud	55	418
Yelp	Closed	Off	Loud	55	390
T 3	Closed	Off	Loud	55	325
Air Horn	Closed	Off	Loud	55	284
Wail	Closed	On	Loud	70	283
Yelp	Closed	On	Loud	70	273
T 3	Closed	On	Loud	70	213
Air Horn	Closed	On	Loud	70	10

While siren manufacturers may try different frequencies, directionality of siren mounting, and other innovations, they are fighting against a consumer desire for soundproof cars, increasing traffic and community noise, distractions from radios/cell phones/ear buds, and an aging population with declining hearing. Skeiber predicted this in 1978 in the final recommendation of his paper – "Realize that sirens will never become an effective

warning device without also becoming an intolerable community noise problem. Order of magnitude improvements in future warning effectiveness will have to be based upon non-auditory means."

Based upon this evidence, it is clear that sirens may not be as effective as many EMS vehicle operators assume, and this is likely why EMSVOs get frustrated, or even angry, with other drivers and this misunderstanding may contribute to the feeling of invincibility that may contribute to misjudgment and EMS vehicle crashes. While in some situations, sirens may be effective in getting the attention of other motorists, EMSVOs should be aware of their limitations. When L&S response is indicated, use the siren should be used judiciously but always when taking privileges that are only permitted by emergency vehicles using L&S. For example, there is no reason for an ambulance traveling at highway speeds with flowing traffic on an interstate to have their siren on continuously during an emergency response. This common sense approach may be contrary to laws in some states that require that both L&S be operated during use of either, and EMS providers need to be aware of their state's laws and regulations.

CONSIDERATIONS

Despite many efforts to enhance siren effectiveness through technological improvements, acoustic limitations are unlikely to ever make these devices a reliable method of gaining the attention of all drivers and pedestrians. EMS agencies and EMS vehicle drivers should consider the following related to siren use:

- Principle – Sirens only attempt to increase the public's awareness of an EMS vehicle. Sirens only request the right-of-way, which should never be assumed until verified by other means.
- Principle – Effective siren distances are deceivingly short, especially when the EMS vehicle and other traffic are travelling at highway speeds and when masked by vehicle soundproofing, buildings/structures, radios, and other distractions.
- EMS agencies should consider installing "rumbler" sirens for better localization and to overcome interior noise and masking
- EMS agencies should consider installing extra speakers directed to sides to improve siren directionality
- Sirens should always be used with emergency warning lights when exercising moving privileges permitted only by emergency vehicles
- EMS vehicle drivers should primarily use a combination of wail and yelp when "requesting right-of-way" with a siren. High-low and air horns are less effective siren modes.
- EMS agencies and EMS vehicle operators should avoid continuous use of siren during L&S response or transport and should limit the siren use when needed to "request right-of-way" or when exercising privileges only permitted by emergency vehicles with L&S. Using sirens when travelling at highway speeds with traffic or when traveling unimpeded without exercising emergency vehicle privileges may impede crucial communication related to the response or patient care.

Time Saved with L&S

The primary reason for L&S use on EMS vehicles is to provide the right of way to the EMS vehicle and permit certain driving privileges, depending upon the state, for the purpose of reducing times of EMS vehicle response and transport. Hunt was the first to publish a study of time saved by L&S transport in Greenville, NC and found an average reduction of 43.5 seconds when L&S were used. (Hunt 1995)

Fifteen studies compared the time saved during L&S response, transport, or both as shown in Tables M and N. While L&S use does statistically decrease EMS vehicle response times, the magnitude of this reduction is generally short, and most of the authors of these studies have suggested that only a small subset of patients will benefit by the time saved. In the O'Brien study, a physician reviewed the 75 patient care reports and believed that the time saved may have benefitted 4 (5%) of the patients. Of note, L&S were used at the discretion of the EMS providers in this system, so presumably, the patients that received L&S transport in this study were only a subset of the total patients transported and overall less than 5% of the cases would have benefited from L&S transport. (O'Brien 1999)

TABLE M
Mean *response* time interval differences related to L&S use
(from seven studies as shown)

Author	Year of Study	Community/Geographical Location	Time Saved (in minutes)	Notes
Dhindsa	1994	Washington, DC	3.6	Poster Abstract
Zachariah	1994	Suburban Texas	1.7	Poster Abstract
Ho	1998	Minneapolis, MN	3.0	
Brown	2000	Syracuse, NY	1.8	
Ho	2001	Becker County, MN (rural)	3.6	
Williams	2005	Anne Arundel County, MD	2.2	Fire Department Report
Yeh	2011	San Francisco, CA	1.9	Response to Stroke Symptoms

TABLE N Mean ***transport*** time interval differences related to L&S use (from eight studies as shown)				
Author	**Year of Study**	**Community/Geographical Location**	**Time Saved (in minutes)**	**Notes**
Dhindsa	1994	Washington, DC	3.0	Poster Abstract
Hunt	1995	Greenville, NC	0.7	
O'Brien	1999	Jefferson County, KY	3.8	
Brown	2000	Syracuse, NY	1.8	
Williams	2005	Anne Arundel County, MD	2.4	Up to 10.2 minutes for areas farther from hospital
Marques-Baptista	2010	New Brunswick, NJ	2.6	Reviewed critical interventions at hospital
Fleischman	2013	Multnomah County, OR	3.1	GPS/Google maps
Dami	2014	Vaud, Switzerland	1.8	No difference at night, 16.6% L&S transport rate

Other observations from this data are that when reported, there are some responses or transports that took longer without L&S – for example in Syracuse, Brown reported L&S response to be anywhere from 3.5 minutes slower to 7.1 minutes faster. (Brown 2000) Additionally, O'Brien and Fleischman reported more time saved with L&S over longer transport times or distances. (O'Brien 1999, Fleischman 2013)

Ho, et al published the most urban study to compare response times with and without L&S, and they found a savings of 3 minutes in Minneapolis. (Ho 1998) While their results are probably useful in considering response time savings in most large urban cities, the dense traffic in cities like New York City and Washington, DC may have unique situations that have not been studied for the effect of L&S. Dhindsa reported only a 3.6 minute faster mean response and 3.0 minute faster mean transport when L&S were used in 37 responses and 27 transports in 1994, but this was only presented as an abstract, and traffic congestion has likely changed in the last 20 years. (Dhindsa 1994) It is possible that L&S in these dense traffic cities may be associated with greater savings in time, or it is possible that the dense traffic congestion reduces the ability to clear lanes of travel for EMS vehicles and L&S are only an annoyance that does not significantly impact response or transport times. This is an area for future research using the methods that have been previously described.

There are other issues related to L&S use in cities with dense traffic congestion at times. During rush hours and at times of dense traffic congestion, judicious use of L&S may be the only way to allow EMS vehicles to make gradual progress, rather than to be stuck at a standstill. It is possible that in these situations, L&S response or transport may not have the significant risks of crash or injury due to low speeds. For these reasons, EMS agencies in the very few urban areas that suffer this gridlock may benefit by a policy that permits discretionary use of L&S to facilitate movement through this traffic.

In some busy EMS agencies, it has been argued that there are not enough EMS resources to permit non-L&S response and transport when indicated, because when applying the few minutes saved on each call over a large volume of calls, the unit-hour utilization and unit availability would be adversely affected. On the short-term, this may make sense, but communities should not use lack of EMS resources to justify unnecessary L&S use with its inherent risks.

There is limited information available about EMS provider attitudes related to L&S transport, and these are likely strongly affected by the traditions and culture related to the use of L&S within the provider's EMS agency. In an abstract, Funk reported on a survey of 99 EMS providers at a conference, and the providers generally believed that L&S saves significant time and did not believe that L&S use leads to increased crashes. (Funk 1999)

CONSIDERATIONS

Several studies have consistently shown that the use of L&S, on average, shortens response and transport intervals by 1.7 minutes to 3.6 minutes and transport times by 0.7 minutes to 3.8 minutes. These time savings have been realized in urban, suburban, and rural settings. Most authors have suggested that the time saved only impacts patient outcome in rare situations.

- EMS agency administrators, managers and medical directors should understand the likely time saved by L&S response and transport in their area and apply this to decisions related to L&S response and transport policies for the system.

The Association between L&S Driving and Crash Risk

There is clearly an increased risk of EMS vehicle crashes or collisions when operating with L&S. L&S attract attention to the EMS vehicle and are used to request the right-of-way. With due regard, the EMS vehicle operator may then take privileges permitted by law for the purpose of arriving at the scene or hospital in less time due to L&S use. But no matter how effective L&S are in drawing attention to the EMS vehicle, any collision with a vehicle that is proceeding through an intersection against a signal increases the risk over normal driving.

Clawson described the "maximal response disease" of sending multiple vehicles, all with L&S, to medical calls that do not justify this response. He estimated that as many as 12,000 EMS vehicle crashes occurred every year in the U.S. in the 1980s and that there are approximately four "wake effect" collisions involving other vehicles for every crash involving an emergency vehicle. (Clawson 1987, Clawson 1997)

Clawson and others also began to gain attention to the issue of EMS vehicle crashes by telling the story of Sharron Rose Frieburg (an 18-year-old who was seriously injured when struck by an ambulance responding to a patient with an ankle injury) and other victims of collisions of ambulances and other vehicles that left innocent bystanders and EMS providers seriously injured. Sharron Rose is now 47 years old and has permanent

injuries that have left her hemiparetic with difficulty walking and speaking. (Clawson 1991, George 1991, Personal Communication with Dr. Jeff Clawson) Almost 15 years later, Hunjadi described his personal fight through rehabilitation after being involved in a crash as an EMS provider. (Hunjadi 2005)

Several authors have described the magnitude and specific attributes of crashes involving EMS vehicles. (Auerbach 1987) The majority of EMS vehicle crashes occur when driving with L&S (Pirallo 1994, Colwell 1999, Kahn 2001), and between 1989 and 1997 in Denver 75% of responses were with L&S, but L&S accounted for 91% of all crashes. (Custalow 2004) When compared with other similar-sized vehicles, ambulance crashes are more often at intersections, more often at traffic signals, and more often have more injuries, with 84% involving three or more people. (Ray 2005)

Maguire calculated 12.7 fatalities among EMS workers per 100,000 personnel. Of these, 9.6 fatalities per 100,000 personnel were related to transportation – this exceeds the rate for law enforcement (6.1/100,000), for firefighters (5.7/100,000), and for other workers (2.0/100,000). Sixty-seven EMS providers were reported to be killed in ground transportation events between 1992 and 1997. (Maguire 2002) Rear occupants in ambulances are 2.7 times more likely to be killed in an ambulance crash. (Kahn 2001)

EMS vehicle crashes are associated with medicolegal risk (Wolfberg 1996) and are the most common cause of insurance claims of over $10,000 for EMS agencies. (HE Wang 2008) In one study 41% of EMS vehicle drivers had a poor crash record (Kahn 2001) and in Houston, TX, five emergency vehicle drivers caused 88% of 17 crashes. (Biggers 1996). The ACEP EMS Committee outlined ethical challenges that included the use of L&S, stating that “it behooves EMS medical directors and EMS responders to develop policies limiting L&S operations as much as possible.” (Becker 2013)

A North Carolina survey that tested EMS provider knowledge of state vehicle laws for ambulances revealed a median score of 1 on a 5-point exam. (Whiting 1998) EMS vehicle operator training to improve understanding of L&S limitations, appropriate use, and driving skills have been suggested as solutions to the issue of EMS vehicle crashes. After all, L&S merely ask the public for permission to have the right-of-way, and many authors and columnists have provided tips for better driving. (Smith 2009, Dick 1980, Erich 2000, Heim 1988, Jones 1986, Page 1993) Despite knowing the risks of EMS vehicle accidents, surveys have suggested that EMS vehicle operators do not apply this knowledge and continue to have unacceptable collision rates and inappropriate use of L&S. (Tennyson 2015) Some have suggested that technologic innovations like “black boxes” or cameras that provide driver feedback and record driving performance may be helpful. (Barishansky 2005, Levick 2005)

Erich described some other interventions aimed at reducing EMS vehicle crash risk in Pennsylvania, including state regulations that recognize EMS vehicle operators as a level of EMS provider certification, required continuing education for EMS vehicle operators, and driver surveillance by continuous monitoring of the Department of Justice database of motor vehicle infractions. (Erich 2010)

CONSIDERATIONS

Many EMS vehicle crashes and collisions are preventable, and many of these crashes occur when exercising privileges that are only legal during L&S driving. EMS agencies should consider the following interventions to reduce the risk of these crashes:

- Principle – EMS vehicle operator training is essential
    - States and EMS agencies should consider requiring EMS vehicle operator training, including initial education, formal recognition of EMS vehicle operators as a level of EMS provider, and required continuing education
    - EMS vehicle operator training should include knowledge of state laws related to L&S driving
    - EMS vehicle operator training should include knowledge of limitations of L&S and safe driving techniques for L&S operations
- Principle – L&S merely ask for the right-of-way
    - EMS vehicle operators must use due regard at all times
    - EMS vehicle operators (assisted by EMS provider passengers) should ensure eye contact with other drivers and clear intersections before proceeding through intersections against a red traffic signal or stop sign
- EMS agency vehicle driving policies should be based upon safest practices, even if those are more restrictive than state laws.
    - EMS vehicle operators should not exceed the speed limit. This increases risk and is not associated with better patient outcome.
    - EMS vehicle operators should bring the vehicle to a “full stop” at a stop sign or red traffic signal, before ensuring that the EMS vehicle has the right-of-way and entering the intersection.
    - Consider a “sterile cockpit” policy and culture with expectation of no unnecessary interruptions during L&S driving. During L&S driving, all conversations and communications with the driver or in the cab should be limited to “mission specific” communication.
    - Consider restricting the driver from distractions of texting, cell phone communication, reading pagers, and other distractions during driving.
- All occupants of EMS vehicles should be secured in appropriate seat belts or restraints, including:
    - Patient
    - Family or friends of patient, who ideally are restrained in the front passenger seat if they must ride in the ambulance
    - EMS vehicle operator/driver
    - Front seat passengers
    - Rear compartment passengers – including EMS providers as much as possible during patient care
- EMS agencies should consider forming a Safety Committee to address issues of driving safety and L&S use.

Traffic Signal Preemption Devices

Traffic signal preemption devices seek to reduce L&S-related collisions at intersections and decrease response times by sensing the responding emergency vehicle and controlling traffic signals to allow clear passage for the emergency vehicle. While many cities use these systems, the literature has limited description of their effectiveness.

A NHTSA publication provides a case series with descriptions of traffic signal preemption for emergency vehicles in Fairfax County, VA, Plano, TX, and St. Paul, MN. These jurisdictions report various advantages that include reduced response times, need for fewer fire stations to maintain response standards, and decreased intersection crashes. The document provides advice for communities that are considering the purchase of traffic preemption devices. (NHTSA 2006)

A USFA document states that “traffic pre-emption devices can provide an additional safety factor during emergency responses but must never be considered a replacement for approaching an intersection with caution and coming to a complete stop.” (USFA 2014)

Hazards of L&S Use for EMS Providers

Several researchers have investigated the potential detrimental effect of EMS work and siren exposure on hearing acuity. Most of these studies, using differing methodologies, have concluded that firefighters and paramedics have an accelerated rate of hearing loss or lower level of hearing acuity than the general population. (Hong 2007, Johnson 1980, Pepe 1985) The literature search located one study by Price that did not identify hearing loss or siren noise exposure that exceeded acceptable per OSHA. (Price 1998) Mounting the siren on the vehicle’s grill or bumper, as opposed to the roof of the cab, may decrease the siren intensity in the cab. (VanBuren 1987)

Another hazard that is peripherally related to L&S transport is the risk of injury when off-balance and unrestrained in the back of the ambulance. This risk is present whether or not L&S are used, but the risk is greater if the L&S transport increases the risk of an L&S-related crash. Slattery also suggested that there are other risks to the caregiver in the patient compartment, including being out of the seatbelts, distractions, loose equipment, and unsafe ambulance designs. (Slattery 2009) These are probably best mitigated by seat belt use and forward-facing seats that are listed in the considerations in the section on Clinical Indications for L&S Transport.

CONSIDERATIONS

Accelerated hearing loss from siren noise and injuries to unrestrained, off-balance providers in the patient compartment are real job-related risks for EMS providers. These hazards can be largely mitigated with inexpensive and readily available actions.

- EMS agencies should consider practices to reduce siren noise for providers
    - EMS agencies should consider mounting sirens on vehicles in positions to reduce interior siren noise

    - EMS vehicle drivers should limit L&S use to situations when “requesting the right of way” and should avoid continuous siren use during response or transport
- EMS agencies should consider ways to encourage the wearing of restraints at all times, including during patient care in the rear compartment.
    - To avoid injury, all EMS providers wear seatbelts at all times, when patient care needs allow, when the vehicle is in motion. EMS providers in the patient compartment can wear restraints the vast majority of the time.
    - EMS agencies should ergonomically design seating in patient compartments to allow for almost all patient care while restrained in a forward-facing provider seat.

Emergency Medical Dispatch and L&S Response

In 1983, Dr. Jeff Clawson described an emergency medical dispatcher course that included the concept of non-L&S response based upon a structured call-taking process including key questions, pre-arrival instructions, and dispatch priorities. At that time, the following calculation was suggested to determine the mode of responses:

> “1. Red light and siren vs. routine
>
> a. Ask yourself the following question of each problem:
>
> 1. Will time make a difference in final outcome?
> 2. How much time leeway do you have?
> 3. How much time can you save going red-light-and-siren?
> 4. When the victim gets to the hospital will the time you saved be significant to the time spent awaiting care (i.e. waiting turn, X-rays, lab tests, etc.)?
>
> 2. True time priority items (one- to five-minute response required):
>
> a. Cardiac or respiratory arrest
> b. Airway problems
> c. Unconsciousness
> d. Severe Trauma/ hypovolemic Shock
> e. True obstetrical emergencies”
>
> 3. Other emergent medical problems should receive responses of less than 10 minutes with all responses (in urban/ suburban areas) within 15 minutes.” (Clawson 1983)

The introduction of the concept that medical screening may be able to separate time-dependent emergencies that require L&S response from those medical emergencies that can have response delayed by a few additional minutes was unique. Prior to this, all responses to medical calls to dispatch centers were generally with L&S. By 1989, the NAEMSP appreciated the value of emergency medical dispatcher training, pre-arrival instructions, dispatch prioritization, and quality improvement for medical dispatch and developed a position statement on the topic. (NAEMSP Position Statement, 1989)

The opportunity to reduce L&S use during response is largely dependent upon the emergency medical dispatch center screens calls for an EMS agency. The rate of L&S

response for an EMS agency depends upon the dispatch prioritization process that is used and also how the EMS agency applies a given response (L&S or no L&S) to this prioritization. For this reason, EMS medical directors and agency managers should measure metrics related to L&S response, response times, and patient outcomes to adjust the response policies to ensure rapid L&S response to conditions that will benefit by the amount of time saved with L&S, while using non-L&S response to the rest of the emergency medical requests. Clawson's questions listed above from 1983 are still valid considerations.

While many agencies have reduced their L&S responses, it is difficult to say what benchmark should be used for the maximum percentage of an agency's response that should be done with L&S. Some agencies have carefully measured the effects of changing response expectations and EMD prioritization. For example, Tulsa/Oklahoma City where 33% of 911 medical calls received an L&S response in 2015.[13] It is probably reasonable to suggest that the vast majority of EMS agencies can reduce their rate of L&S response to no more than 50% of calls without any patient morbidity, and with less risk of injury for EMS providers and the public. While there are examples of EMS agencies that have used EMD to reduce their use of L&S to less than half of their 911 emergency responses, the 2015 NEMSIS data shows that this is not common practice, and only 16.9% of EMS agencies submitting to this dataset used L&S on less than half of their 911 emergency responses, while most EMS agencies use L&S on over 80% of their 911 responses. (Table H) Since few (probably less than 5%) of EMS calls are true time-sensitive emergency, many EMS agencies should be able to safety reduce their L&S use during response to far less than 50% of their 911 calls.

Interestingly, Clawson reported that in 1983 when Salt Lack City instituted emergency medical dispatch to prioritize medical calls, the L&S response decreased by 50%, while incidentally there was a 78% reduction in emergency vehicle collisions in the same year. (George 1991). With reports of emergency medical dispatch reducing L&S response by at least 50% and the recent Oklahoma reduction of L&S response to 33% of 911 calls, it seems reasonable to set a potential performance measure of 50% or less as a recommendation for EMS agencies seeking a benchmark for response.

Shah described a study meant to validate 21 EMD codes associated with low-acuity dispatch, but these codes only identified 17% of the EMS calls as low-acuity by dispatch prioritization. The definition of low-acuity was validated if the patient did not require ALS skills or L&S transport. This definition is very conservative, as many EMS systems respond without L&S to patients that still may receive ALS procedures, and the need for an ALS procedure should not by itself suggest that the initial response required L&S. (Shah 2005)

Agencies that still routinely respond to all 911 dispatches with L&S or have not yet fully leveraged high-quality EMD systems can still identify some calls that will almost never benefit by the time saved with L&S response – for example carbon monoxide alarm without symptoms in occupants, fire stand-bys without potential entrapment or injuries,

[13] Personal Communication, Jeffrey Goodloe, Emergency Medical Services Authority, March 6, 2017.

motor vehicle crashes without known injuries, responses to physician offices where information is available from skilled medical professionals, responses to skilled nursing facilities, and medical alert device activations without additional clinical information. Boland makes the point that the logistics of transferring a patient from a skilled nursing facility (nursing home) to a hospital cause delays, like copying of medical records and calling the attending physician, that negate any time saved by L&S response in most cases, and these facilities have skilled healthcare providers on site. (Cone 2007, Boland 2012)

It is common for municipal contracts with EMS agencies to be structured around a requirement for ALS arrival on scene (response) within 8 minutes of dispatch. Although many EMS agencies do not have response time requirements, the agencies that bid on proposals and have contractual agreements with municipalizes often are held to some form of this 8 minute response requirements, with financial penalties if the response requirement is not met. While rather easy and objective to measure, encouraging EMS agencies to race to a scene with L&S to beat an arbitrary response time may have disastrous consequences in crashes, injuries, and inconvenience to drivers and annoyance to the public.

The contractual requirements for ALS response in an 8 minute window stems from a landmark 1979 study of cardiac arrest outcome in Seattle where the best rates of survival were associated with BLS response within 4 minutes and ALS response within 8 minutes. (Eisenberg 1979) Applying an 8-minute response requirement broadly to all EMS responses when cardiac arrest accounts for about one percent of the calls does not make sense, but NFPA 1710 and many jurisdictional EMS contracts and regulations still call for an ALS response time standard of 8 minutes 90% of the time. Some EMS administrators, managers and medical directors are increasingly suggesting that response time should not be the sole performance indicator for EMS system contracts and patient outcome and quality of care are much more important that response time. (Al Shaqsi 2010) It may be possible to loosen response time parameters for most calls, while taking a targeted approach to identifying the high-priority calls (for example cardiac arrest) for an L&S response. (McCallion 2012, Fitch 2005, Goodwin 2010)

The counties served by the Emergency Medical Services Authority (EMSA) – including Oklahoma City, OK and Tulsa, OK – have recently done this. 911 calls in these areas are triaged for a high or low priority response, and the contracted response times for these responses have recently increased. The response time standard for Priority 1 calls, like cardiac arrest, chest pain, and stroke, are now 10 minutes and 59 seconds (up from 8 minutes and 59 seconds). For Priority 2 calls, like falls, fractures, and minor injuries, the maximum response time is now 24 minutes and 59 seconds. Additionally, in the suburbs the maximum Priority 1 response time will be 11 minutes and 59 seconds. The agency now responds to only 33 % of its 911 medical calls with the use of L&S, which is safer for the EMS providers and the general public. The EMS agency managers and medical directors have not identified cases with increased morbidity or mortality through their QI process, and they have not observed any change in their cardiac arrest survival rate. (Blackwell 2011, Goodloe 2017)

As systems consider changes to response time requirements or levels of response that require L&S, EMS system leaders, managers, and medical directors should all be engaged, time intervals should be continuously measured, and quality improvement processes should measure and follow patient outcomes.

CONSIDERATIONS

Several studies have consistently shown that the use of L&S, on average, shortens response intervals by 1.7 minutes to 3.6 minutes. These time savings have been realized in urban, suburban, and rural settings. Most authors have suggested that the time saved only impacts patient outcome in rare situations.

- Standard setting organizations and geopolitical jurisdictions should consider establishing different response time expectations for high and low priority EMS responses. The traditional requirement for ALS response within 8 minutes 90% of the time is not associated with improved outcomes and risks EMS crashes and stresses EMS resource availability.
- Performance Measure – EMS agencies should use emergency medical dispatch programs to reduce L&S response as much as possible. A possible benchmark is reducing L&S response to 911 calls to less than 50% of all 911 responses.
- The EMS agency administrators, managers, medical director and dispatch center medical director should be involved in establishing and monitoring the safety of emergency medical dispatch protocols and the rate of L&S response.

Clinical Considerations Related to L&S Use during Transport

L&S use during response, and particularly during transport, is a medical therapy. As such, L&S should be "prescribed" based upon a patient's condition and used only when the time that it saves will be expected to benefit the patient's outcome. The clinical value of ambulances being driven at high speed with "open siren" was questioned as far back as 1953 – when ambulances were not yet routinely staffed by attendants with any first aid training.

Long before the era of modern EMS, the Florida Medical Journal presented the findings of a review of ambulance patients arriving with L&S to two Florida hospitals. Over one month of a study at Jackson Memorial Hospital, 808 ambulance patients arrived with L&S – 6 were dead on arrival, 13 died in the emergency department, and 247 were admitted. Overall, 67.1% were not admitted, and a physician chart review determined that 99 of the cases had some medical justification for L&S use. The author stated, "87.8 per cent of the patients arriving by ambulances need not have been rushed to the hospital." In the same publication, the author reported on a review of 378 L&S ambulance transports to Duval Medical Center over an 8-week period. In this group, 71.5% of the patients were not admitted "after a fast ride to the hospital". Additionally, based upon the author's conservative review of the diagnoses of those patients that were admitted, it was felt that only 15% of the admitted patients and 4.2% of all patients were true emergencies. The study further reports that in 1951, a database from the Florida Department of Public Safety reported 25 ambulance crashes with one death and

14 injured persons. Interestingly, they recommend first aid training for ambulance providers, restricting ambulances from running red lights or at high speeds, educating ambulance drivers, and developing a committee of the medical society to develop a list of conditions that would require excessive speed. (Parks 1953)

Forty-one years later, Kupas demonstrated that the use of L&S during patient transport could be minimal when a medical protocol is used to identify patients that may benefit by the time saved with L&S transport. When using this protocol on 1625 patients, only 130 (8%) were transported using L&S. A review of the 92% of cases where L&S was not used, the receiving physicians did not identify any cases of possible morbidity due to a slower transport. (Kupas 1994) Merlin developed an even simpler medical protocol for L&S transport, which reduced L&S transport in this urban New Jersey community from 49.6% to 29.0% for patients transported by ALS providers. (Merlin 2012)

There is some evidence related to types of patients or medical conditions that may or may not benefit from L&S transport. One study of 112 patients transported with L&S found that only five of those patients received a time-critical intervention upon arrival to the emergency department, and none of these procedures was done within the 2.62 minutes saved by L&S transport. (Marques-Batista 2010) A study in Denmark looked for morbidity by studying 94,488 patients transported without L&S and found only 152 patients (0.16%) that died the same day as their ambulance transport. A panel of prehospital anesthesiologists reviewed the patient care reports and found 13 (0.02%) with potentially preventable deaths. If every one of these deaths could have been prevented with L&S transport, the “number needed to treat” would have been 5000 extra L&S transports. (Anderson 2014)

Other authors have examined subsets of pediatric patients. On a medical review of pediatric patients transported with L&S, studies by Burns and Lacher found rates of unnecessary use of L&S transport to be 20% and 39%, respectively. Of note, Burns noted that the baseline use of L&S transport in these pediatric patients was only 7%, and there was still opportunity for improvement. (Burns 2016, Lacher 1997)

Of all medical conditions that may justify L&S transport, the classic time-sensitive illnesses and injuries are often cited as conditions where L&S should be used, but the evidence for this is also lacking. Many authors have questioned the “golden hour” concept in trauma care, and although prompt trauma care by a well-trained team at an organized trauma center is associated with improved outcomes, there is little evidence for this temporal concept. (Barrett 2010, Berger 2010, Lerner 2001). The Resuscitation Outcomes Consortium studied the outcomes for injured patients treated by 146 EMS agencies, transporting to 51 Level I and II trauma centers, in ten North American communities. This large study found no association between survival and EMS time intervals – including response time and transport time. (Newgard 2010)

Because ST-elevation myocardial infarction (STEMI) is a time-sensitive condition, L&S transport is sometimes considered to be of benefit. Although it is clear that time to reperfusion is generally important, few studies specifically consider the effect of the few minutes that are saved with L&S transport. The recent study by Nallamothu extrapolates

the odds ratio for decreasing time to percutaneous intervention by 10 minutes. The authors suggest that a 10 minute reduction in “door-to-balloon” time has an odds ratio of 0.92 for in-hospital death and 0.94 for death within 6-months. When applied to the average reported in-hospital mortality of 5.3%, rendering a coronary intervention 10 minutes sooner (OR 0.92) would be anticipated to decrease deaths by 0.4% or a number needed to treat (NNT) of 250 cases. (Nallamothu 2015)

This statement is simplistic and ignores several nuances and limitations of the study. Since most studies of L&S transport have shown lower time savings (43 seconds to 3 minutes), and we don't fully know the effect of increased adrenaline from siren use on a STEMI patient's myocardium, any effect of time saved during L&S transport is likely much less than this estimate. Additionally, this is only applicable if the EMS crew delivers a patient with STEMI to a cardiac catheterization lab that is staffed and prepared to begin the procedure. If the patient must wait for any delay that is longer than the time saved by L&S transport, any benefit of faster transport is lost. Furthermore, while emergency physicians and cardiologists concentrate on system approaches that reduce door-to-intervention times in STEMI, they also realize that there are potential hazards and errors when rushing to shave off seconds.

Similar issues apply to any advantage to L&S transport for stroke patients. This review did not locate any literature evidence for the impact of L&S transport on stroke patients, but again prehospital notification and preparation at the receiving facility is likely much more important than the few minutes saved with L&S transport. Although not related to transport, an abstract by Yeh found that the difference in response to patients with stroke symptoms in San Francisco was less than 2 minutes longer when L&S were not used. They suggested that further research is needed to determine any potential impact of this difference. (Yeh 2012)

Many systems use L&S transport for the ultimate time-sensitive condition of cardiac arrest. The off balance forces on an EMS provider that is attempting to do cardiopulmonary resuscitation in a moving vehicle may not be any different whether driving with or without L&S (Kurz 2012) – both may lead to physical injury if the provider is jostled, but one can argue that the L&S transport also increases the chance of EMS vehicle collisions when proceeding through a red light that are not present with non-L&S transport. More importantly, there is evidence that the best chance for survival from out-of-hospital cardiac arrest (OOHCA) is to attain return of spontaneous circulation (ROSC) at the scene. Wampler found a survival rate of 0.69% in OOHCA patients that did not have ROSC in the field, and there were no survivors in this group if the cardiac rhythm was asystole. (Wampler 2012) Smith studied a group of infants with apparent sudden infant death syndrome (found lifeless after sleeping), and all died. They suggest that transporting these patients with L&S is not worth the risks. (Smith 2005) Many EMS agencies have protocols for field termination of CPR for certain OOHCA patients that don’t attain ROSC, and these may be beneficial in decreasing the risks to providers of transporting these patients with historically low survival rates.

While L&S transport tends to save a few minutes of time in most situations, we don’t know much about the physiologic effects of L&S transport on patients or about potential

health risks to those effects. Some have hypothesized that the siren and rapid driving would increase a patient's heart rate, blood pressure, pain or anxiety, but the few available studies related to physiologic effects of L&S have variable results. A German study found that L&S caused a 30% increase in heart rate, 14 mmHg average increase in blood pressure, and increased stress (as measured by increased cortisol and corticotrophin levels), (Witzel 1999) but another study found increased epinephrine levels without increases in hemodynamic vital signs. (Dorges 2001) In Austria, two other physiologic studies of "rapid transport" – but without mention of how much the siren was used – did not find a change in heart rate or blood pressure. However, during rapid transport they did record elevated plasma epinephrine and norepinephrine levels in patients with acute coronary syndrome and elevated pro-B-type naturetic peptide levels in patients with heart failure. (Weber 2009, Weber 2010)

More research is needed to identify any adverse effects of L&S use on hemodynamics, cardiovascular work, stress, patient anxiety or other physiologic outcomes, but if L&S cause physiologic changes, it is possible that these decrease or negate or even reverse any outcome benefit achieved by faster transport. This should be considered when L&S benefits are only marginal.

The NEMSIS data presented earlier in this report (see Current Use of L&S in the U. S.) shows that in 2015 L&S were used at some time during the transport for only about 23 percent of patients after a 911 scene response. (Table B) When L&S use was investigated at the agency level, 14.6% of agencies did not use L&S during transport and 43.4% of agencies used L&S on less than 10 percent of their 911 responses. However, as polar opposites, 3.5% of agencies used L&S during every transport and 12.5% used L&S on over 80% of their transports. (Table I) This data suggests that most EMS transports in the U.S. are done without L&S, but there remains dramatic difference in L&S use during transport among EMS agencies. Based upon the literature evidence in this monograph and the lack of hard evidence for improved clinical outcomes from L&S use during transport, it is reasonable to suggest that EMS agencies should take steps to minimize L&S use during transport as much as possible, and a rate of L&S use below 5% of 911 scene responses is likely safe for patients – some excellent EMS agencies strive for "zero L&S transports."

Although other system issues may be used to support L&S transport at some times, for any individual patient, there are few conditions that have a proven outcome benefit by reducing the transport interval by the few minutes saved by L&S use. Any potential benefit must be balanced against risk of vehicle collision, injury to occupants, and potential detrimental effects on the patient's physiology. L&S use during transport should be used like any other medical intervention – does the potential for benefit outweigh the potential for harm?

CONSIDERATIONS

When considering whether L&S is beneficial to a patient's outcome during EMS transport from the scene to a medical facility after the patient has been assessed by an EMS provider, the following principles may be helpful in generating an agency/system policy and safety culture:

- Principle – The EMS provider, with the highest level of training, caring for the patient should direct whether or not L&S are used during transport based upon the patient's medical condition and potential benefit of time saved with L&S transport.
- Principle – EMS providers have a significantly increased risk of injury when not restrained and riding in the patient compartment. Policies should require that providers wear restraints at all times when patient care permits, drivers should be alerted when any occupant is out of restraints, and time out of restraints should be minimized.
- EMS agencies should consider forward-facing attendant seats in the patient compartment and ergonomic designs that permit patient care while restrained and forward-facing.
- Performance Parameter – EMS agencies should consider a target L&S transport rate of less than 5%. The small amount of time saved is likely to be of clinical value in only a small percentage of medical conditions.
- Consider policies or protocols that define medical conditions where L&S transport is appropriate. In general, EMS providers should be able to intervene on the vast majority of patient conditions without the need for expedited transport to a hospital for an immediately life-threatening condition. Rare examples of conditions that may benefit from expedited transport include, 1) a tenuous airway (with complete or incomplete obstruction) and 2) a patient with rapidly decompensating vital signs.
- Consider L&S transport as a parameter for mandatory QI case review (similar to cricothyrotomy or chest needle decompression).
- Consider system opportunities that have greater benefit to patient outcome than L&S transport. The radio saves more time than L&S. If the patient with a time-sensitive illness has any delay after arrival at the hospital that exceeds the few minutes saved by L&S, any advantage to L&S transport is lost, and the healthcare system should concentrate on ways to decrease those delays. For example, during the care of a stroke patient, early notification that permits that patient to be taken directly into a CT scanner on arrival is more valuable than L&S transport followed by a wait for the CT scanner to become available.
- Consider protocols for field termination of most patients with cardiac arrest that do not have return of spontaneous circulation in the field to reduce risks during patient movement and transport.

Public Perceptions and Expectations for L&S Use

It is a common myth is that the public expects L&S response for all 911 requests. In fact, the evidence suggests otherwise. A 1988 phone survey of the public in Connecticut cited sirens and noise (67/604 respondents) as the primary reason for being uncomfortable in calling EMS during an emergency, and this response was followed by "getting lots of attention" (49/604 respondents). (Smackery 1988) Critz reported that the families of terminally ill patients who died at home sometimes felt anger with EMS, and

L&S response was listed as one of the reasons for this. (Critz 1989) While public complaints related to arriving without L&S are possible, EMS agencies certainly receive complaints about the noise pollution caused by L&S in some neighborhoods. Most EMS agencies have probably received 911 calls that include the request to specifically “not use L&S near the scene” – particularly for calls to residential addresses. While some EMS agencies worry about complaints about not arriving with L&S, it is possible that there are some patients that refuse to call EMS for medical emergencies, because they are uncomfortable with the L&S and attention. E. Marie Wilson stressed the importance of maintaining a sense of confidence with the public and stated, “Competence is more often shown by quiet deliberateness than by noisy bravado.” (Wilson 1992)

Although a concern of EMS agencies that non-L&S response or transport may lead to complaints, there is no published evidence for this. Colwell reported on complaints received by Denver EMS over a six-year period, and only 5 percent of the complaints were related to timeliness. Although they did not report specifically if any of those were related to not using L&S, they did report that another 5 percent of the complaints were related to driving. (Colwell 2003) In 2005, Williams investigated public perception in Anne Arundel County, MD when the system was planning to increase their responses and transports without using L&S. They found that 85% of the surveyed public were comfortable with non-L&S response based upon dispatcher screening and with non-L&S transport after EMS provider evaluation. (Williams 2005)

It may also be a myth that an agency will lose EMS providers if they are not able to frequently drive with L&S. A 1988 survey of 2,700 EMS providers in Connecticut found that altruism was the primary reason for working or volunteering in EMS. Helping people and an interest in a healthcare career were the top reasons for doing EMS, and these exceeded excitement. This group did not list L&S as a reason for working in EMS. (Wilson 1989)

Lastly, in a survey in the United Kingdom, one-third of drivers reported feeling stress when navigating away from approaching emergency vehicles with L&S, and the authors believed that drivers found the interactions with emergency vehicles inconvenient and potentially dangerous. (Saunders 2003) Overall, the review of current literature found that surveys report some public uneasiness in using EMS because of sirens, noise and attention. Furthermore, the available literature does not suggest concern that non-L&S responses or transports are related to significant complaints or public uneasiness.

Recommendations for EMS Vehicle Operations Policies

The purpose of this section is to concentrate the considerations and recommendations for EMS agencies and EMS vehicle operators from the various sections of this monograph into a single section of the document.

Recommendations for EMS safety are not one-size-fits-all. While most of these recommendations will improve the safety of EMS providers and patients in every agency, individual agency culture, demographics, and dynamics will make some of these less effective or more difficult to initiate. Additionally, changes to prioritization of calls and response times should be done with careful attention to maintaining patient outcome. The involvement of the EMS agency medical director and operational and administrative leaders is essential to safely change L&S use.

In this section, some recommendations have been highlighted because they are likely to lead to the biggest opportunities in reducing risks of EMS vehicle crashes and provider or patient injury. Agency leaders should concentrate on the recommendations that will have the highest impact.

Recommendations for States

- **Promote statutes and regulations that permit L&S use on EMS vehicle during patient transport only in situations where the patient's clinical outcome may be improved by the estimated time saved by L&S use, rather than just when transporting a patient to a hospital or responding on an emergency call.**
- **Consider EMS vehicle driving regulations that require a full stop before proceeding through a stop sign or red traffic signal, before proceeding with caution when using L&S.**
- Consider EMS vehicle driving regulations that limit speed during L&S driving to the maximum posted speed limit.
- EMS vehicle operator training is essential
    - States should consider requiring EMS vehicle operator training, including initial education, formal recognition of EMS vehicle operators as a level of EMS provider, and required continuing education
    - EMS vehicle operator training should include knowledge of state laws related to L&S driving
    - EMS vehicle operator training should include knowledge of limitations of L&S and safe driving techniques for L&S operations
- Consider recognizing EMS vehicle operators, like other levels of EMS providers, and requiring initial training and continuing education for EMS vehicle operators.

Recommendations for Standard Setting Organizations and Geopolitical Jurisdictions

- **Standard setting organizations and geopolitical jurisdictions should consider establishing different response time expectations for high and low priority EMS responses. The traditional requirement for ALS response**

within 8 minutes 90% of the time is not associated with improved outcomes and risks EMS crashes and stresses EMS resource availability.

- Standard setting organizations should consider forward-facing ergonomically designed seating that minimizes risk of injury during crash and maximizes the time in restraints for EMS providers in the patient compartment

Recommendations for EMS Agency Leaders/Managers/Medical Directors

- **EMS agency administrators, managers and medical directors should understand the likely time saved by L&S response and transport in their area and apply this to decisions related to L&S response and transport policies for the system**
  - **Every EMS agency should have a policy that addresses L&S use during EMS vehicle response and patient transport, with the goal of minimizing L&S use to situations where the patient's clinical condition may be improved by the time saved using L&S.**
  - Several studies have consistently shown that the use of L&S, on average, shortens response and transport intervals by 1.7 minutes to 3.6 minutes and transport times by 0.7 minutes to 3.8 minutes. These time savings have been realized in urban, suburban, and rural settings. Most authors have suggested that the time saved only impacts patient outcome in rare situations.
- **Performance Measure – EMS agencies should use EMD programs to reduce L&S response as much as safely possible. A possible benchmark is reducing L&S response to 911 calls to less than 50% of all 911 responses.**
  - EMS agency administrators, managers, medical director and dispatch center medical director should be involved in establishing and monitoring the safety of EMD protocols and the rate of L&S response.
  - EMD protocols should be used by telecommunications professionals when selecting classification/prioritization of EMS responses.
- **Performance Parameter – EMS agencies should consider a target L&S transport rate of less than 5%. The small amount of time saved is likely to be of clinical value in only a small percentage of medical conditions.**
- **EMS vehicle operators should have initial EVOC training and ongoing continuing education**
  - **EMS agencies should consider requiring EMS vehicle operator training, including initial education, formal recognition of EMS vehicle operators as a level of EMS provider, and required continuing education**
  - **EMS vehicle operator training should include knowledge of state laws related to L&S driving**
  - **EMS vehicle operator training should include knowledge of limitations of L&S and safe driving techniques for L&S operations**
  - **Every EMSVO should be educated to the agency's policies and expectations related to safe driving, including the use of L&S**
- **EMS agencies should screen, review, and monitor the driving history of EMSVOs.**

- **Every EMS agency should have a safety committee that meets regularly. This committee should work to improve the culture of safety in the EMS agency and should specifically monitor L&S use and participate in developing/revising the agency's L&S use policy.**
- Consider policies or protocols that define medical conditions where L&S transport is appropriate. In general, EMS providers should be able to intervene on the vast majority of patient conditions without the need for expedited transport to a hospital for an immediately life-threatening condition. Rare examples of conditions that may benefit from expedited transport include, 1) a tenuous airway (with complete or incomplete obstruction) and 2) a patient with rapidly decompensating vital signs.
- EMS agency vehicle driving policies should be based upon safest practices, even if those are more restrictive than state laws.
    - **EMS vehicle operators should bring the vehicle to a "full stop" at a stop sign or red traffic signal, before ensuring that the EMS vehicle has the right-of-way and entering the intersection.**
    - EMS vehicle operators should not exceed the speed limit. This increases risk and is not associated with better patient outcome.
    - Consider a "sterile cockpit" policy and culture with expectation of no unnecessary interruptions during L&S driving. During L&S driving, all conversations and communications with the driver or in the cab should be limited to "mission specific" communication.
    - Consider restricting the driver from distractions of texting, cell phone communication, reading pagers, and other distractions during driving
- **EMS agencies should have seatbelt and child restraint policies for drivers, EMS providers, patients, families, and others who may ride in EMS vehicles**
    - **EMS provides should be restrained during the majority of transports, at all times when the provider does not need to be out of seat to provide "aggressive patient care" in the rear of the ambulance.**
    - **EMS vehicles should be ergonomically designed so provider seating is forward facing and allows providers to reach most of the necessary equipment without unfastening restraints**
- The culture of safety related to EMS vehicle operations requires bottom-up and top-down reinforcement and support of the agency's policies for EMS vehicle operations (e.g. L&S use, seatbelt use).
- **As part of the agency's quality improvement/performance improvement activity, EMS agencies should regularly measure their percentage of L&S use during 911 scene response and patient transport.** Where appropriate, individual case reviews for compliance with policy/protocols and appropriate use of L&S should be performed as part of regular QI audits.
    - Consider L&S transport as a parameter for mandatory QI case review (similar to cricothyrotomy, chest needle decompression, or endotracheal intubation).
    - Consider system opportunities that have greater benefit to patient outcome than L&S transport. The radio saves more time than L&S. If the patient with a time-sensitive illness has any delay after arrival at the hospital that exceeds the few minutes saved by L&S, any advantage to

L&S transport is lost, and the healthcare system should concentrate on ways to decrease those delays. For example, during the care of a stroke patient, early notification that permits that patient to be taken directly into a CT scanner on arrival is more valuable than L&S transport followed by a wait for the CT scanner to become available.
    - Consider protocols for field termination of most patients with cardiac arrest that do not have return of spontaneous circulation in the field to reduce risks during patient movement and transport.
- Consider policy of response without L&S for the following cases:
    - When EMD system triages the call to a low priority
    - BLS ambulance responses, when ALS is not indicated
    - Carbon monoxide detector activation without reported patient symptoms
    - Response to skilled nursing facility (nursing home) for stable patients
    - Response to physician office or other setting where trained healthcare providers are on scene for stable patients
    - Response to medical alert device activations, unless specific information from individual on scene provides additional information for EMD prioritization
    - Vehicle relocations
- EMS agencies should consider the following aspects of emergency lighting configurations for “requesting the right-of-way”:
    - Consider flashing white lights or automated flashing headlights on the front of the vehicle
    - Consider flashing red lights (or color required by state law) on all top corners of the ambulance that flash in a synchronous pattern, rather than alternating pattern
    - Consider flashing lights on forward corners of front fenders that serve to outline the front of the vehicle
- EMS agencies should design EMS vehicles for conspicuity to augment visibility when emergency warning lights are less effective (e.g. during bright sunlight or during darkness).
    - Consider lime-green vehicle color, which has the maximum conspicuity. Alternatively, consider avoiding black, dark blue or dark red for the EMS vehicle’s color, which are least visible
    - Consider avoiding patterns, pictures, and emblems that may be camouflaging
    - Consider using retroflective material to outline the vehicle in darkness
    - Consider applying a fluorescent, outward-downward chevron pattern of retroflective sheeting on the back of the vehicle
- Effective siren distances are deceivingly short, EMS agencies should consider the following when designing vehicles:
    - consider installing “rumbler” sirens for better localization and to overcome interior noise and masking
    - consider installing extra speakers directed to sides to improve siren directionality

    - Consider that attempts to make sirens more easily heard are not very effective, and more safety can be gained by reducing the overall use of L&S than by trying to install more effective sirens.
- Consider installing automatic daytime running lights or a policy of headlight use at all times when vehicle is moving (when operating with or without L&S)

Recommendations for EMS Vehicle Operators

Note: EMS vehicle operators must be familiar with motor vehicle laws and regulations related to the operation of EMS vehicles in their state. These are general safety recommendations, and pertinent state laws and regulations must be followed as applicable.

- **The driver is responsible for the mode of response to the scene based upon dispatch category, information available from dispatcher, and agency policy**
- **The EMS provider, with the highest level of training, caring for the patient should direct whether or not L&S are used during transport based upon the patient's medical condition and potential benefit of time saved with L&S transport.**
- **L&S merely request the right of way from other drivers, but neither emergency warning lights nor siren are very effective. Do not assume that your vehicle has been seen by other drivers, and always proceed with caution and due regard.**
- Consider the following when driving an EMS vehicle:
    - Automatic daytime running lights or manual headlights increase vehicle visibility and should be on at all times when vehicle is moving
    - Both L&S should be used when exercising moving privileges (e.g. traveling through a red traffic signal or in travel lanes that oppose normal traffic). Likewise, if the driver does not intend to exercise these privileges, neither lights nor siren should be used during the response or transport. Traffic is confused by an EMS vehicle that approaches an intersection with emergency lights operating, but sits and waits for the signal to turn green if the traffic has given the right of way.
    - EMS vehicle operators (assisted by EMS provider passengers) should ensure eye contact with other drivers and clear intersections before proceeding through intersections against a red traffic signal or stop sign
    - EMS vehicle drivers should primarily use a combination of wail and yelp when "requesting right-of-way" with a siren. High-low and air horns are less effective siren modes.
    - EMS agencies and EMS vehicle operators should avoid continuous use of siren during L&S response or transport and should limit the siren use when needed to "request right-of-way" or when exercising privileges only permitted by emergency vehicles with L&S. Using sirens when travelling at highway speeds with traffic or when traveling unimpeded without exercising emergency vehicle privileges may impede crucial communication related to the response or patient care.

- Avoid flashing white lights after dark, as these may blind oncoming drivers
- Do not exceed the posted speed limit in EMS vehicles (some experts suggest not exceeding the speed limit by more than 10 mph)
- Drivers should have the mindset that L&S use is only asking permission of other drivers – never assume that permission will be granted.
- Come to a "full stop" at red traffic signals or stop signs before proceeding, when using L&S
- Limit speed to less than 20 mph when traveling in a lane opposing the normal flow of traffic
- Downgrade L&S use if not indicated after more information becomes available during response or transport
- L&S are not indicated if ALS is not indicated
- L&S use is a medical treatment that should be used only when indicated
- Consider specific approach to crossing intersections during EMS vehicle L&S driving (From Ambulance Insurance Services, Inc. Sample Intersection Crossing Policy)
    - Crossing on Green – slow down, look all 3 directions, proceed with caution
    - Crossing on Red – come to complete stop, make eye contact with drivers of another vehicles, wait for partner to communicate all clear, wait 2 seconds, proceed with caution
    - Making right or left turns across stopped vehicle – come to complete stop next to vehicle, establish eye contact via partner or self, wait for partner to tell you all clear, be aware of vehicles from behind, proceed with caution
    - Other – use yelp siren mode, use headlights hi-lo beam, be patient
    - Other – avoid passing on the right unless it is the last resort
    - Other – avoid traveling in opposing traffic unless you are certain traffic is clear. If you must, use extreme caution and stay to your far right.
- When "blocking the right-of-way" at a scene, consider altering the lighting pattern of the vehicle with the goal of drawing attention without blinding or overwhelming other drivers.
    - Do not use headlights or flashing white lights
    - Consider decreasing the number and intensity of flashing lights overall
    - Consider using scene floodlights to illuminate the scene and areas around the vehicle
    - Consider turning off distracting flashing emergency lights if the EMS vehicle is not the primary vehicle "blocking the right-of-way" for traffic
    - Consider using amber warning lights to warn of hazards ahead or amber directional signals to direct traffic away from hazards

Annotated Bibliography

The purpose of this annotated bibliography is to provide the reader with a comprehensive list of references from both the historical and current literature, related to the use of L&S in EMS. To maintain a comprehensive bibliography that is also useful for reviewing information related to EMS vehicle crashes, some references were retained, even if the article did not specifically identify issues with L&S, but where L&S were specifically mentioned, the annotations included these comments. Annotations have been added to references where deemed appropriate, but not all references have been annotated.

Additionally, this bibliography includes information from both peer-reviewed and non-peer-reviewed (trade) journals. Although the information in trade journals is generally less scientific and could be biased by marketing influences of the publisher, on the topic of L&S, many industry and subject matter experts have provided thoughtful information on the topic in this format. To retain this valuable information and to ensure that the bibliography is comprehensive, many of these have been retained.

To assist readers with a specific interest, the references are listed alphabetically by first author within the following sections, and a few of the citations are repeated in multiple sections if they refer to several topics:

- EMS Vehicle Crash Statistics, Driving (including Driver Training), Liability and Ethics
- Effectiveness of Warning Lights and Sirens (and Vehicle Conspicuity)
- Time Saved with Lights and Siren Response and Transport
- Traffic Signal Preemption Systems
- Public Perception and Expectations Related to Lights and Siren Use
- Provider Safety Issues when Using Lights and Siren
- Emergency Medical Dispatch and Lights and Siren Response
- Clinical Outcomes with Lights and Siren (including Physiologic Effects)
- EMS Operations, Policies, and Guidelines Related to Lights and Siren Use

Literature Search Methodology

A search strategy was constructed using a combination of Medical Subject Headings (MeSH) and free-text terms. MeSH terms included emergency medical services, emergency medical service communication systems, ambulances, transportation of patients, lighting, noise, and sound. Keywords included sirens, “lights and sirens”, and acoustics. The electronic databases searched were MEDLINE and MEDLINE In-Process (via OVID platform, August 2, 2016), PubMed (August 3, 2016), and ProQuest Dialog Healthcare Databases (39 databases, August 30, 2016). To ensure the inclusion of all sources, the author examined bibliographies of searched studies and contacted other experts in the field for additional studies. A significant number of additional references were identified through this secondary process.

EMS Vehicle Crash Statistics, Driving (including Driver Training), Liability, and Ethics

Auerbach PS, Morris JA, Phillips JB, et al: An analysis of ambulance accidents in Tennessee. *JAMA* 1987; 258:1487-1490.
[Journal Article]
In one of the earliest descriptions of ambulance crashes, this group reviewed 102 consecutive ambulance crashes over 42 months beginning in January 1983. They included crashes in Tennessee that either had associated injury or over $200 damage. Twenty-nine of the crashes involved injury of 65 individuals, with one death. The authors recommended mandatory restraint use of both EMS providers and passengers. They also recommended that traffic signals be heeded at intersections and that urban speed limits be obeyed.

Ballam, E. Ambulance crash roundup: a review of emergency vehicle crashes during 2010. *EMS World*. March 2011; 40(3):74-75.
[Non peer-review. Descriptive]
News outlet sources were used to identify 264 news articles about ambulance crashes in the U.S. This method likely underreports the number of crashes. In the review, 43% of the crashes occurred at intersections where roads cross, with most of these involving ambulances that were struck as they proceeded through the intersection. At least 10% of the collisions involved a second ambulance, 16 were related to drug or alcohol abuse, and 21 involved rear-end collisions. News articles are not consistent in information that is reported, and no statement could be made related to L&S use.

Barishansky R. Next generation ambulance puts safety first. *EMS Magazine*. 2005; 30:34.
[Non peer-reviewed, Descriptive]
This descriptive article discusses safety features in ambulance design. Many of the described safety features – seat positions, restraints, and secure equipment storage – are interior and designed to reduce injuries in a crash. Other features are designed to prevent crashes, and these include “black box” monitoring systems that provide real-time driver feedback and lighting and paint designs to improve visibility.

Becker LR, Zaloshnja E, Levick N, Li G, Miller TR. Relative risk of injury and death in ambulances and other emergency vehicles. *Accid Anal Prev*. 2003 Nov; 35(6):941-8.
[Journal Article]
The NHTSA’s Fatality Analysis Reporting System (FARS) and the General Estimates System (GES) databases were reviewed for emergency vehicle (ambulances, police, and fire vehicles) crashes. Details like occupant seating position, restraint use, and vehicle response mode were evaluated for their association with injuries and fatalities. Unrestrained occupants, occupants riding in patient compartment, and especially unrestrained occupants of patient compartment were more likely to be seriously injured or killed. Occupants travelling non-emergency were more likely to be killed or severely injured than those traveling in emergency mode. Ambulances are associated with higher percentages of injuries or death due to crashes than fire or police vehicles.

The findings suggest that ambulance crewmembers riding in the back should be restrained whenever feasible. Family members accompanying ambulance patients should ride in the front-seat of the ambulance.

Becker TK, Gausche-Hill M, Aswegan AL, Baker EF, Bookman KJ, Bradley RN, De Lorenzo RA, Schoenwetter DJ. American College of Emergency Physicians EMS Committee. Ethical challenges in Emergency Medical Services: controversies and recommendations*. Prehosp Disaster Med*. 2013 Oct; 28(5):488-97.
[Journal Article]
This article describes several situations that have ethical considerations and are encountered by EMS providers. Seven of these situations are described in depth, and "Use of Lights and Sirens for Patient Transport" is one of the situations that the authors have included. This ethical review concluded "Emergency responders bear the burden of responsibility not only to provide optimal care to their patients, but also to ensure the safety of the public at large. This includes minimizing risk to pedestrians, drivers, patients and fellow rescuers during emergency vehicle operations. Studies overwhelmingly demonstrate that L&S operation places all parties at an increased risk, with little gained in terms of time savings (in response to the scene or in transportation to the hospital) or in time-critical interventions. It behooves EMS medical directors and EMS responders to develop policies limiting L&S operations as much as possible."

Biggers W A, Zachariah B S, Pepe P E. Emergency medical vehicle collisions in an urban system. *Prehosp Disaster Med*. July-Sept. 1996; 11(2):195-201.
[Journal Article]
This is a retrospective study of EMS vehicle collisions within the Houston Fire Department in 1993. During this year, Houston had 51 ambulances in service, responding with 180,000 vehicle responses to 150,000 requests for EMS. There were 86 EMVCs, or 3.2 EMVC/100,000 miles driven or 4.8 EMVCs/ 10,000 responses. Drivers with previous EMVC were involved in 33% of the crashes. Seventeen patients were transported from these accidents, and there were no fatalities. Five drivers with previous EMVCs were responsible for 15/17 (88.2%) of the injuries.

Bigham BL, Buick JE, Brooks SC, Morrison M, Shojanis KG, Morrison LJ. Patient safety in emergency medical services: a comprehensive literature review. Prehosp Emerg Care. 2012; 16:20-35.
[Journal Article, Literature Review]
These authors did a systematic review of the literature for evidence related to patient safety in EMS. They noted a paucity of peer-reviewed scientific published work in this area – of 5959 titles, only 88 met their criteria for inclusion. Of note, they found 9 articles that they classified as related to ground vehicle safety, and those related to crashes or L&S are included in this bibliography (Becker 2003, De Graeve 2003, Levick 2005, Ray 2007, Ray 2005).

Burke CS, Sales E, Kincaid JP. Emergency vehicles that become accident statistics: understanding and limiting accidents involving emergency vehicles.
Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting-2001; 45(4):508-512.

[Review Article]
The authors reviewed the literature related to emergency vehicle crashes and conducted interviews for the purpose of identifying human factors that may lead to the high rate of crashes. They suggest that lack mandated standardized training and evaluation, multiple stress factors in the operating environment, and little driving job driving experience are possibly associated with the rate of crashes.

Centers for Disease Control and Prevention. Ambulance crash-related injuries among emergency medical services workers - United States, 1991-2002. *MMWR* 2003; 52(8):154-156.
[Journal Article]
The authors describe the characteristics of 300 fatal crashes involving ambulances that were listed in the Fatality Analysis Reporting System (FARS) for an 11-year period. The 300 crashes resulted in 82 deaths among the 816 ambulance occupants (patients and emergency personnel). In addition, 275 occupants of other vehicles and/or pedestrians were killed in these accidents.
The authors estimate that 27 of the deaths were EMS providers. The authors also cite Maguire et al.'s estimated fatality rate of 12.7 per 100,000 EMS personnel; more than double the national average of on-the-job motor vehicle related mortality. One-third of fatalities occurred in unrestrained front seat occupants. 22% of the deaths occurred in unrestrained EMS providers in the patient compartment.

Clawson, JJ: Running "hot" and the case of Sharron Rose, *JEMS* 1991; 16:11-13.
[Non-peer reviewed Article]
[Follow-up: In 2017, the follow-up to the Sharron Rose story will be presented at the International Academy of Dispatch. Sharron was injured as a passenger in a vehicle struck by an ambulance on March 26, 1988 when she was 18. She is now 47 and lives with her mother – her father died in 2005. Sharon’s sister and her four nephews moved to be closer and better able to help with Sharron’s care. Sharron becomes agitated if her mother leaves the room. She can walk short distances with an unsteady gait. She has trouble speaking, and she is hemiparetic. Sharron remembers some of the past, but has no short-term memory. Her mother’s worry is about Sharron’s future after she is gone. A monetary settlement with the city of Bloomington, Ill funds Sharron’s medical care and the expenses for her 24-hour personal care.
This follow-up is a sad reminder of the effects of the EMS vehicle collision that have spanned over 29 years – impact on Sharron, but also her parents, sister, nephews, the city, and many others.]

Clawson JJ: The maximal response disease: Red lights and siren syndrome in priority dispatching. *JEMS* 1987; 12:28-31.
[Non-peer reviewed Article]

Clawson JJ, Martin RL, Cady GA, Maio RF. The wake effect: emergency vehicle-related collisions. *Prehosp Disaster Med.* 1997; 12(4)
In this study, 75 paramedics from the Salt Lake City, UT area were surveyed related to their experiences with emergency motor vehicle crashes. Seventy-eight percent of those responding reported being in an EMVC or witnessing a wake-effect crash, with

55% believing that wake-effect collisions occur more than crashes involving the emergency vehicle. The total number of recalled emergency vehicle involved collisions was 60, while the reported number of wake-effect collisions was 255. The mean number of EMVCs per paramedic was 0.82, but the mean value for reported wake-effect collisions was 3.49 reported to be witnessed by each paramedic. A weakness of this study is that it is a survey of paramedic recalled events. Among the limitations, paramedics are likely to recall emergency vehicle collisions in which they are involved, but they may not have been aware of some wake-effect collisions of civilian vehicles that occurred in relation to the operation of their vehicle. In this survey of recalled paramedic involved crashes, the ratio of EMVCs to wake-effect crashes was 1:4.25.

Clawson J. Unnecessary lights-and siren use: a public health hazard. Public Management. Oct 2002; 1-4.
[Article]
Dr. Clawson describes emergency vehicle crashes as a public epidemic.

Colwell CB, Pons P, Blanchet JH, Mangino C. Claims against a paramedic ambulance service: a ten-year experience. *J Emerg Med*. 1999 Nov-Dec; 17(6):999-1002.
[Journal Article]
Claims filed against the Denver Paramedic Division between 1984 and 1993 were reviewed, whether or not the claim was associated with a lawsuit. There were 82 claims, resulting in 11 lawsuits. The vast majority (72%) of claims and about half of the dollars paid. Of the 59 crash related claims, when known 59% involved L&S runs, 10% were during non-L&S runs, and 31% involved an ambulance that was not on a call or parked. The authors conclude that crashes with L&S carry higher risk than non-L&S runs. They suggest that protocols for L&S versus non-L&S runs need to ensure that the increased risk of MVC is outweighed by potential benefit to the patient.

Custalow CB; Gravitz CS. Emergency medical vehicle collisions and potential for preventive intervention. *Prehosp Emerg Care*. 2004 Apr-Jun; 8(2):175-84.
[Journal Article]
The authors reviewed all EMS vehicle crashes occurring from 1989 through 1997 in Denver. At the time, 75% of the responses were with L&S, but these accounted for 91% of the collisions during response. In 71% of the collisions, the driver had a history of previous emergency vehicle crashes. Recommendations included alerting other drivers at intersections with visual and auditory warnings and reserving L&S responses for “patients in whom the benefits of shorter response and return times outweigh the risk of collision.”

DeGraeve K, Deroo KF, Calle PA, Vanhaute OA, Buylaert WA. How to modify the risk taking behavior of emergency medical service drivers? *European J Emerg Med*. 2003; 10(2):111-116.
[Journal Article]
This article contains two analyses. The first is an analysis of the difference in response time interval between a fast, aggressive sport vehicle (Volvo 850) with a slower and less maneuverable ambulance (Peugeot ambulance) in Ghent, Belgium. The mean difference in response interval was 1.26 min (or 1 min, 15 sec) when comparing the

ambulance (9.6 minutes) to the Volvo response vehicle (8.34 min), p<0.0001. The second analysis is one of the first to report the impact of “black boxes” that provide feedback to EMS vehicle drivers related to aggressive driving behaviors, like braking and cornering. The authors were not able to identify significant changes in driving behavior with the black boxes alone. While EMS drivers were initially skeptical and sometimes “covertly hostile” about the black box driving feedback devices, The authors believe that the combination of the black boxes, well defined guidelines, and close monitoring are a good tool to change risky EMS driving behaviors.

Department of Homeland Security, First Responders Group. A research study of ambulance operations and best practice considerations for emergency medical services personnel. March 2015. Order No: HSHQDC-11-F-00054.
This comprehensive report regarding emergency vehicle driving suggests that initial information from dispatch or local protocols may direct that L&S are required during response to scene. After initial patient care, the senior EMS provider should determine the need for L&S during transport, and the use of L&S should be upgraded or downgraded as needed during transport. Clawson’s description of “wake-effect” accidents is described when cautioning drivers about lane changing with L&S use. This report suggests that a risk assessment should guide the use of L&S and that L&S should not be used in situations where dispatch determines that the incident has a low risk of frequency and severity. “L&S should only be used when the required patient care is greater than the ability of the ambulance to provide”. Lastly, the only other reference to siren use in the report suggests that the siren cadence should be changed when approaching an intersection when no less than 200 feet from the intersection.

Dick T. Rules of the road: some perspectives on emergency driving. JEMS. Nov 1980; 38-40.
[Non-peer reviewed, Article]
This well-known columnist states that EMS vehicle driving is dangerous and a stable environment is required to provide patient care during transport. He provides ten tips for safe driving, including: vehicle checks, driver training, paying attention to peripheral vision, assuming nothing from other drivers, know your territory, ride on the litter occasionally to obtain the patient’s perspective, use an individual outside of the vehicle to assist with backing, come to a complete stop at all intersections where you would not have the right-of-way without L&S, “base your interplay with other drivers upon eye contact, rather than upon what you think they will do”, and give other drivers plenty of room to respond.

Drucker C, Gerberich SG, Manser MP, Alexander BH, Church TR, Ryan AD, Becic E. Factors associated with civilian drivers involved in crashes with emergency vehicles. *Accident Analysis & Prevention*. 2013 Jun; 55:116-23.
[Journal Article]
In this study, the authors analyzed the National Highway Traffic Safety Administrations Fatality Analysis Reporting System and the National Automotive Sampling System General Estimates System for factors in civilian drivers involved in collisions with emergency vehicles. The drivers were more often distracted, had vision obstructed, were driving at night, and were at intersections with traffic signals. The authors suggest

that the findings may be related to civilian driver difficulty in visually detecting emergency vehicles in different environments. This study did not assess potential difficulty hearing approaching emergency vehicles.

Eckstein M. Primum non nocere – first do no harm: An imperative for emergency medical services. *Prehosp Emerg Care*. 2004; 8(4):444-446.
[Editorial]
The author describes the healthcare principle of “do no harm” and discussed how it applies to EMS vehicle driving. Literature is cited related to ambulances being 13 times more likely to be involved in a crash when compared with other vehicles, and the costs of these crashes exceeds $500 million annually. He recommends considering alternative deployment and response strategies as a way to decrease crashes and possibly improve patient outcomes.

Elling R: Dispelling myths on ambulance accidents. *JEMS.* 1989; 14:60-64.
[Non-peer review Article]
This article encourages the EMS industry to recognize that a problem of ambulance crashes exists and to distinguish facts from myths. New York State’s four-year experience with ambulance accidents is analyzed. There is a significant focus on EMS vehicle driver education. Specific driving recommendations include developing an agency standard that requires a complete stop at all red lights and stop signs. The curriculum and approach for ambulance driver education is described.

Erich J. Bells and whistles. When is lights-and-siren transport appropriate? *EMS magazine*. 2010 Mar; 39(3):55.
[Non-peer reviewed Report]
This article discusses Pennsylvania’s statewide EMS guideline for EMS vehicle operations that outlines medical conditions that are appropriate for L&S transport. It also discusses safety enhancements from the 2009 update of the state’s EMS Systems Act that recognizes EMS vehicle operators as a type of certification, and requires education and continuing education for this level of provider. It also describes the PA Bureau of EMS access to the Justice Network, or JNET, which provides regular reports to the Bureau of any EMS provider that has any malfeasances, including moving violations and driving under the influence.

Erich J. Wheels of fortune. Every time you hit the streets, you take your life in your hands-how can you improve your chances? *Emerg Med Serv*. 2000; 29(ll):43-46, 49-50, 52.
[Non-peer review Article]
This article provides several case reviews that describe factors related to emergency vehicle crashes. Human error is considered to be the most common factor in these crashes, and it is the most difficult factor to correct.

George JE, Quattrone MS. Above all – do no harm. *Emergency Medical Technician Legal Bulletin*, MedLaw Publishers. 1991; 15(4)
[Legal Review]
This legal review assesses the story of Sharron Rose Frieburg and discusses the

medical liability of L&S use, particularly with regard to the issues of the Frieburg case and “Good Samaritan” laws. This article also reviews the implementation of medical priority dispatch in Salt Lake City and Los Angeles. The authors report that Dr. Clawson initiated medical priority dispatch in Salt Lake City in 1983 and reported that the number of vehicles travelling with L&S response was decreased by 50% and the fleet’s emergency medical vehicle accident rate dropped by 78%.

Heim WM. EMS training: don’t leave the driver behind. *Emerg Med Services*. Jun 1988; 17(5):27
[Non-peer reviewed, Article]
The author of this article suggests that the one area of EMS training that has been left behind is driver training and certification. He suggests that excessive speed, believe of enhanced visibility, blind spots, tunnel vision and attitude weaknesses are the issues that lead to driver error and collisions.

Heick R, Young T, Peek-Asa C. Occupational injuries among emergency medical service providers in the United States. *J Occup Environ Med*. 2009; 51(8):963–968.
[Journal Article]
Surveys related to occupational injury were sent to 1200 nationally certified EMS providers through the National Registry of EMTs. 675 completed applications were returned. Of these, 29 % of EMS providers reported being injured on the job within the last 12 months. Paid providers were twice as likely as volunteer providers to be injured. 7.7% reported being involved in an EMS vehicle crash, with 100% of those occurring in clear weather and while using L&S. 80% reported driving at the time of the MVC and 80% reported a broadside strike as the type of MVC.

Hunjadi D. From provider to patient. *Emerg Med Serv*. 2005; 34(8):157-160.
[Non-peer review Article]
This article
This is a personal description of an EMT injured in a rural Wisconsin ambulance crash. The provider turned victim was an occupant in the back of an ambulance that rolled during the crash. His injuries left him paraplegic. The description of the physical injuries, ongoing healthcare requirements, and financial hardship of an EMS vehicle crash are described first hand.

Ismail AK, Mohd Salleh NI, Hamdan NA, Mohd Jawi MI, Abdul Razak SN, Jamal S, Shah SA. The use of warning lights and siren by the ambulance crew in the Universiti Kebangsaan Malaysia Medical Centre. *European J Emerg Med*. 2012 Dec; 19(6):408-9.
[Letter]

Jones WT. Apparatus accidents: focus on intersection safety. *Fire Engineering*. Dec 1986:10-11.
[Non-peer reviewed, Opinion]
This short article by the chief of safety for the New York City Fire Department discusses issues and solutions to intersection accidents. It is fire oriented, but he discusses intersection accidents with 2 emergency vehicles headed to the same scene and the

implications not only to the fire department, but also to the victim of the initial call. He makes an argument for a “full stop” at intersections before proceeding through a red traffic signal, and states that his department adopted that practice on December 12, 1968. Although with this change, intersection crashes remained at 37% of their crashes, the injury rate dropped from 19.5% to 7%.

Kahn CA, Pirallo RG, Kuhn EM. Characteristics of fatal ambulance crashes in the United States: An 11-year retrospective analysis. *Prehosp Emerg Care*. 2001; 5(3):261-269.
[Journal Article]
This retrospective study analyzes all fatal ambulance crashes in the U.S. reported to the Fatality Analysis Reporting System (FARS) database between 1987 and 1997. The 42 available variables were studied. There were 405 deaths in 339 ambulance crashes, with 838 associated injuries. Most of the crashes (202/339) and fatalities (233/405) occurred during emergency response or transport. In over two-thirds of the crashes the ambulance was on an improved road, on a dry road, operating in clear weather, and going straight. In 81% of the cases, the ambulance struck another vehicle. The crashes occurred more often at an intersection, at an angle, with another vehicle. Most fatalities were not in the ambulance, but when in the ambulance, fatalities occurred in the rear compartment 2.7 times more frequently than in the front. Deaths in the ambulance were 2.5 times more common in occupants that were not properly restrained. Involvement of pedestrians and bicyclists are also described. It is bothersome that 41% of the ambulance operators had poor driving records, and it is recommended that EMS agencies screen the driving record of EMS providers.

Leonard WH. What a waste when a system fails. *Ambulance Industry News* .1991; 1:6-7, 22, 44.
[Non-peer reviewed, Article]
This author describes the details of a fatal ambulance intersection collision involving Code 3 driving that killed a paramedic and seriously injured 3 other EMS providers. He discusses crew safety, liability, EMS dispatch and medical control. The author asks questions like, “what if the attending paramedic with the patient would have ordered the driver to stop running Code 3 because the patient was stable?” If the base station hospital was responsible for medical control, why did they permit the paramedic to transport a stable patient Code 3 to the hospital?” He makes a case that protocols must mandate that stable patients not be transported with L&S.

Levick NR, Swanson J. An optimal solution for enhancing ambulance safety: implementing a driver performance feedback and monitoring device in ground emergency medical service vehicles. *Annu Proc Accoc Adv Automot Med*. 2005; 49:35-50.
[Journal Article]

Lutman, D., M. Montgomery, P. Ramnarayan, and A. Petros. Ambulance and aeromedical accident rates during emergency retrieval in Great Britain. *Emergency Medicine Journal*. 2008; 25:301-302.

[Journal Article]
The authors suggest that most data on EMS vehicle accidents comes from North America. They provide the first published report of the characteristics of crashes involving ambulances and air ambulances in Great Britain from the years 1999-2004. The information for ground ambulance accidents is taken from a Department of Transport database. All incidents with ambulance listed as the vehicle body-type are included, but the authors recognize issues with underrepresentation using this method. From 1999 to 2004, there were 306-369 accidents involving ambulances each year studied, with 503-634 casualties, including 4-11 fatalities, per year from these accidents.

Maguire BJ, Hunting KL, Smith GS, Levick NR. Occupational fatalities in emergency medical services: a hidden crisis. *Ann Emerg Med* 2002; 40:625--32.
[Journal Article]
Data from 3 occupational fatality databases was used to estimate occupational fatality rate for EMS providers in the U.S. The National EMS Memorial Service database, Census of Fatal Occupational Injuries, and National Highway Traffic Safety Administration's Fatality Analysis Reporting System (FARS) databases were used in the analysis. The fatality rate for EMS providers is estimated to be 12.7/100,000 EMS workers, more than twice the average of 5.0/100,000 for general workers. When looking specifically at transportation injury fatalities, which would include EMS vehicle accidents, the fatality rate was 9.6/100,000 EMS providers, exceeding rates for law enforcement (6.1) and firefighters (5.7). The average transportation fatality rate for all U.S. workers is only 2.0/100,000.

Morse HN. Audible ambulance warnings. Emergency. Jul 1981:65.
[Non-peer review, Legal Case]
This case review discusses a New York case of an intersection crash. The ambulance was exercising a privilege of emergency vehicles (entering an intersection against a traffic signal) with warning lights, but no siren activated. The case was found in favor of the plaintiff and against the ambulance service for not using both audible and visual warning devices in this situation.

Page JO. For whom the siren oinks. JEMS. Nov 1990.
[Non-peer reviewed, Editorial]

Page JO. Waking primal instincts. JEMS. Jun 1993:7.
[Non-peer reviewed, Publisher's Editorial]
EMS lawyer and publisher of JEMS magazine discusses the "primal instinct" that is awakened by attempts to reduce L&S use. He provides some evidence for why L&S are often unnecessary and states that, ultimately, insurance companies will mandate changes due to the "epidemic of ambulance vehicle accidents" that may bankrupt these companies.

Pirrallo RG; Swor RA. Characteristics of fatal ambulance crashes during emergency and non-emergency operation. *Prehosp Disaster Med*. 1994 Apr-Jun; 9(2):125-32.
[Journal Article]
This study is a retrospective review of fatal ambulance crashes reported to the Fatal

Accident Reporting System (FARS) database from1987 to 1990. Twenty variables in the data were analyzed for 109 reported fatal crashes, and characteristics of crashes of vehicles operating in emergency mode with lights or siren were compared to those operating without L&S. 75/109 (69%) of the crashes occurred during emergency use with lights or sirens. Of the 20 variables reviewed, there were differences between emergency and non-emergency mode in only the year (fatal crashes during emergency mode trended downward each year, while fatal crashes in on-emergency mode trended upward), time of day (more emergency crashes between noon and 1800 hours), and light conditions (more non-emergency crashes when light conditions were poor). While this study looked specifically at differences in fatal EMS vehicle crashes in emergency mode, the information does not provide specific data of whether lights and/or siren were used at the time of the crash, and the results of the comparison do not provide information that can be used to make statements regarding L&S use.

Proudfoot SL, Romano NT, Bobick TG, Moore PH. Ambulance crash-related injuries among emergency medical services workers - United States, 1991-2002. *JAMA*. 2003 Apr; 289(13): 1628-1629.
[Journal Article]
This case series summarizes the reports of 3 ambulance crashes and discusses recommendations to prevent future occurrences. The crashes were investigated by the CDC's National Institute for Occupational Safety and Health (NIOSH) and the National Highway Traffic Safety Administration (NHTSA), and this article summarizes the crash investigation reports.

Proudfoot SL, Moore P, Levine R. Safety in numbers: a survey on ambulance patient compartment safety. *JEMS*. 2007 Mar; 32(3):86-90.
[Non-peer reviewed Article, Survey]
This paper discusses the findings of a survey conducted by the National Registry of EMTs. 1773 EMS providers responded to the questionnaire. The survey of attitudes toward safety devices revealed that many providers 23%) reported that they would rarely use restraints in the patient compartment of an ambulance, even if they provided mobility. 29% of respondents reported being willing to wear a helmet inside of the ambulance, while 44% reported that they would rarely wear a helmet if available. This study did not address any specific L&S issues.

Quinlavin J: Alive. *Emergency* 1993; 25:29-31, 46-48.
[Non-peer reviewed, Article]
This article provides a long list of short descriptions of fatal and serious injuries from emergency vehicle crashes. The article states that only five percent of emergency calls are life-threatening and justify an emergency response. The author states, “Justified is the key word. Just as the decision to transport a patient by scoop stretcher, spine board, cot, and so forth is based upon the patient’s medical needs, so should the decision to use lights and sirens en route to the hospital.”

Ray AM, Kupas DF. Comparison of crashes involving ambulances with those of similar-sized vehicles. *Prehosp Emerg Care*. 2005; 9(4):412-415.

[Journal Article]
This is a retrospective analysis of vehicle crash data from the Pennsylvania Department of Transportation between 1997 and 2001. Characteristics of ambulance crashes were compared with those of crashes involving similar truck-type configurations. Ambulances were more likely to be involved in crashes at intersections and traffic signals. Ambulance crashes involved more individuals, with three or more people involved in 84% of ambulance crashes. Recommendations included additional driver training and reinforcing a “complete stop” at stop signs and red lights to reduce intersection accidents.

Ray AM, Kupas DF. Comparison of rural and urban ambulance crashes in Pennsylvania. *Prehosp Emerg Care*. 2007; 11(4):416-420.
[Journal Article]
A retrospective analysis of crash data in the Pennsylvania Crash Outcome Data Evaluation System (CODES) database from 1997 to 2001 is used to describe and compare characteristics of ambulance crashes that occur in rural and urban areas. The CARES process does a probabilistic matching of law enforcement accident reports, PA EMS patient care reports, and information from hospital discharges. 1745 crashes were reviewed, including 311 from rural areas. Operator error was the primary cause of crashes in rural (75%) and urban (93%) incidents. Rural crashes were more common on snowy roadways (13% vs. 5%) and at nighttime without road lighting (25% vs. 4%). Rural crashes more often involved striking a fixed object (33% vs.7%). Urban crashes more likely involved intersections (67% vs. 26%). There were no specific comparisons related to L&S use.

Sanddal ND, Albert S, Hansen JD, Kupas DF. Contributing factures and issues associated with rural ambulance crashes: literature review and annotated bibliography. *Prehosp Emerg Care*. 2008; 12(2):257-267.
[Review Article]
This literature review focuses on factors associated with rural ambulance crashes. The annotated bibliography is global in nature and does not focus only on rural issues. The bibliography includes sections entitled: description of the problem, safety issues, and lights and sirens use. The article also includes an appendix with a model L&S response protocol.

Sanddal TL, Sanddal ND. Ward N, Stanley L. Ambulance Crash Characteristics in the US Defined by the Popular Press: A Retrospective Analysis. *Emerg Med International*. 2010:7.
[Online Journal Article]
This study used a website that captures stories in the popular media to find reports of ambulance crashes. News reports from May 1, 2007 through April 30, 2009, were reviewed. There were 466 ambulance crashes, with 358 causing injuries in 982 individuals. 79 of these crashes involved fatalities, with a total of 99 people killed. Several of the recommendations focus on interventions reducing L&S use as methods to decrease ambulance crashes.

Saunders SE and Heye C, Ambulance Collisions in the Urban Environment: *Prehosp*

Disaster Med. April-June 1994; 9(2)118-24.
[Journal Article]
In this study from San Francisco, L&S driving was associated with a higher risk of collision per L&S travels (45.9/100,000 vs. 27.0/100,000) and a statistically significant increase in injuries per L&S travels (22.2/100,000 vs 1.5/100,000).

Smith M. Surviving driving: tips for surviving the mean streets behind the wheel. *EMS*. 2009:16
[Non-peer reviewed, Editorial]
This regular trade journal contributor makes several points about EMS vehicle driving with L&S. He suggests that L&S mean little, if anything, in their impact – stating that drivers should think of L&S use as asking the public for permission, but should never assume that permission will be granted. Additionally, he makes the argument that high-speed driving means even less than L&S benefit, while increasing the risk of crash.

Solomon S, Hill P. Emergency vehicle accidents: prevention, reconstruction and a survey of state law. Lawyers and Judges Publishing Company, Inc. 2002
[Book]
This book is co-edited by an optometrist with four decades of firefighting experience and a special interest in emergency vehicle visibility and by a lawyer. The first section of the text covers human factors in emergency vehicle visibility and siren detection, emergency vehicle operations, and a discussion about medical conditions that may warrant L&S response or transport.
The second section describes emergency vehicle accident reconstruction, litigation, and case studies of emergency vehicle accidents.
The third section is a state-by-state summary of laws related to the use of L&S and also a summary of case law.

St. John DR, Shephard RD Jr: EMS dispatch and response. *Fire Chief* 1983; 26:142-144.
[Non-peer review article]
Ambulance involvement in fatal crashes by person type of fatalities and crash type.

Tennyson J; Maranda L; Darnobid A. Knowledge and beliefs of EMS providers toward lights and siren transportation. *The Western Journal of Emergency Medicine*. May 2015; 16(3):465-71.
[Journal Article]
This study used a survey to understand EMS provider beliefs related to L&S use. The authors were from Massachusetts, and the 108 surveys were distributed at staff and quality improvement meetings within the EMS agencies for which the authors provided medical direction. Providers tended to believe that transport with L&S use decreases transport time interval, does not change patient outcomes, and increases the risk of crashes. Despite this, the providers reported that L&S are used on 82% of their transports, and ALS providers estimated L&S use on a mean of 89%. The authors conclude, “The data demonstrate the surveyed providers are aware of the risk posed by warning lights and sirens to themselves, their patients, and the public. Nevertheless, their practice in the absence of rigid protocols suggests they disregard this knowledge.”

Many of the respondents (55%) have been in an EMS vehicle crash, and 32% reported in being in more than one EMS vehicle crash.

Vukmir RB. Medical malpractice: managing the risk. *Med Law* 2004; 23(3):495-513. [Review Article]
This article is a global review of medicolegal errors and risks, but specifically, it suggests that in EMS, the biggest risk is of EMS vehicle crashes rather than clinical care.

Wang HE, Fairbanks RJ, Shah MN, Abo BN, Yealy DM. Tort claims and adverse events in Emergency medical Services. Ann Emerg Med. 2008 Sep; 52(3):256-62. [Journal Article]
This study group retrospectively reviewed insurance liability claims from a two-year period (2003-2004) from a large EMS insurance company. Relatively minor incidents, including those with less than $10,000 damage, were excluded. 326 claims were analyzed, and those related to emergency vehicle crashes or movement were the largest group, 122 (37%). Other causes included patient handling (118, 36%), clinical management (40, 12%), response or transport events (25, 8%), and other events (33, 10%). The claims data was insufficient to analyze details of the events, and no statements were made related to how L&S use or non-use contributed to any of the claims.

Weiss SJ, Ellis R, Ernst AA, Land RF, Garza A. A comparison of rural and urban ambulance crashes. *Am J Emerg Med*. 2001; 19(1):52-56. [Journal Article]
This is a review of EMS crashes in Tennessee from 1993 to 1997 using a state database developed from mandatory reporting of ambulance crashes. When comparing rural and urban crashes, rural crashes were more likely to result in injuries, more likely to have severe injuries, and more likely to be a frontal impact. There was no report of L&S information related to these comparisons.

Whiting J, Dunn K, March J, Brown L. *EMT knowledge of ambulance traffic laws*. *Prehosp Emerg Care*. 1998; 2(2):136-140. [Journal Article]
295 EMS providers from North Carolina were surveyed at a statewide conference. The median correct response on the 5-question survey was 1 correct answer. EMS providers that had previously taken an emergency vehicle operators course (EVOC) were more likely to score above the median. The paper describes differences in volunteer providers and those who have taken an EVOC course. In general, this study shows that EVOC courses appear beneficial in affecting the knowledge of EMS vehicle state law, and the authors suggest that additional EVOC training is warranted. Interestingly, two of the commonly missed questions were related to speed and traffic signals when using L&S. The correct answer for these questions are arguably unsafe practices – at the time, NC law permitted ambulances with L&S to proceed through traffic lights without stopping and permitted exceeding the speed limit without any restriction on maximum speed.

Wolfberg D, Lights, Sirens and Liability. *JEMS*. 1996 Feb; 21(2):38-40.
[Non-peer review, Journal Article]
This established EMS lawyer begins this opinion paper by noting at the time of this article that he believes “that light-and-siren use probably causes more deaths and injuries than it prevents”. He describes his thoughts about L&S use after being involved in a crash while responding to a patient with a minor medical issue. He gives several recommendations, but more importantly, he describes how legislative solutions and other changes may be hampered by the emotion regarding L&S use.

Effectiveness of Warning Lights and Sirens (and Vehicle Conspicuity)

Balastegui A, Romeu J, Clot A, Martin SR. New siren tones optimized for increased detectability distances of emergency vehicles. *Applied Acoustics*. 2013; 74:803-811.
[Journal Article]
This Spanish article from an acoustic and mechanical engineering lab seeks to find a balance between the annoyance factor of sirens to the general public and the effectiveness of sirens while accounting for issues like noise reduction in modern vehicles. New tones are proposed and tested for annoyance factor and effectiveness.

Caelli T, Porter D. On difficulties in localizing ambulance sirens. *Human Factors*. 1980; 22,719-724.

Catchpole K, McKeown D. A framework for the design of ambulance sirens. *Ergonomics*. Jun 2007; 50(8):1287-1301.
[Journal Article]
A framework was developed for emergency vehicle siren design. This was tested using acoustic measurements and transit times in 240 vehicle responses using two different siren systems. The authors recommend mounting the siren behind the radiator grill to reduce noise and increase effective distance in front of vehicle. They also recommend modifying high frequency sirens to improve vehicle penetration.

Chapleau W. Lights & sirens. *Emergency Medical Services*. 2002 Jun; 31(6):59.
[Non-peer reviewed Journal Article]

Childs B. The siren. *JEMS.* Feb 1983:49, 51.
[Non-peer review, Editorial]
This editorial gives the authors tips related to siren use, reasons why the public may not hear the siren, and situations (like highway driving) in which the siren may be a hindrance.

Corlis EL, Jones FE. Method for estimating the audibility and effective loudness of sirens and speech in automobiles. *Journal of the Acoustical Society of America*, 1976; 60:1126-1131.

DeLorenzo RA. Bright lights, big noise: how effective are vehicle warning systems? *JEMS*. Jun 1992:57-62.

[Non-peer review, Journal Article]
From 1984 -1987, there were 1,412 ambulance crashes in New York State, with 1,894 injuries and 6 deaths. It is recommended that sirens be mounted on the front grille, rather than roof, to improve sound projection, and two speakers angled outward reportedly improves right-angle sound transmission – an issue at intersections. Due to the effective distances of sirens reported by Skeiber and calculated stopping distance, this author suggests that the maximal safe speed to enter an intersection with a red light is 10 mph – but several other sources in this bibliography argue for a full stop policy. The optimal color for flashing lights is controversial with no conclusive evidence. The concept that strobe lights may cause a seizure has never been proven. The Opticom system uses a vehicle strobe light to preempt traffic signals, but the expense limits implementation.

DeLorenzo RA, Eiler MA. Lights and siren: A review of emergency vehicle warning systems. *Ann Emerg Med* 1991; 20:1331-1334.

Ding H, Lu J, Qiu X, and Xu B. An adaptive speech enhancement method for siren noise cancellation. *Applied Acoustics*. Apr 2004; 65(4):385-399.
[Journal Article]
Siren noise in the driver compartment of emergency vehicles can diminish the effectiveness of voice communication. This study describes a filter that effectively blocks the siren noise from frequencies of voice communications, but there are some issues, including the need for a different filter for each siren mode.

Dunkel RE. Apparatus color saves tax dollars. Speaking of Fire. Oklahoma State University. Winger 1988.
[Editorial]
This department collected information from multiple sources related to the lime-yellow high visibility color for emergency vehicles. They collected information from to fire, driving, automobile and law journals, and they also contacted Dr. Solomon in Owego, NY who originated the lime-yellow color for emergency vehicles. They contacted the Department of Transportation, Federal Aviation Administration, Department of Defense, and Dean of College of Optometry at Ohio State University, and the Ryder truck rental company. The data collected was shared with the company that provides their fleet insurance, leading to the statement that the “articles and reports support the view of a causal relationship between vehicle color and accident rates”, and they received a 5% reduction in insurance rate for each vehicle painted lime-yellow.

Fidell S. Effectiveness of audible warning signals for emergency vehicles. *Human Factors*. 1978; 20:19-26.
[Journal Article]
In this study, the authors test the ability of 24 drivers in detecting siren noise. Various siren types were tested. It was noted that for the signal-noise ratio effective detectability required sounds about 10 dB louder than needed for perfect detection.

Keith-Lucas T. How sirens vary as attention getters. *Fire Engineering*. Feb 1978; pp 27-

28, 31.
[Non-peer reviewed, Review Article]
This article reviews various aspects of siren effectiveness. The differences between electronic and mechanical sirens are discussed. Our best hearing frequencies for speech overlap with the frequencies of sirens, which makes it difficult to understand verbal or radio spoken messages when they coincide with a siren. Various issues related to location of sirens mounted on emergency vehicles and types of speakers are discussed. The author prefers electronic sirens for their better clarity, detectability, versatility and lower current drain. Air horns may be useful for clearing traffic.

Lenne MG; Triggs TJ; Mulvihill CM; Regan MA; Corben BF. Detection of emergency vehicles: driver responses to advance warning in a driving simulator. Human Factors. 2008 Feb; 50(1):135-44.
[Journal Article]
These Australian researchers studied 22 drivers in a driving simulator to assess their response to an approaching emergency vehicle. They studied the use of an advance warning device that would provide the vehicle driver with an early warning when an emergency vehicle is within a 300-400 meter radius of the study vehicle. Drivers received a visual and auditory warning of an approaching vehicle, and this was associated with a slowing of speed and earlier lane change to avoid the vehicle. This is an early description of in-vehicle technology that may be able to improve detection of approaching emergency vehicles.

Maddern AJ, Privopoulos EP, Howard CQ. Emergency vehicle auditory warning signals: physical and psychoacoustic considerations. Proceedings of Acoustics 2011. 2011; paper number 3:1-5.
[Review, Presented at Acoustics 2011]
This review article from Australia nicely reviews issues that limit siren effectiveness, including standards that limit siren output and vehicle noise reduction efforts that diminish effectiveness inside modern vehicles.
Key issues are identified, and recommendations made to improve siren effectiveness related to these issues. These include 1) Install Federal Signal’s “Rumbler” siren to a) improve localization, b) avoid shadowing by vehicles, c) overcome vehicle noise reduction efforts, and d) overcome masking; 2) Install extra speakers directed towards sides of emergency vehicle, for activation at intersections, to improve siren speaker directivity; and 3) Use “MS 4000 Priority” at intersections to improve perceived urgency.

NRMA. (2006). Emergency vehicles-What to do. Open Road. Retrieved from http://www.mynrma.com.au/cps/rde/xchg/mynrma/hs.xsl/emergency.htm
NRMA. (2009). Sounding sirens causing collisions. NRMA Insurance Media Releases Retrieved March 19, 2010, fi·om http://www.nrma.com.au/about-us/mediare leases/2 009062 6.html

Potter RC, Pei H. How well can audible warning devices of emergency vehicles be localized by the driver of an automobile? (Abstract) *Journal of the Acoustical Society of America*. 1976; 59(S1):S16.

Privopoulos EP, Howard CQ, Maddern AJ. Acoustic characteristics for effective ambulance sirens. *Acoustics Australia.* Aug 2011; 39(2).
[Journal Article]
This Australian group studied several commercial-off-the-shelf sirens using acoustic measurements to assess detectability. They recommend that ambulance agencies "install sirens that broadcast sideways to the ambulance that broadcast low frequencies so the sound can penetrate into the vehicle cabins, and that have signals with short repetition periods to convey high perceived-urgency."

Romeu J, Clot A, Martin SR. New siren tones optimized for increased detectability distances of emergency vehicles. *Applied Acoustics*. Jun 2013; 74(6): 803-811.

Skeiber SC, Mason RL, Potter RC: Effectiveness of Audible Devices on Emergency Vehicles. Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration, Publication No. DOT-TSC-OST-77-38, 1977.

Skeiber SC, Mason RL, Potter RC. Effectiveness of audible warning devices on emergency vehicles. *Sound and Vibration*. 1978; 12: 14–22.
[Journal Article]
This is a summary of a Department of Transportation sponsored test program to examine emergency vehicle auditory warning devices.

Saly AJ. Lime yellow. *Firehous*e. Jan 1980; 34-38.

Solomon SS. Ambulance Accident Avoidance. *Emergency*. Jan 1985:34-35, 44.
[Non-peer review, Opinion]
This is a review of use of L&S and thoughts behind siren use, light patters, and vehicle color. The author cautions that once the brain has received the warning information from flashing lights, it is important that these do not "overwhelm or paralyze" other drivers. A case for corner lights on the back of vehicles that flash in synchrony rather than alternating. The author discusses vehicle color and that there was no research or references to support the 1972 specifications that ambulances should be primarily white with Omaha Orange trim. He also discusses the historical roots to using the color red for vehicles, and ultimately makes the case for lime-yellow.

Solomon SS. Lime yellow color as related to reduction of serious fire apparatus accidents – the case for visibility in emergency vehicle accident avoidance. *J Am Optom Assoc*. 1990; 61:827-831.
[Journal Article]
The case is made for lime-yellow as the most visible color for emergency vehicles, and Solomon makes the case for lime-yellow preventing more crashes than L&S.

Solomon SS. Strobes not safe. *JEMS* Feb 1983:4-5.
[Non-peer review, Review Article]
This article makes the argument that strobe lights are not safe and reviews several case reports of bystanders having seizures near emergency vehicles with strobe lights activated.

Solomon SS. The case for the lime yellow. *Firehouse*. May 1991:56-58, 65.

Solomon SS. The safety color. *Firehouse*. Jun 1984:106-108.

Solomon S, Hill P. Emergency vehicle accidents: prevention, reconstruction and a survey of state law. Lawyers and Judges Publishing Company, Inc. 2002
[Book]
This book is co-edited by an optometrist with four decades of firefighting experience and a special interest in emergency vehicle visibility and by a lawyer. The first section of the text covers human factors in emergency vehicle visibility and siren detection, emergency vehicle operations, and a discussion about medical conditions that may warrant L&S response or transport.
The second section describes emergency vehicle accident reconstruction, litigation, and case studies of emergency vehicle accidents.
The third section is a state-by-state summary of laws related to the use of L&S and also a summary of case law.

Solomon SS, King JG. Influence of color on fire vehicle accidents. *J Safety Research*. 1995; 26(1):47.
[Journal Article]
This study compared the crash numbers and estimated rates for fire department pumpers in Dallas, TX. The city had two color schemes, red/white or lime-yellow/white for fire pumpers over a period of time, and fire department records were used to study crash rates. Rates were lower for vehicles painted lime-yellow in the following situations: overall crashes, daylight crashes, L&S crashes, intersection crashes, tow-away crashes, and crashes with injuries. The overall rates estimated per million miles driven were 28.2 for lime-yellow and 62.1 for red color schemes.

Turner DJ. RETTmobil and the future of EMS safety. *EMS World*. Aug 2013:42(8):30-33.
[Non-peer review, Journal Article]
RETTmobil billed as the largest trade show for emergency vehicles in the world and is held annually in Germany. This article reviews some of the EMS vehicle and provider safety innovations at the 2013 event. The following statement is made about the conspicuity of European-style EMS vehicles, “The most obvious quality to be observed in European EMS is color. There is almost no red or blue to be found. Bold, fluorescent shades of yellow, orange and green color nearly every vehicle. Boarders, edges and even entire surfaces are highlighted in retroflective accenting colors, in striking patterns such as checkerboards and chevrons.” The common use of forward facing seats that are close to the stretcher permit active patient care by the EMS provider, while he or she is restrained during transport.

U.S. Fire Administration, IFSTA. Emergency Vehicle Visibility and Conspicuity Study. FEMA. FA-323, August 2009. Available at http://www.usfa.fema.gov/downloads/pdf/publications/fa_323.pdf
[Government Document]

This document analyzes the effectiveness of emergency lighting devices and retroflective markings on emergency vehicles in preventing injuries to responders.

Wang J. The effectiveness of daytime running lights for passenger vehicles. National Highway Traffic Safety Administration. 2008
[NHTSA Technical Report]
This is the third analysis of daytime running lights (DRLs) by the NHTSA. DRLs significantly reduced daytime two-vehicle crashes of light trucks and vans by 5.7%, but there was no similar statistical difference for other personal vehicles. Of note, this study used vehicle VIN numbers and installed DRLs to determine which vehicles had DRLs, and there was no accounting for cases where a driver without DRL turns on their headlights for the same effect. Also of note is that this reduction in crashes did not carry over to crashes with pedestrians or motorcycles, where DRL trended to increases in these crashes, and although neither of these is statistically significant, this author states that it can't be ignored. The literature review finds that most European studies of DRLs show reduction in crashes (reductions varied from 4-27% based upon type of crash), and many of these use a behavior method that requires drivers to turn on their headlights, rather than the technology method of automatic DRLs that was used in this study. This paper nicely reviews the European and Canadian studies related to DRL crash reduction.

Whitehead S. Trailblazing: the latest innovations in emergency vehicle lights & sirens. *JEMS*. 29(8):44-5, 2004 Aug.
[Product Listing]
This article lists several sirens and light bars that are described as being most innovative at the time of listing. It is an incomplete product list that does not describe evidence behind the new siren modalities. Light bar information focuses on halogen, LED, etc., but not evidence of effectiveness. There is no information about how these specific products were selected to be showcased.

Withington DJ, Paterson SE. Safer sirens. *Fire Engineers Journal*. 1998; 1-5.
[Article, unclear if peer-reviewed]
This article, from a journal in the United Kingdom, suggests that sirens are not particularly effective devices and that one issue is the ability to localize the direction of an approaching emergency vehicle by hearing the siren. The study provides data related to a new siren technology that is reported to be easier for drivers to localize.

Time Saved with Lights and Siren Response and Transport

Al-Shaqsi SZK. Response time as a sole performance indicator in EMS: Pitfalls and Solutions. *Open Access Emerg Med*. 2010; 2:1-6.
[Editorial, Opinion]
This is a review of the historical use of response time as a system indicator for EMS. Historically, the targets of basic life support within 4 minutes and advanced life support within 8 minutes started with a report of cardiac arrest survival in Seattle published in 1979. Planning an EMS system around short response times is financially costly and

has risks to patients, EMS providers, and the public. This editorial suggests that patient outcome is more important than response time and that quality of care should become the measure of an EMS system.

Bailey ED, Sweeney T. Considerations in establishing emergency medical services response time goals. Prehosp Emerg Care. Jul-Sep 2003; 7(3):397-99.
[Position Statement of NAEMSP]

Bigdeli M, Khorasani-Zavareh D, Mohammadi R. Prehospital care time intervals among victims of road traffic injuries in Iran. A cross-sectional study. BMC Public Health. 2010; 10:406-412.

Blackwell TH, Clawson JJ, Eckstein MK, Miramonti C, Wang HE (Editors Goodloe JM, Thomas SH). Emergency medical services evidence-based system design white paper for EMSA. University of Oklahoma. White Paper. July 2011; pp 18-28.
[White Paper, System Design]

Bledsoe, BE. EMS Myth #4: Lights and sirens save a significant amount of travel time and save lives. *Emergency Medical Services*. 2003 Jun; 32(6):72-3.
[Non-peer reviewed Journal Article]
This article reviews some of the references related to time saved with L&S and the risks of injury in EMS. The author considers the clinical benefits of L&S. The conclusions suggest that L&S driving are related to dangers to both EMS providers and the public. He suggests that in most cases time can be saved, but the time is only of benefit to a small number of patients. In summarizing, “a patient’s medical condition, and nothing else, should determine whether L&S should be used.”

Brown LH, Whitney CL, Hunt RC, Addario M, Hogue T. Do warning lights and sirens reduce ambulance response times? *Prehosp Emerg Care*. 2000 Jan-Mar; 4(1): 70-74.
[Journal Article]
This prospective study was done in the setting of urban Syracuse, NY. EMS response times with L&S were compared to times to drive same route without L&S at same time on same day of week. Thirty-two responses were measured. Mean L&S response was 1 minute, 46 seconds faster (p=0.0001), range with L&S from 3 minutes, 30 seconds slower to 7 minutes, 5 seconds faster. Authors believe time saved would be clinically significant in “only a very few cases”.

Dami F; Pasquier M; Carron PN. Use of lights and siren: is there room for improvement? European Journal of Emergency Medicine. 21(1):52-6, 2014 Feb.
[Journal Article]
This retrospective study in western Switzerland (State of Vaud) compared the mean patient transport times with and without L&S. They also collected data on patient demographics, type of call, and severity using a National Advisory Committee for Aeronautics score. Overall, transport times with L&S were 1 minute, 45 seconds faster (11.09 min vs. 12.84 min; p<0.001), but there was no difference in time with L&S for calls at night (10.2 second difference; P=0.27). Of note, L&S were only used on 16.6% of the 24,506 ambulance calls. Despite this relatively low rate of L&S transport the

authors believed there was still opportunity to further reduce L&S use at certain times of day.

Dhindsa HS, McIntyre A, Bass R, Howell J, Thornton E. Impact of red lights and siren on response and transport times in an urban EMS system. *Prehosp Disaster Med*. 1994; 9(3):S73.
[Abstract – poster presentation 1994 NAEMSP meeting, Portland, OR]
This prospective observational study measured travel times with L&S for 37 EMS responses and 27 transports in Washington, DC and compared these to a "chase ambulance" traveling without L&S. Responses with L&S were an average of 3.6 minutes faster (5.0 minutes vs. 8.6 minutes) ($p<0.01$), and the authors concluded this may be of clinical importance in patients requiring CPR or other ALS. During transport, L&S saved 3.0 minutes (6.4 minutes vs. 9.4 minutes) ($p=0.003$).

Fisher JD, Freeman K, Clarke A, Spurgeon P, Smyth M, Perkins GD, Sujan MA, Cooke MW. Patient safety in ambulance services: a scoping review. *Health Serv Deliv Res* 2015; 3 (21).
[Review]
This is a publication of the National Health Service in the United Kingdom through the National Institute for Health Research. This entire volume of the Health Services Delivery Research is dedicated to patient safety in ambulance services. Within the document, a table reviews several studies that compared response or transport time with and without lights and sirens. The only conclusion in the document regarding L&S operations is that the use of L&S "may save time". There is no discussion regarding risks or ground EMS vehicle crashes.

Fitch J. Response times: Myths, measurement & management. *JEMS*. 2005; 30(9):47–56.
[Non-peer review, Journal Article]
This EMS consultant discusses the NFPA 1710 standard and the concept of the 8 minute, 59 second 90% fractile response time standard. The distinct parts of the total interval from incident to EMS provider arrival are presented. The paper discusses why the one-size fits all approach is not ideal in optimizing patient outcome or ambulance utilization. A separate section of the article discusses the 2001 United Kingdom standard for 8 minute, 0 second response to 75% of the highest priority calls, but a tiered lower standard for the rest of the calls.

Fleischman RJ; Lundquist M; Jui J; Newgard CD; Warden C. Predicting ambulance time of arrival to the emergency department using global positioning system and Google maps. *Prehosp Emerg Care*. 2013 Oct-Dec; 17(4):458-65.
[Journal Article.]
This study used a Google Maps web application to retrospectively study a model to predict ambulance arrival time. The model studies EMS scene transports in Multnomah County, Oregon during 2008 and included a derivation and validation set. The accuracy was improved by adding factors for weather, patient characteristics, L&S use, daylight, and rush-hour. The model predicted arrival time with L&S within 5 minutes 77% of the time. Of note, L&S saved an average of 3.1 minutes for transports under 8.8 minutes,

and 5.3 minutes for longer transports.

Funk DL, Triner W, Green S. Out-of-hospital provider beliefs regarding use of red lights and sirens. (Abstract) *Ann Emerg Med*. 1999; 34(4) Part 2, S81.
[Abstract]
While only published as an abstract, this survey of 99 EMS vehicle drivers of various levels of training found that most drivers believed that L&S driving saved significant time and many of these did not believe that L&S operations are associated with an increased risk of vehicle crash.

Goodloe JM, Knoles CL, McAnallen D, Cox ML, Howerton DS. Oklahoma's data-driven approach to urban EMS response time reform. JEMS online. Feb 1, 2017. Accessed on 3/12/17 at http://www.jems.com/articles/print/volume-42/issue-2/features/oklahoma-s-data-driven-approach-to-urban-ems-response-time-reform.html
[Non-peer reviewed, Article, Case Study]
This article is a description of a structured approach by an EMS agency – EMSA, serving Oklahoma City and Tulsa, OK – to change their response time standards based upon evidence and data. A 2011 University of Oklahoma "white paper" study was used to alter response time parameters. In November 2013, EMSA changed response times for Priority 1 possibly life-threatening calls from 8:59 minutes to 10:59 minutes and for Priority 2 lower level calls from 12:59 to 24:59. They discontinued using L&S for the Priority 2 calls. The effect of these changes led to an increase in Priority 1 90% fractile response by 1:14 in Oklahoma City and by 1:20 minutes in Tulsa. The 90% fractile response times increased for the non L&S responses to Priority 2 calls by 6:06 and 5:59 minutes respectively. In two years of responses 229,667 L&S responses were eliminated.

Goodwin J. A need for speed? Why experts are divided on the new response time standards. *Best Practices in Emergency Services*. 2010; 13(1):7–9.
[Non-peer review, Article]
This is a discussion of the NFPA 1710 standards from 2001 regarding response time for EMS. It presents the clinical care of cardiac arrest and the need for rapid response, but also how these response times do not make sense for the rest of the medical calls. The public and media build their conceptions around the premise that definitive medical care begins at a hospital, and EMS is merely a transport mechanism, rather than recognizing that care starts when EMS arrives.

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. *Annals Emerg Med.* 1998 Nov;
32(5):585-8.
[Journal Article]
This prospective study compared the response times for 64 ambulance responses over 9 months in an urban Minneapolis, MN. The authors compared the response times of the ambulance using L&S and a companion "chase" vehicle travelling to the same scene over the same route without L&S. The average response time with L&S was 4.46 minutes and 7.48 minutes without L&S, saving a mean of 3.02 minutes or 38.5%

(P<0.01).

Ho J, Lindquist M, Time saved with the use of emergency warning lights while responding to requests for emergency medical aid in a rural environment. *Prehosp Emerg Care*. 2001 Aug-Jun; 5(2):159-162
[Journal Article]
This prospective study compared the response times for 67 ambulance responses over 21 months in the primarily rural setting of Becker County, MN. The authors compared the response times of the ambulance using L&S and a companion “chase” vehicle travelling to the same scene over the same route without L&S. The average response time with L&S was 8.51 minutes and 12.14 minutes without L&S, saving a mean of 3.63 minutes or 30.9% (P<0.01). Shorter response distances had higher time savings per mile.

Hunt RC; Brown LH; Cabinum ES; Whitley TW; Prasad NH; Owens CF Jr; Mayo CE Jr. Is ambulance transport time with lights and siren faster than that without? [Erratum appears in *Ann Emerg Med* 1995 Jun; 25(6):857] *Ann Emerg Med*. 1995 Apr; 25(4):507-11.
[Journal Article]
This prospective study compared ambulance transport time with L&S to time driving the same route at same time of day on same day of week. This was a convenience sample of fifty transports in Greenville, NC – population 46,000. The mean response with L&S was 43.5 seconds faster. In the authors’ opinion, the time difference did not justify L&S transport, except in rare clinical situations.

Hunt RC; Brown LH; Whitley TW; Prasad NH; Owens CF Jr. Emergency warning lights and sirens. *Ann Emerg Med*. 1999 Jul; 34(1):114-5.
[Comment. Letter]
Comment on: Ann Emerg Med. 1998 Nov; 32(5):585-8.
Comment in: *Ann Emerg Med*. 1999 Jul; 34(1):114-5.

Marques-Baptista A, Ohman-Strickland P, Baldino KT, Prasto M, Merlin MA. Utilization of warning lights and siren based on hospital time-critical interventions. *Prehosp Disaster Med*. 2010 Jul-Aug; 25(4):335-9.
[Journal Article]
This retrospective study explored the time saved using L&S during transport and potential hospital interventions done within the time saved. The study reviewed data from all 112 ALS ambulance transports to a single New Brunswick, New Jersey emergency department over a three-week period. Time differences were analyzed by comparing the actual L&S transports with times measured in another vehicle traveling the same route without L&S at the same time on the same day of the week. Time saved with the use of L&S was 2.62 minutes on average (14.5 minutes with L&S vs. 17.1 minutes without L&S). Of the 112 patients, five received a time-critical intervention at the hospital, but none of these occurred within the time saved by using L&S.

McCallion T. The great ambulance response time debate: Is speed the best measure of an EMS system? *EMS Insider*. 2012; 39(2):1, 8–9.

[Non-peer reviewed Editorial]
In this paper directed toward EMS managers, McCallion describes comments in a presentation by Matt Zavadsky at an American Ambulance Association conference. He debates the value of the 8-minute response rule that is the NFPA 1790 standard. Zavadsky reported that 74% of the ambulance crashes in his system (MedStar Mobile Healthcare, Fort Worth, TX) occur during L&S driving. A natural experiment occurred during an unusual snowstorm when the agency suspended L&S use. They found no difference in cardiac arrest outcomes at this time. The paper also discusses the changes in response time standards at EMSA in Oklahoma.

NFPA 1710: Standard for the organization and deployment of fire suppression operations, emergency medical operations, and special operations to the public by career fire departments. (2010.) National Fire Protection Association. From www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards?mode=code&code=1710.

O'Brien T, Prices M and Adams J. The effectiveness of lights and siren use during ambulance transport by paramedics. *Prehosp Emerg Care*. 1999; 3(2):127-130.
This study involves a convenience sample of 75 ambulance calls in suburban Jefferson County, KY. In cases where EMS providers believed L&S should be used, the transport time was measured for the transporting ambulance and a companion "chase' vehicle that followed the same route without L&S. Mean time saved with L&S was 3 minutes, 50 seconds (11 minute, s seconds versus 14 minutes, 56 seconds) ($p<0.0005$). The average distance travelled was 8.2 miles. Longer distance traveled and traffic intensity were associated with more time saved with L&S. The authors opined that L&S are warranted in some cases, and ALS providers can reduce that need. It should be noted that L&S were used during these transports based upon the judgment of EMS providers that they were warranted, but the receiving physicians only felt that 4 of the 75 cases may have clinically benefitted by the time saved.

Williams AS. Identifying issues when responding without lights and siren to selected call types for the Anne Arundel County Fire Department. December 2005
[Unpublished Report]
In response to a firefighter death, this study was conducted to analyze and consider situations in which the Anne Arundel County Fire Department could use non-L&S response for EMS and fire calls. The study used seven sequential steps to understand the issue, including: literature review, survey of agencies across U.S., identifying frequency and severity of crashes within the county, education about the Priority Dispatch System, survey of citizen attitudes related to non-L&S response and transport, analyze call types that may be candidates for non-L&S response, and analyzing L&S and non-L&S response times in the county.
Anne Arundel Co mean difference in travel time was 2 min 11 sec to scene and 2 min 21 sec to hospital, but rural unit difference to hospital was 10 min 11 sec
Citizen survey showed 85% of citizens were not opposed to dispatcher screening that reduced some responses to non-emergent to decrease collisions and provide safety to everyone on the highway and 85% were also not opposed to non-emergent transport to

the hospital after evaluation by medical personnel if felt to be in their best interest.

Yeh C, Bloom E, Ramanujam P. A comparison of time to scene response intervals for acute stroke: Is time saved by red lights and siren response? *Ann Emerg Med.* 2011; 1:S301.
[Abstract]
This abstract reported on the time saved in response to patients with dispatch symptoms related to possible stroke. The retrospective, observational study was done using the San Francisco 911 center data. Of 2800 patients with stroke presentation on dispatch, 2755 (98.3%) had L&S response with mean response interval of 3 minutes, 33 seconds compared with time interval of 5 minutes, 25 seconds for 45/2800 patients with non-L&S response. On average, L&S response was 1 minute, 52 seconds longer to patients with stroke symptoms on dispatch.

Zachariah BS, Pepe PE, Persse DE, Curka PA. The effect of warning lights and sirens on EMS response intervals. Abstract. *Ann Emerg Med*. Mar 1994; 23(3):637
[Abstract]
This study measured response intervals in a suburban EMS system with 7,000 annual incidents. An observer recorded parameters for EMS responses using L&S, including response time, route, day of week, time of day and weather conditions. Transit time without L&S was measured later while driving the same route with the same conditions. Data was measured for 63 EMS responses. Mean response time was 6 min, 13 seconds for L&S response (range 1 min, 1 sec to 15 min, 10 sec) and 7 minute, 54 seconds for non-L&S interval (range 1 min, 13 sec to 19 min, 40 sec). On average L&S response was 101 seconds faster than non-L&S response. Of note, in one-third of the cases, L&S interval was less than a minute shorter than control, and in 4 cases, the L&S interval was longer than the control. The time savings with L&S was statistically significant, but the authors suggest the value of the time savings is of unknown clinical significance for the majority of the cases.

Traffic Signal Preemption Systems

Hanbali RM, Fornal CJ. Emergency vehicle preemption signal timing constraints and solutions. Institute of Transportation Engineers, *ITE Journal*, 2004; 74(7):32.

Lamm WH. Vehicle warning systems. Emergency. Oct 1983:32-35.
[Non-peer review, Review Article]
This paper discusses sirens and warning lights. It recommends that sirens not be used when not effective, e.g. when travelling on 4 lane highways or stuck in traffic that cannot move. There is a significant discussion about signal control systems – types include programed route systems, optical systems, radio controlled systems, and siren controlled systems. The signal control systems that preempt traffic signals are not discussed in detail.

NHTSA. Traffic Signal Preemption for Emergency Vehicles: A Cross-Cutting Study. *NHTSA publication*. January 2006; US DOT: FHWA-JPO-05-010

PDF accessed on March 8, 2017 at:
https://ntl.bts.gov/lib/jpodocs/repts_te/14097_files/14097.pdf
This U.S. DOT study (Federal Highway Administration and National Highway Traffic Safety Administration) describes traffic signal preemption systems in Fairfax County, VA, Plano, TX, and St. Paul, MN. These jurisdictions report reduced response time, need for fewer fire stations to maintain response time standards, or decreased intersection crashes. The document provides advice for communities considering traffic preemption devices, and it cautions that when using these devices, a green light is not guaranteed.

Public Perception and Expectations Related to Lights and Siren Use

Colwell CB, Pons PT, Pi R. Complaints against an EMS system. *J Emerg Med*. 2003; 25(4):403-08.
[Journal Article]
The Denver Paramedic Division report on complaints received related to EMS service over a 6-year period from 1993-1998. 286 total complaints were reviewed, averaging 48 per year and 9.3 per 10,000 responses. Patients initiated 53% of the complaints, healthcare personnel 19%, and family members 12%. The report does not specifically state that any complaints are due to L&S use or non-use, but 5% were due to timeliness and 5% were due to driving skills.

Critz SH. The attitudes and experiences of families with death determination in the home. *Am J Hospice Care*. 1989 Sep-Oct; 6(5):38-43.
[Journal Article]
In this study, family members of 53 home care patients in Southeast Michigan were surveyed to identify their attitudes and experiences related to the deaths of their terminally ill family members. Eighteen percent of the respondents had feelings of anger related to the death experience, and one of the reasons for anger was arrival of emergency medical services personnel with L&S. Recommendations included educating emergency responders to improve their sensitivity.

Grant P. An exploratory study on the perspectives of Western Australian drivers towards responding emergency vehicles. (Thesis) Edith Cowan University. 2010. Retrieved from http://ro.ecu.edu.au/theses_hons/1027
This honors thesis explores the attitudes of drivers toward emergency vehicles, including police, fire, and ambulance vehicles.

Saunders G; Gough A. Emergency ambulances on the public highway linked with inconvenience and potential danger to road users. *Emergency Medicine Journal*. May 2003; 20(3):277-80.
[Journal Article]
A survey of members of the public in Staffordshire, United Kingdom was used to study interactions between ambulances using L&S and public users of highways. Surveys were randomly sent by mail to residences, and there was a 67% return rate. One third

of those surveyed found interactions with ambulances stressful, although 91% of respondents felt believed they acted in a controlled manner. L&S caused 61% to move from their chosen position on the road – one quarter of respondents found this to be a difficult maneuver. While avoiding ambulances, 23% reported having to negotiate an obstacle, 20% had to reverse vehicle or retract their course to avoid ambulance. Authors conclude that L&S interactions with ambulances create inconvenience and potentially dangerous situations.

Smackery B, Wilson EM. Emergency medical services and the public: a research report on consumer attitudes toward EMS in Connecticut. Office of EMS, Connecticut Department of Health Services and Barney School of Business and Public Administration, University of Hartford. Jan 1988.
[Report]
This study was a follow-up on a 1985 survey of the public regarding attitudes toward EMS in Connecticut. On this follow-up study, telephone interviews were conducted with 604 individuals across Connecticut. Interviewees listed 21 separate reasons for feeling most uncomfortable in calling EMS during a medical emergency, with the number of participants selecting each ranging from 3-67. The top 4 reasons given for being uncomfortable in calling EMS were: Sirens/Noise (67), Getting a lot of attention (49), Abilities of ambulance crew (40), and Dealing with strangers (37), while the bottom 4 reasons were: Reckless driving (3), Do not like medical service (3), Hospital makes me nervous/anxious (4), and Unfamiliar environment (4).

Williams AS. Identifying issues when responding without lights and siren to selected call types for the Anne Arundel County Fire Department. December 2005
[Unpublished Report]
In response to a firefighter death, this study was conducted to analyze and consider situations in which the Anne Arundel County Fire Department could use non-L&S response for EMS and fire calls. The study used seven sequential steps to understand the issue, including: literature review, survey of agencies across U.S., identifying frequency and severity of crashes within the county, education about the Priority Dispatch System, survey of citizen attitudes related to non-L&S response and transport, analyze call types that may be candidates for non-L&S response, and analyzing L&S and non-L&S response times in the county.
Anne Arundel Co mean difference in travel time was 2 min 11 sec to scene and 2 min 21 sec to hospital, but rural unit difference to hospital was 10 min 11 sec
Citizen survey showed 85% of citizens were not opposed to dispatcher screening that reduced some responses to non-emergent to decrease collisions and provide safety to everyone on the highway and 85% were also not opposed to non-emergent transport to the hospital after evaluation by medical personnel if felt to be in their best interest.

Wilson EM, Sackmary B. Survey of emergency medical technicians in Connecticut: a research report on EMT attitudes toward EMS. Office of EMS, Connecticut Department of Health Services. August 1989.
[Report]
To better understand issues of recruiting and retaining EMS providers, Connecticut performed a mail survey of 2700 EMS providers within the state in 1987. EMS providers

generally felt comfortable in calling EMS if they had an emergency, but only about half felt that the public had the same level of comfort. Altruism was determined to be the primary reason that individuals sought opportunities in EMS, and the report does not list excitement or L&S as a reason that participants gave for joining EMS. In addition to helping people, interest in health career and interest in advancing first aid training were listed before “excitement” as reasons for becoming an EMT.

Wilson EM. Quality: It’s in the eye of the patient. Rescue-EMS Magazine. May-Jun 1992; 32-35
[Non peer-reviewed Article]
In this 1992 article, quality is described as being the core of the public judgment of EMS. Members of the public who rated the quality of their local EMS as excellent were more likely to state that they would call EMS in an emergency, and those who did not know about the quality of their local EMS were even less likely to call EMS than those who thought the quality was poor. In categories of crew training, ambulance equipment, response time, concern for victims, treatment of victims and overall quality, the percent of EMS providers rating these as excellent significantly exceeded the scores given by consumers of EMS.

Provider Safety Issues when Using Lights and Sirens

Hong O, Sarno DG. Hazardous decibels: Hearing health of firefighters. *AAOHN Journal*. 2007; 55(8):313-319.
[Review Article]
This review article describes the noise levels to which firefighters are subjected and the evidence of irreversible noise-related hearing loss in firefighters. The authors suggest noise reduction strategies to decrease siren noise – mounting siren on bumper rather than roof, closed cabs, and air-conditioned cabs – but they do not suggest reducing L&S responses. The authors also suggest hearing protective devices for some noisy roles, but it is unclear what effect those may have on critical activities that require hearing for safety.

Johnson DW, Hammond RJ, Sherman RE. Hearing in an ambulance paramedic population.
Annals Emerg Med. 1980; 9:557-561.
[Journal Article]
This article examined ambulance noise levels, hearing in 56 paramedics, and hearing loss in 4 paramedics over 14 years. The setting was the Ambulance Service of Hennepin County Medical Center, Minneapolis, MN. Mean siren noise in ambulances conditions was 102.5 dBA (above OSHA guidelines of 90 dBA). Hearing acuity in tested paramedics was lower than expected, and hearing was lost at a faster rate over 14 years than that for normal peers.

Pepe PE, Jerger J, Miller RH, Jerger S. Accelerated hearing loss in urban emergency medical services firefighters. *Annals Emerg Med*. 1985; 14:438-442.
[Journal Article]

The authors tested 192 randomly selected EMS providers from Houston, TX. The hours of siren noise exposure correlated with decreased ability to sense mid-frequency and high-frequency sound. The rate of hearing loss was 150% of that expected for age-matched individuals who are not exposed to siren noise.

Price TG, Goldsmith LJ. Changes in hearing acuity in ambulance personnel. Prehospital Emergency Care. 1998; 2:308-311.
[Journal Article]
In this retrospective study with Louisville, KY EMS providers, audiograms of EMTs and paramedics were reviewed in an attempt to identify hearing loss in EMS providers. The authors were not able to identify hearing loss that could be associated with sirens. In the test vehicle, siren noise was measured during a shift and ranged from 58 dBA in the patient compartment when stationary to 84 dBA in cab with windows down. Noise levels did not exceed OSHA guideline limits.

Slattery DE, Silver A. The Hazards of Providing Care in Emergency Vehicles: An Opportunity for Reform. *Prehosp Emerg Care*. 2009; 13(3):388-397.
[Review Article]
The high incidence of transportation related fatalities are a substantial factor in the disproportionally high rate of occupational death in EMS providers. This narrative review of the literature seeks to describe factors that lead to vehicular injuries to EMS providers and to suggest strategies to reduce the risk. Some factors related to injuries during L&S transport include distractions in the driver compartment, unsafe ambulance design and loose equipment, lack of seatbelt use (particularly in the patient compartment), and off-balance providers during patient care. Providing cardiac arrest resuscitation is examined as an illustrative case for provider risks in a moving ambulance. To mitigate these risks, the authors suggest the strategies of improved ambulance design for safety, improve driver behavior (sterile cockpit concept, devices that monitor g-forces and give driver feedback), decrease the use of L&S driving (by reducing L&S use and also by using field termination of cardiac arrests to reduce transports), use aviation safety strategies like “sterile cockpit” operations during L&S operations, and increase safety belt use during transport.

Tetreault MW. Evaluating injuries to firefighters while performing patient care in a moving ambulance. An applied research project submitted to the National Fire Academy as part of the executive Officer Program. Londonberry NH. May 2009.
[Project not reviewed, but abstract provided here]
ABSTRACT: The Londonderry firefighters and their equipment are not properly restrained while performing patient care in the back of a moving ambulance. In the event of a crash the firefighter or the patient could be injured or killed due to this uncontrolled movement of personnel and equipment. This research is to evaluate the types and mechanisms of injuries to passengers in the back of a moving ambulance and to determine which methods are most effective in preventing such injuries. The purpose of this research is to prevent injury and death to firefighters and patients be transported in an ambulance. The descriptive research method was used to answer the following relevant questions: (1) What are the current mechanisms for preventing uncontrolled movement of firefighters while caring for patients in a moving ambulance?

(2) What are the types and mechanisms of injury that occur to firefighters while riding in the patient compartment of a moving ambulance? (3) What strategies would have been successful in preventing uncontrolled movement during patient care, and how have these affected patient care? (4) What modifications can be made from technological and/or procedural perspective to decrease the effects of uncontrolled movement of firefighters riding in the patient compartment of a moving ambulance? The results focused upon necessary policy modifications, and the technological modifications needed for current in-service ambulances, current ambulance purchases and what to expect in the future. Finally advocating for comprehensive crash worthiness standards for ambulances including, federal oversight and crash testing to determine what changes need to be made in ambulance design.

Van Buren M, Caple G. Ambulance sirens and in-vehicle noise exposure – an investigation into alternative siren speaker placement. *Journal of the Acoustical Society of America*. 1987; 81.S48.
[Abstract]
This research abstract studied the acoustic effectiveness of sirens mounted to the front grill of an ambulance when compared with mounting on the roof of the cab. Noise measurements were taken 1.2 meters off of the ground over a 180 degree radius up to 30.5 meters from the vehicle. Measurements were also recorded at various locations inside the vehicle. The grill-mounted siren was 14 dB more intense directly in front of the ambulance, and it was also 11-16 dB quieter inside the ambulance.

Emergency Medical Dispatch and Lights and Sirens Response

Blackwell TH, Kaufman, JS. Comparison of response time and survival in an urban emergency medical services system. *Acad Emerg Med*. 2002; 9(4):288–295.
[Journal Article]
This observational study compared response times to patients treated by EMS who either survived or did not survive. The authors found a significant survival benefit for response times of less than 5 minutes when compared to those of more than 5 minutes, but the mortality curve was flat for response times that exceeded 5 minutes.

Blackwell TH, Kline JA, Willis J, et al. Lack of association between prehospital response times and patient outcomes. *Prehosp Emerg Care*. 2009; 13(4):444–450.
[Journal Article]
These authors compared 373 EMS patients with response times exceeding 10 minutes, 59 seconds with 373 matched controls with response times less than 10 minutes, 59 seconds. They found no difference in mortality or ALS interventions between the groups.

Boland LL; Hagstrom SG. No need for speed. *JEMS*. 2012 Jul; 37(7):52, 54-6, 58.
[Non-peer reviewed Journal Article]
An EMS response program to skilled nursing facilities in a community in Minnesota is described. The logistical steps required to prepare a nursing home patient for transfer to an emergency department often eliminate any time benefit of an L&S response to the nursing facility. In addition, L&S response to these facilities may be associated with disruption and anxiety among other residents. In this community, law enforcement and the fire department is also sent to L&S medical dispatches. For these reasons, the authors suggest that a program that classifies appropriate patients to a non-L&S response improves safety, use of community emergency resources, and benefits nursing home residents. L&S responses are still used when warranted.

Clawson J, Olola C, Heard A, Patterson B, Scott G. Ability of the medical priority dispatch system protocol to predict the acuity of “unknown problem” dispatch response levels. *Prehosp Emerg Care*. 2008; 12:290-296.
[Journal Article]
When using the proprietary Medical Priority Dispatch System, 5-8% of calls have little medical information available, and are placed into the “Unknown Problem” category. This study of calls to London Ambulance reviews the results of the prioritized dispatch of calls for these incidents. In a single year from 2005-06, 3,947 calls coded as unknown were reviewed for cardiac arrest or use of L&S in transport due to patient’s condition as determined by the paramedic. When some amount of information is available (for example patient standing, sitting, or talking) the Unknown category predicts a low chance of cardiac arrest or need for L&S transport, but when no information is available, the Unknown category is not predictive that the patient will not have a serious medical condition.

Clawson JJ. Emergency medical dispatching. In: Rousch WR, Aranosian RD, Blair TMH, Handal KA, Kellow RC, Stewart RD, eds. Principles of EMS Systems.

Dallas: American College of Emergency Physicians; 1989:119-133.

Clawson JJ. EMS response dispatch priority training…strengthening the weak link. APCO Bulletin. Feb 1983, pp. 18, 40-41.
[Editorial article]
A 25-hour course for emergency medical dispatchers is described, with examples of call taker interrogation with structured questions and a priority card system. The concept of non-L&S responses is included in the training. The article describes the first 250 public safety and private dispatchers trained through the program and certified as EMDs by Utah Bureau of EMS. The article includes a table with questions to help EMD decide if L&S necessary and lists 5 clinical situations that are described as “true time-priority items” where one to five minute response is required.

Clawson JJ: Medical priority dispatch. It works! JEMS 1983; 8:29-33.

Clawson J, Dernocoeur K. Principles of Emergency Medical Dispatch, Second Edition. Priority Press, 1998

Cone DC, Galante N, MacMillan DS. Can emergency medical dispatch systems safely reduce first-responder call volume? *Prehosp Emerg Care*. 2008 Oct-Dec; 12(4):479-85.
[Journal Article]
This prospective before-after study compared a system that dispatched fire engine BLS first responder to all EMS calls compared with using an emergency medical dispatch system to screen calls appropriate for first responder dispatch. In the before phase, first responders were sent L&S to 8278/9820 (84.3%) of EMS calls, and in the after phase, they were sent to 3804/9943 (39.1%) of calls. In reviewing the patient care reports of the EMS calls that did not receive a BLS first responder, reviewers identified 10/1816 (0.55%) of cases where there may have been a benefit to a first responder. The dispatch screening reduced BLS engine response with L&S in about half of the cases and authors felt that the low under triage rate was safe for patients.

Cone DC, Galante N, MacMillan DS, Perez MM, Parwani V. Is there a role for first responders in EMS responses to medical facilities? *Prehosp Emerg Care*. 2007 Jan-Mar; 11(1):14-18.
[Journal Article]
This prospective before-after study reviewed care by BLS first responders at physician-staffed medical facilities. When using emergency medical dispatch protocols to reduce first response to calls at outpatient medical facilities, BLS first response was reduced from 64% of calls to 4%, and ALS first response was reduced from 48% to 4%, many of the after phase first response dispatches were errors in protocol use. On review of the “after” cases, none were found where first responder treatment would have been beneficial.

Craig AM; Verbeek PR; Schwartz B. Evidence-based optimization of urban firefighter first response to emergency medical services 9-1-1 incidents. *Prehosp Emerg Care*. 2010 Jan-Mar; 14(1):109-17.
[Journal Article]

These authors constructed a model for EMS dispatch that identified 27 of 509 Medical Priority Dispatch System categories that were associated with the need for first responder procedures (e.g. CPR, bag-mask ventilation, and defibrillation). Reducing the dispatch of firefighter first responders to these calls retrospectively would have decreased L&S responses by 83%. Every emergency vehicle responding with 'lights and sirens' is at risk for a collision, as are other drivers as they try to get out of the way of the emergency vehicle, a phenomenon referred to as 'wake effect'. The model was not validated during this study.

Curkas PA, Pepe PE, Ginger VF, Sherrard RC, Ivy MV, Zachariah BS. Emergency medical services priority dispatch. *Ann Emerg Med.* 1993; 22(11):1688-95.
[Journal Article]
In this system with tiered BLS/ALS ambulance response, this retrospective review of EMS records determined that emergency medical dispatch computerized questions can decrease the need for dispatching ALS ambulances by 14100 (40.2%) responses. Only 41/14100 (0.3%) of these cases later received medications and only 27(0.2%) received an ALS resuscitation intervention. This reduction was felt to be safe and significantly increased availability of ALS to the community.

DeMaio VJ, Stiell IG, Wells GA, Spaite DW. Optimal defibrillation response intervals for maximum out-of-hospital cardiac arrest survival rates. *Ann Emerg Med*. 2003 Aug; 42(2).
[Journal Article]
These authors question the traditional 8-minute response time for EMS. They found that there is a survival benefit if a BLS responder with defibrillator arrives in <5 minutes of dispatch to cardiac arrests, but the survival curve levels off for response times >5 minutes.

Eisenberg MS, Bergner L, Hallstrom A. Cardiac resuscitation in the community. Importance of rapid provision and implications for program planning. *JAMA*. 1979; 241(18):1905-1907.
[Journal Article]
This landmark study set the standard that optimal cardiac arrest survival is dependent upon BLS arrival within 4 minutes and ALS arrival within 8 minutes.

George JE, Quattrone MS. Above all – do no harm. *Emergency Medical Technician Legal Bulletin*, MedLaw Publishers. 1991; 15(4)
[Legal Review]
This legal review assesses the story of Sharron Rose Frieburg and discusses the medical liability of L&S use, particularly with regard to the issues of the Frieburg case and "Good Samaritan" laws. This article also reviews the implementation of medical priority dispatch in Salt Lake City and Los Angeles. The authors report that Dr. Clawson initiated medical priority dispatch in Salt Lake City in 1983 and reported that the number of vehicles travelling with L&S response was decreased by 50% and the fleet's emergency medical vehicle accident rate dropped by 78%.

Hinchey P, Myers B, Zalkin J, Lewis R, Garner D Jr. Low acuity EMS dispatch criteria can reliably identify patients without high-acuity illness or injury. *Prehosp Emerg Care*. 2007; 11(1):42-48.
[Journal Article]
These authors used the Medical Priority Dispatch System to identify 2703 alpha dispatches for low priority calls. Of these, 21 were inappropriately dispatched as low-priority due to protocol errors and 14 (<1%) were transported L&S to the hospital. This emergency medical dispatch system was 99% accurate in identifying patients who do not have a high-priority illness.

Isenberg D; Cone DC; Stiell IG. A simple three-step dispatch rule may reduce lights and sirens responses to motor vehicle crashes. *Emergency Medicine Journal*. 2012 Jul; 29(7):592-5.
[Journal Article]
In many locations, an ambulance responds with L&S to motor vehicle crashes, despite low rates of serious injuries in victims of the crash. When prehospital providers are involved in a crash with L&S, the rate of their injury on average is 15 times higher than in crashes without L&S use. This study used the CDC Field Triage Guidelines, which predict patients who require care at a trauma center, to determine whether L&S was warranted during the EMS response. EMS patient care reports from July 2007 through June 2008 were retrospectively reviewed and analyzed. The data was used to develop a simple three-step dispatch rule to determine which motor vehicle crashes warrant L&S response. The rule was not prospectively validated.

Kallsen G, Nabors MD: The use of priority medical dispatch to distinguish between high- and low-risk patients. *Ann Emerg Med* 1990; 19:458-459.
[Journal Article]

Key CB, Pepe PE, Persse DE, Claderon D. Can first responders be sent to selected 9-1-1 emergency medical services calls without an ambulance? Acad Emerg Med. 2003 Apr; 10(4):339-46.
[Journal Article]
In this before-after study, a traditional BLS ambulance response was replaced by fire department first responder providers with an AED for selected 911 calls that were felt to be low risk. The first responder only response was used for automated medical alert monitoring systems, motor vehicle crashes where caller could not answer dispatcher questions, and calls to 911 that were disconnected. In the group with automated medical alert systems, the before and after rates for transport (7% vs. 10%) and ALS (1% vs. 4%) were very low. One patient of 330 in the after group required endotracheal intubation. The motor vehicle crash group had a higher rate of transport (39% vs. 33%) but only 2% ALS care in both. This study showed first responder alone to be a safe response configuration to selected incidents.

Kuisma M, Holmstrom P, Repo J, Maatta T, Nousila-Wiik M, Boyd J. Prehospital mortality
In an EMS system using medical priority dispatching: a community based cohort study. *Resuscitation*. 2004; 61:297-302. [Journal Article]

Marques-Baptista A, Ohman-Strickland P, Baldino KT, Prasto M, Merlin MA. Utilization of warning lights and siren based on hospital time-critical interventions. *Prehosp Disaster Med*. 2010 Jul-Aug; 25(4):335-9.
[Journal Article]
This retrospective study explored the time saved using L&S during transport and potential hospital interventions done within the time saved. The study reviewed data from all 112 ALS ambulance transports to a single New Jersey emergency department over a three-week period. Time differences were analyzed by comparing the actual L&S transports with times measured in another vehicle traveling the same route without L&S at the same time on the same day of the week. Time saved with the use of L&S was 2.62 minutes on average (14.5 minutes with L&S vs. 17.1 minutes without L&S). Of the 112 patients, five received a time-critical intervention at the hospital, but none of these occurred within the time saved by using L&S.

National Association of EMS Physicians position paper: Emergency medical dispatching. *Prehosp Disaster Med*. Oct-Dec 1989; 4(2):163-66.
[Position Statement]
This position statement describes medical dispatching as the last major area in prehospital EMS chain of care to be identified and developed. Emergency medical dispatch (EMD) is considered to be an essential part of the EMS system, and medical direction of the EMD and the dispatch center is also essential. The statement describes EMD training, pre-arrival instructions, dispatch prioritization to establish the urgency and type of response, and quality assurance for EMD programs.

National Association of EMS Physicians position paper revision: Emergency medical dispatching *Prehosp Emerg Care* 2008; 12:217.

Neukamm J, Grasner JT, Schewe JC, Breil M, Bahr J, Heister U, Wnent J, Bohn A, Heller G, Strickman B, Fischer H, Kill C, Messelken M, Bein B, Lukas R, Meybohm P, Scholz J, Fischer M. The impact of response time reliability on CPR incidence and resuscitation success: a benchmark study from the German Resuscitation Registry. Crit Care. 2011; 15(6):R282.

Pons PT, Haukoos JS, Bludworth W, Cribley T, Pons KA, Markovchick VJ. Paramedic response time: does it affect patient survival? *Acad Emerg Med*. 2005; 12(7):594-600.

Price L. Treating the clock and not the patient: ambulance response times and risk. *Quality and Safety in Health Care*, 2006; 15:127-130.

Shah MN, Bishop P, Lerner EB, Fairbanks RJ, Davis EA. Validation of using EMS dispatch codes to identify low-acuity patients. *Prehosp Emerg Care*. Jan-Mar 2005; 9(1):24-31.
[Comparative Study. Journal Article. Validation Studies]
This study took place in Rochester, NY and sought to validate the ability of 21 low-priority EMS dispatch codes. Codes were considered validated if 90% of patients treated with the code were not transported using L&S and did not have ALS procedures. In 2002-2003, only 7540/43602 (17.3%) calls were dispatched as low-priority.

7197/7540 (95%) of the low-acuity dispatches did not require ALS and were not transported with L&S, and 11 of the codes were validated, with low acuity care provided at least 90% of the time. Of the low-acuity dispatch cases that required ALS or L&S transport only 62/343 (18%) were deemed by an expert panel to have received interventions that had a clinical impact.

Clinical Outcomes with Lights and Siren (including Physiologic Effects)

Andersen MS; Johnsen SP; Hansen AE; Skjaerseth E; Hansen CM; Sorensen JN; Jepsen SB; Hansen JB; Christensen EF. Preventable deaths following emergency medical dispatch – an audit study. *Scandinavian Journal of Trauma, Resuscitation & Emergency Medicine*. 2014; 22:74.
[Journal Article. Multicenter Study. Denmark]
In this study, a panel of prehospital anesthesiologists reviewed non-L&S responses to 152 patients who died on the same day as their EMS call. These patients represented 0.16% of the 94,488 non-high-acuity calls to the Emergency Medical Communication Center in three of the five regions in Denmark. The panel found no definitively preventable deaths, but they determined that 18 (0.02% of all non-high-acuity calls) were potentially preventable. In 13 of the 18 cases of potentially preventable death, the dispatch protocol was either not used or incorrectly used.

Barrett TW; Brywczynski JJ; Schriger DL. Annals of Emergency Medicine Journal Club. Is the golden hour tarnished? Registries and multivariable regression. *Ann Emeg Med*. 2010 Mar; 55(3):247-8.
[Comment. Journal Article]
This comment/opinion article reviewed the concept of a “golden hour” in trauma and found no association between the time interval of EMS care and the clinical outcome of 3,656 injured patients with abnormal vital signs or mental status that were transported by 146 EMS agencies from across North America. The authors suggest that “routine lights-and-sirens transport for trauma patients, with its inherent risks, may not be warranted.”

Berger E. Nothing gold can stay? EMS crashes, lack of evidence bring the golden hour concept under new scrutiny. *Ann Emerg Med*. 2010; 56(5):17A-19A.
[Opinion/ Perspective]
This editorial reviews the development of the golden hour concept in trauma care and questions the validity of this concept. More research is needed to define the time interval that is critical to survival of specific patient populations in trauma care.

Bigham MT; Schwartz HP; Ohio Neonatal/Pediatric Transport Quality Collaborative. Quality metrics in neonatal and pediatric critical care transport: a consensus statement. Pediatric Critical Care Medicine. 2013 Jun; 14(5):518-24.
[Consensus Development Conference. Journal Article]
During a 2-day state quality metrics conference, a consensus technique was used to develop recommendations related to the transportation of neonatal and pediatric patients. Nineteen transport leaders representing six neonatal/pediatric specialty programs were involved in the process. The group developed 23 quality metrics,

including use of L&S. For consistency, a definition was developed for each metric.

Burns B, Hansen ML, Valenzuela S, Summers C, Van Otterloo J, Skarica B, Warden C, Guise JM. Unnecessary use of red lights and sirens in pediatric transport. *Prehosp Emerg Care*. 2016 May-Jun; 20(3):354-61.
[Journal Article]
This study is a record review of all pediatric L&S transports in an urban EMS system from 2008-2011 using a standardized chart abstraction tool. Approximately 7% of pediatric patients treated in emergency departments arrive by ambulance, and approximately 7% of those arrive with L&S. The charts were reviewed by physicians and paramedics, and descriptive statistics were used to measure the frequency of unnecessary transports and of unnecessary L&S use. Experts identified 96 (19.6%) of 490 L&S transports to have unnecessary use of L&S. Half of the cases of unnecessary L&S transport were associated with trauma etiology, and normal vital signs were associated with a higher rate of unnecessary L&S use. In addition to the tragedy of fatalities or injuries from EMS vehicle crashes, the authors also point out that an EMS vehicle crash takes more than 3 vehicles out of service – the responding vehicle, the second vehicle that must be sent to the original scene, and the additional vehicle that must be sent to the crash scene.

Dorges V; Wenzel V; Kuhl A; Dix S; Huppe M; Gehring H; Schumann T; Gerlach K. Emergency medical service transport-induced stress? An experimental approach with healthy volunteers. Resuscitation. 2001 May; 49(2):151-7.
[Journal Article. Randomized Controlled Trial]
This randomized controlled trial studied heart rate, epinephrine levels and norepinephrine levels in individuals with simulated EMS care and transport. Heart rate, epinephrine, and norepinephrine levels were significantly higher when the study subject was being carried on a stretcher, but only the epinephrine levels were statistically increased during simulated transport at high-speed with sirens. The study did not assess transportation conditions that compared non-L&S transport with L&S transport. The physiologic results suggest that being carried in a stretcher was more stressful than a high-speed L&S transport, but the individual's epinephrine levels were increased during the sirens transport portion of the study.

Greenwood MJ; Heninger JR. Structured communication for patient safety in emergency medical services: a legal case report. *Prehosp Emerg Care*. Jul-Sep 2010; 14(3):345-8.
[Case Reports. Journal Article. Legal Cases]
This case study and corresponding discussion relates to an interfacility transfer of a patient who died during transport, leading to litigation due to communication failures during transport. The discussion includes the noise of L&S transport as one of the factors that can compromise hearing and communication between the patient care provider and the driver during transport. The discussion focuses on the use of structured communication techniques, like read-back, to limit communication failures.

Kupas, DF, Dula, DJ, Pino BJ: Patient outcome using medical protocol to limit "lights and siren" transport. *Prehosp Disaster Med.* 1994; 9:226-229.
This prospective study was the first to use a medical protocol to determine which patients should be transported by ambulance with L&S and which should not. The study was done in a suburban/rural county in Pennsylvania. After applying the protocol and transporting the patient to the hospital, the receiving physician was asked whether the patient's care would have been improved by arriving at the hospital sooner with L&S. In the study, with the medical protocol, the rate of L&S transport was 8% (130/1625) of all scene transports after calls to 911, and there were no adverse events reported in the 92% of patients transported without L&S.

Kurz MC; Dante SA; Puckett BJ. Estimating the impact of off-balancing forces upon cardiopulmonary resuscitation during ambulance transport. Resuscitation. 2012 Sep; 83(9):1085-9.
[Journal Article]
To study the potential impact on CPR quality during patient transport, the authors reviewed an onboard ambulance monitoring system for acceleration data during transport of 50 patients in cardiac arrest. These data were compared with similar data from non-emergent transports. The study found significant acceleration vectors, with a potential to decrease the quality of CPR by off-balance EMS providers, in both the cardiac arrest cases and the non-emergent transports. The off-balancing forces were similar despite lower speeds and driving without L&S. The authors conclude that "reducing speed or driving out-of-hospital cardiac arrest patients without L&S does little to mitigate these forces."

Lacher ME, Bausher JC. Lights and siren in pediatric 911 ambulance transports: are they being misused? *Ann Emerg Med*. 1997; 29(2):223-227.
[Journal Article]
Investigators reviewed audio recordings of EMS communication with a pediatric medical control center over 7 months. There were 504 EMS responses, and 312 cases used L&S during transport. The investigators reviewed the medical records for each case to determine whether L&S were indicated. L&S use was deemed inappropriate in 123 of 312 cases. BLS providers were more likely to use L&S inappropriately, and the authors suggested that EMS providers should receive additional education related to L&S use.

Lerner EB, Moscati RM. The golden hour: scientific fact or medical ''urban legend''? *Acad Emerg Med*. 2001; 8(7):758-760.
[Review Article]
This article is a review of the literature related to the concept of the "golden hour" in trauma care. Evidence could not be found to substantiate the golden hour. The authors note that some studies have supported "shorter total out-of-hospital time is better" concept, but they have significant weaknesses, while other studies, with equally poor quality, refute the "shorter is better" concept.

Marques-Baptista A, Ohman-Strickland P, Baldino KT, Prasto M, Merlin MA. Utilization of warning lights and siren based on hospital time-critical interventions. *Prehosp Disaster Med*. 2010 Jul-Aug; 25(4):335-9.

[Journal Article]
This retrospective study explored the time saved using L&S during transport and potential hospital interventions done within the time saved. The study reviewed data from all 112 ALS ambulance transports to a single New Jersey emergency department over a three-week period. Time differences were analyzed by comparing the actual L&S transports with times measured in another vehicle traveling the same route without L&S at the same time on the same day of the week. Time saved with the use of L&S was 2.62 minutes on average (14.5 minutes with L&S vs. 17.1 minutes without L&S). Of the 112 patients, five received a time-critical intervention at the hospital, but none of these occurred within the time saved by using L&S.

Merlin MA, Baldino KT, Lehrfeld DP, Linger M, Lustiger E, Cascio A, Ohman-Strickland P, Dossantos F. Use of a limited lights and siren protocol in the prehospital setting vs standard usage. Am J Emerg Med. 2012 May; 30(4):519-25.
[Journal Article]
This prospective cohort study introduced a protocol for medical indications that warrant L&S transport in 4 communities and compared L&S transport with 4 control communities that did not use the protocol. 808 EMS calls were reviewed after initiating the protocol. L&S were used during transport on 201/405 (49.6%) in communities not using the protocol, and on 117/403 (29.0%) in the intervention communities. Odds of L&S use during transport were 5.6 times more likely in communities not using the protocol. Of note, all ALS responses to scene were with L&S.
L&S use in these communities before the study was not known, and L&S use was associated with longer transport times – authors suggest this may be for stopping to do procedures or may be due to more L&S use by EMS providers for longer transport distances. The protocol was relatively simple and only included a few indications for L&S transport, but the last indication was a general statement of “worsening of patient at any time”. Due to the high number of L&S transports even in the intervention group, it is likely that this general indication was used frequently. The study does not identify how many times L&S were used for each of the protocol indications. L&S use had no impact on patient disposition.

Myers LA; Russi CS; Schultz JL. Paramedic intercepts with basic life support ambulance services in rural Minnesota. *Prehosp Disaster Med*. Mar-Apr 2010; 25(2):159-63.
[Journal Article]
This study examined ALS/paramedic “intercepts” over a 5-year period (from 2003-2007) in rural Minnesota. Of 1675 intercept calls, the ALS vehicle responded with L&S to 97.5% but only transported 24.2% (405/1675) to the hospital with L&S. ALS procedures were limited to ECG monitoring and/or IV access in 955/1481 (64.4%) of the cases where any ALS procedure was done. The authors concluded that there is a significant discrepancy between L&S response and the ALS care that is rendered during these intercept calls.

Nallamothu BK, Normand ST, Wang Y, Hofer TP, Brush JE, Messenger JC, Bradley EH, Rumsfeld JS, Krumholtz HM. Relationship between door-to-balloon times and

mortality after primary percutaneous coronary interventions over time: a retrospective study. *Lancet*. 2015; 385:1114-22.
[Journal Article]
This retrospective study reviews the National Cardiovascular Data Registry CathPCI Registry, which includes data on 150,116 procedures from 423 hospitals between 2005 and 2011. Although the average door-to-balloon (D2B) times have decreased in this time, the mortality has increased. The authors speculate that sicker and more elderly patients are responsible for this increase in mortality in the population. The authors used multilevel analyses of this huge data set to find individual patient mortality improvements with decreased D2B times. The authors suggest that time relationship is important for the individual patient and that the odds ratio for in-hospital mortality for STEMI patients is 0.92 for every 10 minutes reduction in D2B time, and the odds ratio for 6-month mortality is 0.94 for every 10 minute decrease in D2B. When applied to the average reported in-hospital mortality of 5.3%, rendering a coronary intervention 10 minutes sooner (OR 0.92) would be anticipated to increase deaths by 0.4% or a NNT of 250.

Newgard CD, Schmicker RH, Hedges JR, Trickett JP, Davis DP, Bulger EM, Aufderheide TP, Minei JP, Hata JS, Gubler KD, Brown TB, Yelle JD, Bardarson B, Nichol G and Resuscitation Outcomes Consortium Investigators. Emergency medical services intervals and survival in trauma: assessment of the “Golden Hour” in a North American prospective cohort. *Ann Emerg Med*. 2010 Mar; 55(3):235-246.e4.
[Journal Article]
In this article, there was no association between EMS time intervals, including response time, and survival for injured patients that had serious physiologic instability, including hypotension, respiratory rate <10 or >29, advanced airway placement or GCS<13. The study population included patients transported by 146 EMS agencies to one of 51 Level I or II trauma centers in 10 sites across North America.

Parks LL. Are speeding, open sirens and red light-breaking by ambulances necessary? J Fla Med Assoc. 1953; 40(1):20-22.
[Journal Article]
This study reviews data from ambulance transports in Florida. 808 patients were brought by ambulance to Jackson Memorial Hospital between Jan 12 and Feb 12, 1953. Of those, 6 were dead on arrival, 13 died in the emergency department, 247 were admitted, 114 were transferred to convalescent homes, and 428 were discharged to home. Overall, 67.1% were not admitted. When reviewed by a physician, 99/808 cases were felt to have justification for rapid transport – “87.8 per cent of the patients arriving by ambulances need not have been rushed to the hospital.” At Duval Medical Center cases were recorded between Feb 6 and Mar 31, 1953. In that time, there were 378 ambulance transports. 71.5% were not admitted “after a fast ride to the hospital.” A list of the diagnoses for the 108 admitted patients is provided. The author suggests that based upon the diagnosis alone, few of the admitting conditions would be emergencies. They suggest that conservatively 15% of the admitted patients and 4.2% of all patients are true emergencies. In 1951, the FL Department of Public Safety reported 25 ambulance crashes with 1 death and 14 injured persons. This paper includes several interesting recommendations, like first aid training for ambulance attendants, restricting

ambulances from running red lights or high speeds except in special circumstances, and educational program for ambulance drivers, and a committee of the medical society to develop a list of conditions that would require excessive speed.

Smith MP; Kaji A; Young KD; Gausche-Hill M. Presentation and survival of prehospital apparent sudden infant death syndrome. *Prehosp Emerg Care*. Apr-Jun 2005; 9(2):181-5.
[Journal Article]
This study examined 113 infant cardiac arrests in Los Angeles and Orange County, CA. The study included all cases of apparent SIDS where the infant was found lifeless after being laid down to sleep. Outcomes were available for 110 of the cases. While ROSC was obtained in 5% of the cases, no patient survived to be discharged from the hospital. L&S transport was documented in 44% of the cases, but the mode of transport was ambiguous in the rest. The authors conclude that based upon this zero survival rate, EMS policies should reconsider L&S transport and field termination for similar cases with apparent SIDS.

Wampler DA, Collett L, Manifold CA, Velasquez C, McMullan JT. Cardiac arrest survival is rare without prehospital return of spontaneous circulation. *Prehosp Emerg Care*. 2012 Oct-Dec; 16(4):451-5.
[Journal Article]
Data prospectively CARES (Cardiac Arrest Registry to Enhance Survival) data from San Antonio, TX and Cincinnati, OH from 2008-2010 was retrospectively analyzed for the relationship of ROSC to survival. Survival to hospital discharge with ROSC in the field before transport was 154/894 (17.2%) while survival without field ROSC was 11/1589 (0.69%). No patient with asystole and no ROSC in the field survived to hospital discharge.

Weber U, Reitinger A, Erdeii T, Hellmich C, Steinlechner B, Hager H, Selzer M, Hiesmayr M, Rajek A, Kober A. Effects of high-urgency ambulance transportation on pro-B-type natriuretic peptide levels in patients with heart failure. *Am J Emerg Med*. 2010; 28(5):568-576.
[Journal Article]
Thirty-two patients with clinical signs of heart failure had various measurements every 3 minutes during ambulance transport, including heart rate, blood pressure, and pulse oximetry. Venous proBNP levels and visual analog scale for pain and anxiety were measured before and after transportation. ProBNP levels increased significantly during transport (278.13 to 984.67, $p<0.01$), but there was no significant change in heart rate, blood pressure, pain, or anxiety. Despite having a physician and two paramedics on each ambulance, the Austrian Red Cross Ambulance Service guidelines identify acute coronary syndrome as a condition requiring “maximum speed of transport”, so these patients were “fixed on a stretcher with security belts and transported at high speed with L&S”, but there was no reporting of the amount of siren usage during transport.

Weber U, et al, Emergency ambulance transport induces stress in patients with acute coronary syndrome. *Emerg Med J*. 2009; 26(7):524-28.
[Journal Article]

This study was done in Austria by the Vienna Red Cross and Vienna University Hospital. Thirty-two patients with clinical signs of acute coronary syndrome had various measurements every 3 minutes during ambulance transport, including heart rate, blood pressure, and oxygen saturation. Venous epinephrine, norepinephrine and lactate levels and visual analog scale for pain and anxiety were measured before and after transportation. Plasma levels of epinephrine and norepinephrine increased significantly during transport (epinephrine 159.29 ng/L to 211.03 ng/L, norepinephrine 632.53 ng/L to 782.93 ng/L, $p<0.01$), but there was no significant change in heart rate, blood pressure, pain, or anxiety. The authors attribute the rise in catecholamines to stress of emergency ambulance transportation. Despite having a physician and two paramedics on each ambulance, the Austrian Red Cross Ambulance Service guidelines identify acute coronary syndrome as a condition requiring “maximum speed of transport”, so these patients were “fixed on a stretcher with security belts and transported at high speed with L&S”, but there was no reporting of the amount of siren usage during transport.

Witzel K. Effects of emergency ambulance transportation on heart rate, blood pressure, corticotrophin, and cortisol. *Ann Emerg Med*. 1999; 33(5):598-99.
[Study, Letter to Editor]
This German study is described in a letter to the editor. 54 healthy subjects rode on an EMS stretcher in an ambulance that was either driving fast with siren use or slower without siren use. The authors note that the mean heart rate of the subjects was up to 30% higher in the siren transport, and the mean arterial blood pressure was 14 mmHg higher during the siren transport. These were both reported to be statistically significant ($p<0.01$). Additionally, the authors measured increased levels of cortisol and corticotrophin in the siren transport group ($p<0.01$ and <0.05 respectively). These were healthy individuals and patients with medical conditions and anxiety about illness were not discussed.

Yeh C, Bloom E, Ramanujam P. A comparison of time to scene response intervals for acute stroke: Is time saved by red lights and siren response? *Ann Emerg Med* 2011; 1:S301.
[Abstract]
This abstract reported on the time saved in response to patients with dispatch symptoms related to possible stroke. The retrospective, observational study was done using the San Francisco 911 center data. Of 2800 patients with stroke presentation on dispatch, 2755 (98.3%) had L&S response with mean response interval of 3 minutes, 33 seconds compared with time interval of 5 minutes, 25 seconds for 45/2800 patients with non-L&S response. On average, L&S response was 1 minute, 52 seconds longer to patients with stroke symptoms on dispatch.

EMS Operations, Policies, and Guidelines Related to Lights and Siren Use

Bailey ED, Sweeney T. Considerations in establishing emergency medical services response time goals. Prehosp Emerg Care. Jul-Sep 2003; 7(3):397-99.
[Position Statement of NAEMSP]

Boone CM, Malone TB. Ambulance Driver Best Practices. BMT Designers & Planners. Aug 15, 2013. Accessed on 3/15/17 at:
https://www.nasemso.org/Projects/AgencyAndVehicleLicensure/documents/Ambulance-Driver-Best-Practices-15Aug2013.pdf
[Review Article, Best Practices]
This monograph was prepared for the Department of Homeland Security. It is a comprehensive review of ambulance driving best practices, and it includes information on L&S best practice recommendations. User research included interview input on L&S from attendees at the 2012 EMS World Expo in New Orleans, LA. Recommendations include use of retroflective sheeting material, use of fluorescent yellow, retroflective contour markings, not exceeding posted speed limit by more than 10 mph, not exceeding speed limit when proceeding through intersections with a green signal, respond with L&S based upon dispatch assessment of high severity conditions, use L&S only when the required patient care is greater than the ability of the ambulance to provide, upgrade/downgrade L&S use as needed during course of treatment.

Clawson JJ, Forbuss R, Hauert SA, Hurtado F, Kuehl AE, Leonard WH, Manigas PA, Ryan JL, Sharpe DL. Use of warning lights and siren in emergency medical vehicle response and patient transport. NAEMSP Position Paper. *Prehosp Disaster Med*.1994 Apr-Jun; 9(2):133-136.
[Position Statement – NAEMSP]
This paper outlines the positions of the NAEMSP and NAEMSD related to L&S use during EMS response and transport. Close oversight by EMS medical directors is required to ensure that L&S use is medically necessary. This suggests that L&S use should be based upon standardized protocols and that L&S to the scene should be based upon emergency medical dispatch prioritization. The position calls for a national reporting system for emergency vehicle collisions. Adopted in 1994, this position statement was reaffirmed in 2002.

Erickson TW. Driving tips and techniques: common sense suggestions. *JEMS*. Dec 1985:42.
[Non-peer review, Opinion]
Various tips provided. Does not focus on L&S, but suggests that full stop policy at intersections is wise.

International Association of Fire Chiefs. Guide to IAFC model policies and procedures for emergency vehicle safety. IAFC/USFA. Accessed on 4/15/17 at:
http://sites.iafc.org/files/1SAFEhealthSHS/VehclSafety_IAFCpolAndProceds.pdf
[Web-based Policy Document]
This document provides guidance related to policies and procedures for operation of fire and emergency vehicles, including ambulances.

International Association of Fire Fighters. Best practices for emergency vehicle and roadway operations safety in the emergency services. IAFF. 2010. Accessed on 4/15/17 at: http://www.iaff.org/hs/EVSP/guides.html
[Guideline Document]
This report of best practices covers emergency vehicle and roadway safety guidelines. Best practices are applicable to law enforcement, fire, and EMS vehicle responses and roadway operations.

LaDuke S. Making ambulance transports safer for nurses. Dimensions of Critical Care Nursing. 2000 May-Jun; 19(3):32-4.
[Review Article]
This review begins with the story of a nurse that died in an ambulance crash while she was accompanying a stable patient on an interfacility transport. This author makes recommendations to nurse managers, supervisors and administrators who play a role in providing nurse staffing for ambulance transport of patients, including allowing for the nurse's right to decline to participate, creasing a transport safety policy for the healthcare facility, encouraging nurses to file incident reports related to risky driving, and ensuring that nurses are competent in assessing patient. The author suggests that nursing managers should review an EMS agency's policies for L&S and seatbelt use. The author states that nurses should insist upon safe ambulance driving.

LaDuke S. Risky rides. Make ambulance transports safer for your nurses. Nursing Management. 1999 Sep; 30(9):29-31.
[Review Article]
Note: This article is identical to the one published in *Dimensions of Critical Care Nursing* listed above.
This review begins with the story of a nurse that died in an ambulance crash while she was accompanying a stable patient on an interfacility transport. This author makes recommendations to nurse managers, supervisors and administrators who play a role in providing nurse staffing for ambulance transport of patients, including allowing for the nurse's right to decline to participate, creasing a transport safety policy for the healthcare facility, encouraging nurses to file incident reports related to risky driving, and ensuring that nurses are competent in assessing patient. The author suggests that nursing managers should review an EMS agency's policies for L&S and seatbelt use. The author states that nurses should insist upon safe ambulance driving.

National Association of EMS Physicians. Emergency medical dispatch. Prehosp Emerg Care. 2008; 12:217.
[Position Statement of NAEMSP]
This position statement is an update of the initial version published in 1989 in Prehospital and Disaster Medicine. The associated resource document by Yancey, et. al. is referenced in this bibliography.

NFPA 1917—Standard for Automotive Ambulances - proposed, 2013 edition. Quincy, MA. National Fire Protection Association. (2011).
[Standards Document – NFPA]

This document defines NFPA minimum standards for design of emergency ambulances.

National Highway Safety Administration and American College of Emergency Physicians. Strategy for a national EMS culture of safety. October 3, 2013. Accessed on 4/15/17 at https://www.ems.gov/pdf/Strategy-for-a-National-EMS-Culture-of-Safety-10-03-13.pdf

Pennsylvania Department of Health Bureau of EMS. Statewide EMS Vehicle Operations Safety Protocol, within Statewide BLS Protocols. July 2015.
Accessed on 4/15/17 at:
http://www.health.pa.gov/My%20Health/Emergency%20Medical%20Services/EMS%20Statewide%20Protocol/Documents/Statewide_BLS_Protocols-2015%20draft%201-11-15.pdf
[Statewide EMS Protocol]
Pennsylvania uses statewide EMS protocols to define expectations for EMS care within the Commonwealth. The statewide EMS Protocols contain a statewide EMS Vehicle Operations Safety protocol, listed as protocol #123 within the statewide BLS protocols. This protocol sets operations expectations for EMS vehicle operations, including lights and siren use, seatbelt use, patient restraint, and other operations safety parameters.

Polsky SS Editor. Continuous quality improvement in EMS. ACEP. Dallas, TX. 1992:291
[Textbook]
This text includes a sample policy for use of L&S. It suggests that both L&S should be used when an EMS vehicle is exercising privileges that are not available to vehicles in general. They also suggest several examples, not inclusive, of conditions that warrant L&S transport, including major trauma, severe respiratory distress, shock, cardiac arrest, life-threatening arrhythmia, and unstable cardiac chest pain.

Sanddal T, Sanddal N. Ambulance vehicle operator: driver behavior and performance checklist (D1). Western Transportation Institute. April 6, 2010. Accessed on 4/15/17 at:
http://www.westerntransportationinstitute.org/documents/reports/4W2008_Final_Report_D1.pdf
[Checklist]
This monograph on safe ambulance operations was published online by the Western Transportation Institute. The checklist format provides a list of parameters for safe driving, including an introduction to driver training curriculum and requirements for EVOC training listed by state. The checklists are in the categories of administrative measures to guide driving issues for personnel administration, pre-response measures that apply before the vehicle hits the road, and response measures that suggest best practices for EMS vehicle drivers.

U.S. Fire Administration. Emergency Vehicle Safety Initiative. FA-272. Federal Emergency Management Agency. August 2004. Accessed 4/15/17 at:
http://www.iaff.org/hs/EVSP/USFA%20Emergency%20Vehicle%20Safety%20Initiative.pdf
[Government Document]

This broad report on emergency vehicle safety covers all aspects of emergency vehicle safety. The report contains agency profiles that describe the safety initiatives of various, mostly urban, fire departments. It also includes discussion of vehicle markings, restraints, warning lights, electronic monitors, traffic preemption controls, and priority dispatch. The training section describes human factors, training courses, driving simulators, and vehicle maintenance. The descriptions and discussions have a focus on fire apparatus vehicle safety, but there are many references to ambulance operations also. There is no discussion of patient condition or decision-making for mode of transport. Most responses, 82% in one case, of the responses of the described fire departments are medical in nature, but no medical organizations were involved in the project. Many of the recommended best practices are applicable to both fire and ambulance vehicles. Note: This document was updated by the 2014 version, FA-336.

U.S. Fire Administration. Emergency Vehicle Safety Initiative. FA-336. Federal Emergency Management Agency. August 2014
Accessed on 4/15/17 at:
https://www.usfa.fema.gov/downloads/pdf/publications/fa_336.pdf
[Government Document]
This document updates the initial 2004 document due to a tremendous amount of research and information that is available, but scattered in multiple documents. This 2014 version examines injuries and deaths related to emergency vehicle operations, focuses on the last decade of research in emergency vehicle response, with emphasis on application to emergency operations. EMS provider and vehicle statistics are included. The document discusses intersection accidents, speed, driver distractions, siren syndrome, fatigue, seatbelt usage, and vehicle lighting and conspicuity research.

U.S. Fire Administration, IFSTA. Emergency Vehicle Visibility and Conspicuity Study. FEMA. FA-323, August 2009. Accessed 4/15/17 at:
http://www.usfa.fema.gov/downloads/pdf/publications/fa_323.pdf
[Government Document]
This document analyzes the effectiveness of emergency lighting devices and retroflective markings on emergency vehicles in preventing injuries to responders.

Wang HE; Mann NC; Jacobson KE; MS MD; Mears G; Smyrski K; Yealy DM. National characteristics of emergency medical services responses in the United States. *Prehosp Emerg Care*. 17(1):8-14, 2013 Jan-Mar.
[Journal Article]
This article uses the 2010 National Emergency Medical Services Information System (NEMSIS) data to describe the characteristics of over 7.5 million EMS responses from 29 states. The authors describe variations in L&S use and other parameters of EMS use.

Widmeier K. Deadly driving: tips to ensure a safe ride for you & your patient. *JEMS*. 36(12):44-8, 2011 Dec.
[Journal Article]

Widmeier K. Driving procedures keep providers safe on the road. JEMS Online. Nov 30,

2011.
[Online Non-peer review Article]
This review article provides tips for safe EMS vehicle driving. There is a focus on distracted driving. Drivers that eat while driving are 1.6 times more likely to be involved in a collision, and the author points out that eating on the road is common in EMS. The author recommends alternating driving so passenger can eat. Inputting information into a GPS is also a distraction risk, as is radio communication. Passengers can do most of these roles during a response with a two-person crew. Radio communications should be done by the driver only when vehicle is stationary. The author recognizes that all of these recommendations may not be feasible, but dangerous distractions should be minimized where possible. Texting while driving increases likelihood of collision by 23 times. 70% of EMS vehicle collisions are while driving L&S.

Yancey A, Clawson J. EMD Position Paper Resource Document. Ann Emerg Dispatch & Response. 2014; 2(2):33-40.
[Resource Document]
This resource document provides additional background and material related to the NAEMSP position statement on emergency medical dispatch.