American Journal of Emergency Medicine (2012) **30**, 519–525

ELSEVIER

The American Journal of Emergency Medicine

www.elsevier.com/locate/ajem

Original Contribution

Use of a limited lights and siren protocol in the prehospital setting vs standard usage

Mark A. Merlin DO, EMT-P[a,*], Kimberly T. Baldino EMT-B[b], David P. Lehrfeld MD[b], Matt Linger[b], Eliyahu Lustiger EMT-B[b], Anthony Cascio[c], Pamela Ohman-Strickland PhD[d], Frank DosSantos DO, MPH[e]

[a]*Emergency Medicine and Pediatrics, University of Medicine and Dentistry of New Jersey-Robert Wood Johnson Medical School, New Brunswick, NJ 08901, USA*
[b]*Department of Medical Education, University of Medicine and Dentistry of New Jersey-Robert Wood Johnson Medical School, New Brunswick, NJ 08901, USA*
[c]*Robert Wood Johnson University Hospital, New Brunswick, NJ 08901, USA*
[d]*University of Medicine and Dentistry of New Jersey-Public Health, New Brunswick, NJ 08901*
[e]*United States Navy, USA*

Received 17 December 2010; revised 11 January 2011; accepted 13 January 2011

Abstract

Objective: Our objective was to determine if implementing a standard lights and sirens (L&S) protocol would reduce their use and if this had any effect on patient disposition.

Methods: In a prospective cohort study, we trained emergency medical services (EMS) personnel from 4 towns in an L&S protocol and enrolled control personnel from 4 addition towns that were not using the protocol. We compare the use of L&S between them over a 6-month period. Our protocol restricted the usage of L&S to patients who had maladies requiring expedited transport. Emergency medical services personnel from the control towns had no such restrictions and were not aware that we were tracking their usage of L&S. We also considered if patient disposition was affected by the judicious usage of L&S.

Results: Prehospital EMS personnel who were trained in an L&S protocol were 5.6 times less likely to use L&S when compared with those not trained. Of the 808 patients transported by both types of workers, no difference in patient disposition was observed.

Conclusions: Our protocol significantly reduced the use of L&S. Judicious use of L&S has significant implications for transport safety. By allowing for selective transport with L&S usage, we observed no impact in patient disposition.

1. Introduction

1.1. Background

The routine use of lights and sirens (L&S) by emergency medical services (EMS) personnel has been a long-standing tradition, but with evidence mounting concerning its risks,

* Corresponding author. Tel.: +1 732 235 8717.
E-mail addresses: merlinma@umdnj.edu (M.A. Merlin), baldinkt@umdnj.edu (K.T. Baldino), mlinger@gmail.com (M. Linger), elyelu@gmail.com (E. Lustiger), anthony.cascio@rwjuh.edu (A. Cascio), fdsdo@yahoo.com (F. DosSantos).

0735-6757/$ – see front matter © 2012 Elsevier Inc. All rights reserved.
doi:10.1016/j.ajem.2011.01.014

many are now questioning its use [1-5]. Position articles such as "Use of warning lights and sirens in emergency medical vehicle response and patient transport from the National Association of EMS Physicians (NAEMSP)" state that protocols should be in place for all uses of L&S, secondary to the risks associated with ambulance collisions such as injury, death, and substantial financial cost [6]. No study to date has demonstrated lives saved or improvement in morbidity by using L&S. As little as 43.5 seconds saved with L&S has been recorded, and in a previous study of ours, we found a 2.62-minute mean reduction in transport time, calling into question the common perception that L&S significantly reduce transport time [7,8]. Although the dangers associated with L&S are repeatedly discussed, national standards have not been implemented [9-11]. Multiple variables associated with transport prioritization make a universal protocols elusive, leaving L&S use to the discretion of individual EMS personnel.

1.2. Importance

The timely, safe transport of patients to definitive care has significant implications for mortality and morbidity, but the hazard created by the unsafe driving associated with the use of L&S is of concern to the public, EMS, and patients [12,13]. Because no national protocol exists for the use of L&S, our L&S protocol, if effective, can serve as a model for the development of practical standards. By judiciously using L&S, EMS systems can hope to reduce consequences due to inadvertent motor vehicle collisions.

1.3. Goals of this investigation

Our primary goal was to investigate whether patient disposition was affected by the implementation of an L&S protocol designed to expedite the transport of only patients for whom time-critical transport was essential. We hoped to demonstrate that a veteran advanced life support (ALS) team would implement a protocol designed to reduce unwarranted L&S usage. In addition, we examined whether use of L&S was associated with discharge status and whether that association was modified by protocol implementation. For discharge status, we included 4 categories: (1) discharged from the emergency department (ED), (2) admitted to the hospital with heart monitoring, (3) admitted to the hospital—excluding the intensive care unit (ICU), and (4) trauma surgeon (trauma alert notification) or ICU needed.

2. Methods

2.1. Theoretical model of the problem

Expedited transport should benefit certain patients, whereas slight reductions in prehospital times should have no bearing on others' outcomes. Lights and sirens driving by EMS personnel carries additional risks for patients, EMS personnel, and the public [14]. With these 2 variables in mind—timely delivery to definitive care and safe transport—guidelines for the use of L&S should reduce the risk associated with L&S while still maintaining speedy transport for critical patients.

2.2. Study design and selection of participants

In a prospective cohort study, we implemented an L&S protocol in 4 towns and compared the use of L&S in the protocol towns with 4 towns that did not have a protocol. In forming the protocol, we identified patient conditions for which time-sensitive care was warranted and designed a protocol to expedite the transport of select patients to the ED (Table 1). This was based on the previous aforementioned research by the authors as well as clinical experience in prehospital care. Emergency medical services management and medical directors instructed EMS personnel from 4 towns to use L&S under specific guidelines. These 4 towns are completely contracted out by our EMS system. We required EMS personnel to abide by these regulations. Subsequently, these locations will be referred to as the intervention towns. Emergency medical services personnel were trained to recognize conditions relating to cardiac function, pulmonary function, anatomical injury, neurologic deficit, and overall patient status as criteria for the use of L&S in transit to the ED.

Table 1

Category	Condition
Respiratory	Airway cannot be secured • More than 2 failed intubation attempts • Abnormal anatomy Cannot adequately ventilate • Oxygen saturation <93% with NRB mask • Flail chest, tension pneumothorax
Cardiac	SBP <90 despite IV fluid bolus Abnormal heart rate • Symptomatic bradycardia not responding to transcutaneous pacing • Persistent tachycardia not responding to fluid bolus ST elevation MI
Neurologic	ST elevation MI • New focal deficit within 3 hours of onset • Evidence of spinal cord injury • Seizure without return to baseline within 10 minutes of onset
Anatomical	Burn >20% total body surface area Penetrating injury to head, neck, torso, extremities above elbow/knee Amputation above wrist/ankle High voltage electrical injury
Overall Status	Worsening patient status from any cause

Table 1 was provided to these EMS personnel. Criteria were reviewed during a 30-minute training session during a department meeting, In addition, the protocols were sent out on our electronic medical report system that required them to be reviewed. A 30-day question and answer period was provided before implementation. Data on L&S usage were collected for 6 months after protocol implementation.

The control towns had individual EMS squads that are not obligated to follow our L&S protocol and subsequently used L&S at the team's discretion. They were not aware that we were collecting data on their usage. This deidentified collection was approved by the hospital institutional review board. Similar towns were matched based on geographic distance to our hospital and baseline population. Because we only have 4 towns that we have complete control of for both basic life support (BLS) and ALS, the pair-matched towns that did not have the intervention were based on these characteristics as much as possible (see Table 2).

Emergency medical services from 4 control towns were given no training under the protocol and continued to operate as usual. Regular standing orders remained in place for all towns studied, and personnel were instructed to continue normal operating procedures with the exception of the protocol, where implemented. Included in the study were all transports during the study period, with the following exemptions: private transport companies operating within these 8 towns, transports by mutual aid coming from other towns, patients who died in the ED, transfer patients who were having a myocardial infarction (MI), and patients who left the hospital against medical advice.

2.3. Setting

Our 2-tiered EMS system is composed of 6 ALS units based at a university level I trauma center. The mean amount of experience for the 232 system providers is 6.48 years.

The ED treats approximately 93 000 patients per year. The ED is a tertiary care center for multiple specialties. Only board-certified or board-eligible emergency physicians evaluated and treated the patients.

The county population of approximately 800 000 residents is made up of 68.4% white, 13.9% Asian, 13.6% Hispanic, and 9.1% African American residents. The county occupies 323 square miles with a combination of urban cities and suburban communities. The system covers 85% of the county for 911 responses.

The EMS system is composed of a combination of paid and volunteer BLS units and paid hospital-based ALS units that contain 2 paramedics per unit. Regionally based units are dispersed based on population census and call volume. There are 8 BLS units and 6 ALS units that respond to approximately 30 000 dispatches per year, 6500 of these being treated by ALS.

The system contains 90 paramedics, 140 basic emergency medical technicians, 1 full-time medical director, and 2 EMS fellows, all of whom were trained in the L&S protocol. The system provides 100% online medical direction with standing orders. Supervisors respond on all "critical calls," as defined by the medical communicators.

Our medical communication center directly answers 911 calls in our city and receives requests for ALS units from police of neighboring towns. Most of these requests do not provide sufficient information for call prioritization. Therefore, even with recent reports on successful medical priority dispatch system protocols limiting the use of L&S, our system would not be able to implement these protocols given the insufficient information [15]. Consequently, all ALS units are dispatched using L&S. Once the patient has been evaluated, our EMS system had no policy guiding L&S use in transit to the ED.

2.4. Methods of measurement

Pertinent information on each of the patients from the 8 study towns was collected in an electronic medical record (EMS Charts, West Mifflin, PA). Data were collected from prehospital patient charts, recording age, sex, chief complaint, interventions, change in patient condition, time departing the scene to the ED, and whether L&S was used. The use of L&S was recorded in the EMS charts along with justification based on the protocol, where applicable, from a novel drop-down menu. We built a mandatory drop-down

Table 2 Baseline characteristics of towns with and without the protocol

Town	Protocol/ nonprotocol	Approximate distance (mile)	Population	Median income in thousands (2000)	Bachelor's degree or higher
1	N	6	47 760	101	52.4%
2	N	2	13 999	53	59.5%
3	N	18	27 999	53	28.5%
4	N	12	37 734	53	49%
5	P	6	36 287	61	37%
6	P	3	23 040	66	36.6%
7	P	3	50 482	69	40.5%
8	P	[a]	48 573	36	19.2%

[a] Town in which receiving hospital is located.

menu for all EMS providers to verify if L&S were used. They were unable to complete the chart if this menu was not selected. After 6 months, data from the patients transported from all 8 study towns were gathered from the Emergency Department Information Management (Livingston, NJ) database. These data included diagnosis, hospital interventions, and admission or discharge status.

2.5. Data collection and processing

An investigator trained in Microsoft Access and the Emergency Department Information Management database collected all data. Patient care reports were completed on portable computers by the treating paramedic and reviewed by the EMS fellow. All data were collected in the 6 months after protocol implementation.

Statistical analysis was carried out using SAS 9.1 TS level 1M0, XP_PRO platform (SAS Institute Inc, Cary, NC) and MINITAB 15 (MINITAB Inc, State College, PA).

2.6. Primary data analysis

Generalized estimating equations [16,17] were used to evaluate differences between towns implementing and not implementing the protocol. Specifically, controls for sex, age, and time models were constructed to examine the effect of protocol implementation on L&S use. These models assumed a Bernoulli distribution and logit-link function for use of L&S. In addition, an exchangeable working correlation structure was used to ensure appropriate standard errors for the effect of protocol use controlling for clustering of observations within town.

A significant interaction would indicate that differences in L&S use and times to the ED exist between towns with and without implementation. In the presence of an interaction, stratified analyses were conducted to look at the association between L&S use and times to the ED within study and control towns.

In addition, we examined whether use of L&S was associated with disposition status as a surrogate for illness severity and whether that association was modified by the protocol implementation. For disposition status, we included 4 categories of increasing severity: discharged from the ED, admitted to the hospital, admitted to the hospital with heart monitoring, and trauma surgeon or ICU needed. Because of too few cases during the 6 months of this study, patients who died in the ED, patients who were seen at another hospital first and then transferred to our ED, patients who were having a MI, and patients who left the hospital against medical advice but would have been admitted were not included in this analysis. To conduct this analysis, an interaction term between disposition status and whether the town did or did not implement the protocol was added to the original model. Estimates of the effect of implementation on the use were estimated as ratios of odds ratios (ORs), then the ORs comparing use of L&S for patients with different admission statuses were estimated for each set of towns (with/without implementation).

Finally, we evaluated whether the use of L&S is changing over time in towns with protocol implementation when compared to those without. This hypothesis was conducted by adding an interaction of time since start of study and implementation to the original model described above.

3. Results

A total of 808 patient charts were studied from July 1, 2009, through December 31, 2009. Of these, 405 patients were in the control group, with 201 transported with L&S (49.6%), and 403 were in the intervention group where the protocol was used, with 117 L&S transports (29.0%). Within towns not implementing the protocol (towns 1-4), the odds of L&S use were 5.6 times (95% confidence interval [CI], 3.1-10.2; $P < .0001$) the odds in towns implementing the protocol (towns 5-8). Among the patient runs in which the L&S protocol had been implemented for the provider, the OR for the actual use of L&S was 2.4%.

Overall, L&S use was not significantly associated with hospital admission status ($P = .14$). However, there was some suggestion of an effect based on pairwise comparisons to cases in which the patients were discharged vs those requiring further care. Use of L&S was more likely for patients needing an ICU or trauma activation (OR, 3.23; 95% CI, 2.08-5.02; $P < .0001$) and for those admitted to the hospital, non-ICU (OR, 1.88; 95% CI, 1.03-3.45; $P = .041$) but not for those admitted for heart monitoring (telemetry unit) (OR, 1.18; 95% CI, 0.54-2.60; $P = .67$). Overall, protocol implementation did not significantly affect the association between L&S use and admission status ($P = .16$). However, when examined individually, pairwise comparisons of disposition status did differ between towns with and without protocol implementation. Specifically, the ORs differed between protocol and nonprotocol towns when comparing those admitted for heart monitoring vs those discharged (ratio of ORs, 3.65; 95% CI, 1.43-8.84; $P = .0065$) but did not differ when comparing patients in need of ICU care or trauma alert vs those discharged (ratio of ORs, 0.55; 95% CI, 0.22-1.42; $P = .22$). There was also no difference in L&S use between the 2 groups of towns when comparing those admitted to a non-ICU hospital unit (ratio of ORs, 1.51; 95% CI, 0.62-3.63; $P = .36$).

For towns implementing the protocol, the odds of using L&S were actually less for patients admitted for heart monitoring than for discharged patients (OR, 0.47; 95% CI, 0.29-0.77; $P = .0024$). For towns not implementing the protocol, there was no significant difference in the odds of using L&S when comparing patients admitted for heart monitoring and discharged patients (OR, 1.68; 95% CI, 0.73-3.86; $P = .22$).

There was no statistical evidence that the L&S use changes differently over time in towns with and without implementation of the protocol ($P = .34$).

Use of L&S was associated with longer times from the scene to the ED in the towns with ($P = .0026$) and without ($P = .0050$) the protocol. This effect was more pronounced in towns with the protocol than in those without the protocol (interaction $P = .015$). However, this difference was not statistically significant when controlling for admission status (interaction $P = .16$).

The odds of using L&S decreased by 10% for every additional minute taken getting to the ED within towns using the protocol (not controlling for admission status). Within towns that did not use the protocol, the odds of using L&S decreased by 5% for every additional minute taken getting to the ED (not controlling for admission status). When controlling for admission status, these decreases in the OR were 5% and 6%, respectively. All analyses were adjusted for age and sex.

4. Limitations

Because of limited access to towns in the study, we were forced to choose towns that had similar baseline characteristics; however, variability between these sets of towns does exist. We believe that these variables were mitigated because patients of all demographics lived within these regions have similar characteristics of trauma; medical and pediatric calls.

Still, the relative similarities among the towns within and between groups indicate a relatively homogeneous backdrop against which to implement a protocol such as this. Protocol and nonprotocol towns were of roughly similar makeup, but we did not attempt to control for variables such as road quality, distance from dispatch to a specific residence, or distance to a major thoroughfare. Implementation and control towns are roughly of similar makeup in median household income (65 000 in nonprotocol vs 58 000 in protocol towns) and average population (32 000 vs 40 000). Both sets of towns have higher than national rates of bachelor's or higher degree holders (48% vs 33%), and both sets of towns are primarily racially white (77% vs 51%), with Asians being the largest minority group in the nonprotocol towns (18%) and African Americans being the largest minority group in the protocol towns (26%). With these characteristics, it is difficult to assume exactly similar characteristics.

In addition, we are not aware of the penetration of L&S into these towns before our protocol implementation. It is plausible that differences existed before our study. We were unable to study prior data because verification of L&S was extremely limited. Although the crews often documented if L&S were used, it was not mandated, and specific instances of why the protocol was or was not used could not be verified.

5. Discussion

This is the first prospective analysis in the literature introducing an L&S protocol into multiple towns and subsequently comparing towns with similar characteristics that did not use the protocol. We found that nonprotocol towns were 5.6 times more likely to use L&S than protocol towns. Because baseline characteristics of towns were similar, it is evident that the protocol affects EMS personnel and their decisions. This is significant because the EMS community resists changes to long-standing, de facto practices such as when and when not to use L&S. In our study, experienced EMS workers incorporated this new protocol into their practice over a short period. This has implications for retraining veteran groups as well as initial training for novice emergency medical technicians.

In both protocol and nonprotocol towns, use of L&S was associated with longer times to the ED, and no significant difference existed between these 2 groups. This finding is unusual because other studies have demonstrated that longer times are typically associated with no L&S [18]. Because L&S patients were sicker (more ICU admissions and trauma alerts), they may have required more prehospital procedures. More procedures potentially result in longer times to the ED. Although one would expect faster times, we often see EMS pull over to do these procedures, which increases the overall transport time. It is more probable, however, that EMS put on L&S more often when distances were further from the hospital in general and did not use them when they were closer. Typically, studies have found that the nonuse of L&S corresponds to longer time to the hospital, and this should be coincident with less aggressive (ie, safer) driving. Because the addition of a few minutes does not impact patient outcome, EMS employers (municipalities, hospitals, and private companies) should encourage ambulance transport without L&S. This study demonstrates that EMS can implement a protocol that does reduce the use of L&S, with the potential to avoid motor vehicle collisions and otherwise dangerous transport situations.

The data from this study showed no association between L&S usage and likelihood of hospital admission in nonprotocol towns or protocol towns. No statistically significant difference exists between these 2 groups. The protocol was not designed to help EMS personnel determine the likelihood of a patient requiring admission to the hospital, and in many cases, a patient who requires rapid transport to definitive care is not coincident with a patient needing long-term care in an ICU. For instance, a child having an asthma attack and whose O_2 saturation falls below 93% would require L&S under the protocol, but that child might not require admission to the hospital and may be discharged from the ED. For the protocol towns, the likelihood of a patient requiring admission should not necessarily correlate with L&S usage. There are many prehospital conditions indicated in the L&S protocol that would lend themselves to surgery/ICU admission (eg, paralysis).

For the nonprotocol towns, their generalized use of L&S is not indicative of any type of prehospital condition because there is no discipline in the application of L&S; that decision is left to the discretion of individual EMS.

In nonprotocol towns, L&S were more likely for patients requiring ICU admission and trauma alerts (trauma called from the prehospital setting). Similarly, in protocol towns, L&S were more likely for patients requiring ICU admission and trauma alerts. No statistically significant difference exists between the 2 groups. These data speak to the ability of prehospital workers to identify the sickest patients in most need of definitive care. In both groups, EMS workers could identify the patients for whom quick admission to surgery or expeditious intensive care matters most. Because the protocol does not necessarily correspond to symptoms indicating a need for long-term care, this result is not surprising. The use of L&S based on this protocol should only coincide with patients whose current condition is unstable or may become unstable, without judging whether ongoing care in the hospital will be needed.

In nonprotocol towns, no difference exists between the odds of using L&S for patients later discharged from the ED and those admitted. In protocol towns, the odds of using L&S were greater for patients discharged than admitted to with cardiac monitoring. Discharge status itself was statistically different between nonprotocol and protocol towns. Patients admitted for heart monitoring were more likely to have had L&S transport than patient's later needing ICU admission or trauma alert. At least 3 of the protocol criteria pertain directly to cardiac conditions: systolic blood pressure less than 90, irregular rate, and ST-elevation MI. These have very concrete, easy-to-access data points and may be some of the most recognizable signs that a patient fits the L&S protocol and is in need of time-sensitive care. Therefore, it follows that the use of L&S is more frequent in transport of patients eventually admitted for cardiac monitoring under the protocol.

At the same time, some of the patients for whom trauma alerts are called may not require L&S based on this protocol. For instance, amputations below the ankle/wrist may require a trauma alert without requiring use of the L&S protocol. A gunshot wound to the forearm would not fit the protocol requirement for L&S, but it may require admission to surgery. In both cases, the increased risk added by aggressive driving with L&S is not warranted as the addition of a few minutes in transit should not impact patient outcome. These patients most likely would, however, see admission to the hospital. Similarly, there are a few protocol criteria that may preclude L&S while indicating ICU admission. For example, EMS personnel may decide that a patient has burns covering 15% of her/his body and, therefore, not use the protocol (which requires L&S with burns over 20% of the body); however, at the ED, the house officer may then decide that the patient needs ICU admission.

The protocol, therefore, does not indicate the necessity of admission to the hospital and was not designed to teach EMS personnel to identify which patients would require discharge from the ED or admission to the ICU. Instead, these guidelines were designed to bring patients who need immediate definitive care to the ED faster than those for whom a few extra minutes of transport matters little. Those patients for whom these few dilatory minutes affect care may not translate to the patients for whom hospital admission or ICU care is necessitated, although in this study, L&S were more likely for patients eventually admitted to the ICU or indicated as trauma call.

These data also suggest that the EMS squads that were not trained in judicious usage of L&S are not following clear criteria for L&S based on specific patient indicators. The data from this study did not show a change in L&S usage over time in towns without a protocol, indicating that the limiting of L&S by surrounding organizations did not affect their mode of transport decisions. One can assume that these organizations will not change their practices without a policy change, whereas those directly taught will change, based on the success of protocol implementation in this system. Therefore, EMS employers and managers should implement a specific protocol for L&S use and provide training for ALS and BLS providers to enable them to recognize conditions for which L&S will be of most immediate benefit to the patient.

References

[1] Blum A. The need for not breaking the sound barrier. JAMA 1980;244:1327-8.

[2] Clawson JJ. Running "hot" and the case of Sharron Rose. JEMS 1991;16:11-3.

[3] Elling R. Dispelling myths on ambulance accidents. JEMS 1989;14:60-4.

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

[5] Lacher ME, Bausher JC. Lights and siren in pediatric 911 ambulance transports: are they being misused? Ann Emerg Med 1997;29:223-7.

[6] Clawson JJ, Forbuss R, Hauert SA, Hurtado F, Kuehl AE, Maningas PA, et al. Use of warning lights and siren in emergency medical vehicle response and patient transport. National Association of Emergency Medical Services Physicians (NAEMSP) and the National Association of State EMS Directors (NASEMSD). Prehosp Disaster Med 1994;9:133-6.

[7] Hunt RC, Brown LH, Cabinum ES, et al. Is ambulance transport time with lights and siren faster than that without? Ann Emerg Med 1995;25:507-11.

[8] Marques-Baptista A, Ohman-Strickland P, Merlin MA, et al. Utilization of warning lights and sirens based on hospital time-critical interventions. Prehosp Disaster Med 2010;25(4):335-40.

[9] US Department of Transportation NHSA. A review of information on fatal traffic crashes in the United States; 1991. p. 11.

[10] US Department of Transportation NHSA. Ambulance involvement in fatal crashes by person type of fatalities and crash type. Fatal Accid Rep Syst 1990:9-12.

[11] Kupas DF, Dula DJ, Pino BJ. Patient outcome using medical protocol to limit "lights and siren" transport. Prehosp Disaster Med 1994;9:226-9.

[12] Clawson JJ, Martin RL, Cady GA, Maio RF. The wake-effect–emergency vehicle–related collisions. Prehosp Disaster Med 1997;12:274-7.

[13] Pirrallo RG, Swor RA. Characteristics of fatal ambulance crashes during emergency and non-emergency operation. Prehosp Disaster Med 1994;9:125-32.

[14] Saunders CE, Heye CJ. Ambulance collisions in an urban environment. Prehosp Disaster Med 1994;9(2):118-24.

[15] Cone DC, Galante N, MacMillan DS. Can emergency medical dispatch systems safely reduce first-responder call volume? Prehosp Emerg Care 2008;12:479-85.
[16] Zeger SL, Liang KY. Longitudinal data analysis for discrete and continuous outcomes. Biometrics 1986;42:121-30.
[17] Liang KY, Zeger SL. Regression analysis for correlated data. Annu Rev Public Health 1993;14:43-68.
[18] Ho J, Casey B. Time saved with use of emergency warning lights and sirens during response to requests for emergency medical aid in an urban environment. Ann Emerg Med 1998;32(5):585-8.