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Emergency Medical Services

The impact of using time critical intervention-based dispatch thresholds on lowering lights and siren use to EMS 911 incidents

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Abstract

Objectives: Emergency Medical Services (EMS) has historically utilized lights and sirens (L&S) to respond to 911 incidents. L&S are used in 86% of scene responses nationally; however, time critical interventions (TCIs) occur in less than 7% of these incidents. Responses with L&S are associated with increased risk of crashes and injuries. Our objective was to determine the impact of TCI-based dispatch thresholds on L&S use, dispatch accuracy, and response times.

Methods: We performed a before-after retrospective evaluation of TCI-based dispatch methodology at a suburban EMS system. We categorized all EMS interventions as TCI or not, and we determined a TCI threshold above which we would use L&S. We then assigned response priorities to each call nature based on the proportion of TCIs within them. We compared historical results with those from the 6 months following implementation in terms of L&S use, dispatch accuracy, and response times.

Results: There were 13,879 responses in the "before" group and 14,117 in the "after" group. The rate of L&S use decreased from 56.2% in the before group to 27.6% in the after group, while TCIs were performed in 6.9% of responses in the before group and 7.6% in the after group. Accuracy increased from 48.8% to 75.1% and median response time increased by 0.1 min from 8.3 to 8.4 min.

Conclusion: Using TCI-based dispatch thresholds, we decreased L&S use and increased accuracy with minimal increased response time. Our results support the use of this methodology to determine EMS response modes.

KEYWORDS
dispatch, EMS, lights and sirens, medical priority dispatch, safety

1 | INTRODUCTION

1.1 | Background

Emergency medical services (EMS) traditionally utilizes warning lights & sirens (L&S) when responding to 911 emergency incidents on the assumption that they save time and result in time critical interventions (TCIs), ultimately resulting in better patient outcomes.[1] Between 86% and 97% of 911 incidents in the United States utilize L&S when responding to the scene.[2,3] Despite the frequent use of L&S, TCIs were found to occur in less than 7% of all 911 responses.[2]

1.2 | Importance

The use of L&S has been associated with a 50% increase in the odds of ambulance crashes during response.[4] The majority of fatal crashes involving ambulances were with L&S use.[5,6] Because crashes and fatalities are more likely when responding with L&S, it is prudent to consider L&S use like any other clinical intervention and use it only when the potential benefits (when TCIs are predictable) are more likely than the potential risks. If L&S could potentially be of benefit in only 7% of responses, the risk of L&S likely outweighs the possible benefits in most responses.

Using a large national dataset, the proportion of EMS incidents resulting from a 911 call in which a TCI was performed was calculated by each dispatcher-derived call nature and found to vary by agency from 0% to 45%.[2] This analysis evaluated calls from multiple agencies that may have used differing dispatch systems. While helpful to understand the general scale of L&S benefit, it was not useful for any particular agency to use when determining which incidents to respond to with L&S. It did, however, present a useful methodology with which to analyze data within a system. To our knowledge, no work to date has used this methodology to objectively determine L&S use within a single system. Additionally, it is not clear to what extent using such a methodology may impact dispatch accuracy or response times.

1.3 | Goals of this investigation

We aimed to develop a TCI threshold-based dispatch model using historical data from our EMS system to determine response modes (L&S or no L&S) and determine the effect on the use of L&S, dispatch accuracy, and response times.

The Bottom Line

Despite their use in most emergency medical services (EMS) responses nationally, warning lights & sirens use increases the risk of crashes and results in few time-critical interventions. Restricting the use of lights & sirens to only those calls that are likely to result in time critical interventions has the potential to match patient need more objectively to method of response, thus improving safety. A suburban EMS system developed a system of time-critical intervention-based thresholds to determine which calls EMS units responded to with lights and sirens. This system resulted in a 29% decrease in the use of lights & sirens, a 26% increase in dispatch accuracy, with only a 6 second median increase in the response time.

2 | METHODS

2.1 | Study design

We performed a retrospective before-after cohort study to evaluate the effectiveness of a new TCI threshold-based dispatch response plan. Incident number, call nature, response times, and all interventions were electronically extracted from the electronic patient care record (ePCR) for analysis. The before group consisted of incidents between April 4, 2022, and October 3, 2022. This group was used to develop the new response plan and as a baseline comparator. The data from the before group was compared to the after group, which was collected between October 5, 2022 and April 6, 2023. This study was reviewed by the Baylor Scott & White IRB and approved for a waiver of consent/authorization (application 023-347). We followed STROBE guidelines for reporting on observational studies.

2.2 | Setting

Williamson County EMS (WCEMS), located in suburban Austin, TX, with a population of just over 650,000, responds to approximately 40,000 911 incidents a year. WCEMS is a third-service agency provided by the County government and staffed by 21 Advanced Life Support ambulances. At the time of this study, all ambulances had a dual-paramedic crew configuration. The system comprises the county-based EMS system and 17 municipal fire-based first responder organizations, all of whom operate under a single medical director. All ambulance dispatches are made through Williamson County Emergency Communications Center (WCEC). WCEC utilizes the Medical Priority Dispatch System (MPDS) produced by Priority Dispatch Corporation. MPDS uses structured questioning to categorize 911 calls based on caller complain and severity into protocols referred to by a card number (hereafter referred to as call natures), each with a priority determinant. Priority determinants range from low acuity (Omega) to critical (Echo) with Charlie being the middle priority. Prior to implementation of the new response plan, units were dispatched with L&S for priority determinants of Charlie, Delta, and Echo. Determinants of Omega, Alpha, and Bravo were assigned non-L&S responses. Non-L&S use in this system does not utilize any form of warning lights. Call natures are entered into our computer aided dispatch (CAD) system (CentralSquare) All interventions, patient demographics, vital signs, response times, and dispositions are entered into our ePCR system (ESO) by the responding EMS clinician using automated imports from the CAD for response time and call natures.

2.3 | Panel participants

We developed the new TCI threshold-based response plan in several steps. First, we created a list of potential TCIs by abstracting every distinct intervention performed within the system and available for documentation as a procedure in the ePCR. These interventions are documented by the attending EMS clinician from a forced-choice list of selections pre-populated by the system. These available interventions did not change across the study intervals. This list included procedures, medications, and pre-arrival hospital notifications, for example, "stroke alerts."

Next, we convened a panel (TCI panel) made up of EMS clinicians to evaluate each intervention. Invitations to participate were sent to all field clinicians, senior medical officers (SMO), field training officers (FTO), field commanders, office-based clinical practices staff (senior paramedics promoted to clinical administration roles), the system medical director, and EMS director. Additionally, the EMS liaisons of each first responder organization (FRO) were invited to participate or appoint a representative. All invitees who volunteered to participate were selected. Participants met virtually by email, receiving instructions and answering survey questions. Participants were provided a definition of a TCI as one reasonably expected to "reverse a critical condition or rapidly improve hemodynamic stability." Participants voted electronically by indicating if they felt each intervention was time critical or not. An intervention was considered a TCI if it received a vote of 51% or greater among all participants during a single round of voting. We calculated an interclass correlation coefficient (ICC) to assess the level of agreement between participants.[7,8]

We next assembled a separate consensus panel (threshold panel) to determine a TCI-based threshold above which call natures should be assigned an L&S response. This panel was intended to be composed of individuals who were responsible to the public for setting policy and therefore would be best suited to making the ultimate determination of where the balance between potential benefit and risk should be. Invitations to participate were sent to the EMS director and medical director, each fire Chief, County Commissioners, and EMS field commanders. Everyone who volunteered was selected and participated. A virtual meeting was conducted with all participants to provide a briefing by the EMS medical director of the rationale for more objectively determining when to use L&S based on balancing the potential risks and benefits of L&S use. During this meeting, we provided participants with a definition of TCI-based threshold as the "proportion of calls having a given call nature that resulted in a TCI using historical data, above which we should respond with L&S." The panel was not, however, provided with any information on the actual proportion of calls in our system resulting in TCIs. This was done to obtain a threshold determination unbiased by knowledge of the frequency of TCIs. Following the informational meeting, simple votes were submitted by each panel member with their recommended threshold percentage. These votes were tabulated, and a simple mathematical average was used as the final threshold.

2.4 | Measures and data analysis

To calculate the proportion of calls within each call nature that resulted in a TCI, we first grouped each distinct EMS response by incident (any given incident might result in one or more EMS responses, that is, multiple ambulance responses for multiple patients involved in, for example, a motor vehicle collision). For each incident, we created a variable that was true if there was a TCI performed by any responding unit at any time during that response. The variable was false if there was no TCI performed. We then grouped each incident by call nature. Within each group, we calculated the TCI proportion by dividing the number of true TCI values by the total number of incidents within that call nature. We developed a new response plan by assigning an L&S response to all call natures with more than the threshold of TCIs determined by panel. Responses during the "before" group utilized the existing response plan.

Response times were calculated by subtracting the times noted in CAD for enroute time from on-scene time. This interval begins when the crew begins traveling to the call and ends upon their arrival on scene. It is analogous to travel time and excludes the time needed for call processing by dispatchers, crew movement to the unit, or patient access time once the crew arrives on scene. This interval was chosen because it is the only portion of the total response potentially impacted by using L&S.

After excluding calls that were canceled enroute (and, thus, had no patient contact), we describe the between group difference in L&S use, true positives, true negatives, false positives, false negatives, and accuracy. We defined true positives as L&S response with TCI performed, true negatives as non-L&S response without TCI performed, false positives as L&S use without TCI performed, false negatives as non-L&S use with TCI performed, and accuracy as True positives + true negatives divided by the total responses. To evaluate the potential harm of the new response plan, we further calculated differences in response time, TCIs performed, and L&S transports between the two groups among the population with false negative responses. We described the absolute difference in accuracy between groups with 95% confidence intervals. We compared categorical variables with a chi-square test. To compare response times, we first excluded all calls without valid response times but included calls in which no patients were found (including canceled calls) and then determined the median and interquartile (IQR) response times between groups. We compared the difference and 95% confidence interval in response times using a Wilcoxon rank sum test.

TABLE 1 List of all time-critical interventions in the 'after' group.

AED defibrillation	Amiodarone	Amiodarone infusion
BiPAP/VPAP	Cardioversion	CPAP
CPR	Dual sequence defibrillation	Epi 1:100,000
Epi 1:1000	Epi 1:10,000	Epi infusion
iGel	Magill forceps	Manual defibrillation
Mechanical CPR	Narcan	NPA
OPA	Pacing	Pericardiocentesis
Pleural decompression	Rocuronium	Simple thoracostomy
STEMI alert	Stroke alert	Suction
Surgical cricothyroidotomy	Tourniquet	Trauma alert
Video laryngoscopy		

AED, automatic external defibrilator; BiPAP, bileve positive airway pressure; CPR, cardiopulmony resuscitation; CPAP, continuous positive airway pressure; NPA, Nasopharyngeal airway; STEMI, ST-segement elevation myocardial infarction; VPAP, variable positive airway pressure.

3 | RESULTS

3.1 | Characteristics and results of panel determinations

The TCI panel consisted of a total of 15 participants: the medical director, three officers from the clinical practices division, three field clinicians, five SMOs, two FRO representatives, and a field commander. They identified 31 TCIs (Table 1). Final votes for all interventions can be found in Table S1. There was significant inter-rater agreement for classifying interventions as TCI with an overall ICC of 0.45 (95% confidence interval [CI] 0.38–0.53), $p < 0.001$.

The threshold panel consisted of six individuals: the medical director, system director, three fire chiefs, and a field commander. They determined that a threshold of above 7% of TCIs within a determinant would result in an L&S response.

3.2 | Main results

There were 13,879 incidents in the "before" group. Among these, 56.2% responded with L&S. The median response time during the before group was 8.3 min (interquartile range [IQR] 6.0, 11.4). The 90th percentile response time was 15.4 min. Among the L&S responses, 823 (5.9%) resulted in a TCI and among the non-L&S responses, 131 (0.9%) resulted in a TCI. The overall dispatch accuracy was 48.8%.

There were 14,117 incidents in the "after" group. Among these, 27.6% responded with L&S. The median response time during the after group was 8.4 min (IQR 6.2, 11.6). The 90th percentile response time was 15.7 min. Among the L&S responses, 728 (5.2%) resulted in a TCI and among the non-L&S responses, 338 (2.4%) resulted in a TCI. The overall dispatch accuracy was 75.1%.

Overall, the new dispatch criteria resulted in a decrease in the use of L&S from 56.2% to 27.6%, a reduction of 28.6% (95% CI 27.5–29.7) and an increase in dispatch accuracy from 48.8% to 75.1%, an increase of 26.4% (95% CI 25.3–27.5). Median response times increased from 8.3 to 8.4 min, an increase of 0.1 min, or 6 s (95% CI 0.06–0.25). The 90th percentile response times increased from 15.4 to 15.7 min, an increase of 0.3 min (95% CI 0.06–0.5) or 18 s (Table 2).

While overall accuracy improved significantly, there was also a small but statistically significant increase in false negatives from 0.9% in the before group to 2.4% in the after group. The 90th percentile response time among these false negatives decreased from 18.0 to 14.7 min, $p < 0.001$. L&S transports, a surrogate marker for clinical acuity, increased among false negative responses from 50.0% to 65.8%, $p < 0.001$. The most common interventions performed in these calls varied in the before and after groups (Table S2).

4 | LIMITATIONS

Our work has several limitations. Most importantly, our determination of TCI and TCI threshold is subjective and other agencies are likely to develop different TCI lists and thresholds. We used a consensus process of stakeholders to develop our TCI lists and thresholds in as objective a manner as possible, however the process is still subject to bias. It is unclear what impact different lists of TCIs or different thresholds would have on dispatch accuracy. We used a different list of TCIs than prior work, however we still found an almost identical proportion of patients needing these interventions.[2] It is likely that any reasonable list of interventions will likely produce similar results. Dispatch thresholds, however, are likely to vary greatly and may have a larger impact on L&S use and dispatch accuracy. Thresholds are a manifestation of risk tolerance, and this is most appropriately determined at the local. It is worthwhile when considering risk tolerance, however, to recall that any dispatch decision is imperfect and carries risk. Responding to all 911 calls with L&S can assure no false negative responses, however it carries the maximal risk of crash with minimal benefit.

We chose accuracy as a measure of improvement because we felt it was the best way to balance the need for rapid response with L&S for those patients who can benefit from them with the need to minimize the risks of L&S response for those patients who do not need

TABLE 2 Impact of time critical intervention (TCI)-threshold based dispatch: Comparison between before and after groups.

	Before *n* = 13,879	After *n* = 14,117	Absolute difference (95% CI) (before–after)
L&S use, *n* (%)	7802 (56.2%)	3902 (27.6%)	28.6% (27.5–29.7)
TCI use, *n* (%)	954 (6.9%)	1066 (7.6%)	0.7% (0.1–1.3)
TP, *n* (%)	823 (5.9%)	728 (5.2%)	0.8% (0.2–1.3)
TN, *n* (%)	5946 (42.8%)	9877 (70.0%)	27.1% (26.0–28.2)
FP, *n* (%)	6979 (50.3%)	3174 (22.5%)	27.8% (26.7–28.8)
FN, *n* (%)	131 (0.9%)	338 (2.4%)	1.5% (1.2–1.8)
Accuracy	6769 (48.8%)	10,605 (75.1%)	26.4% (25.3–27.5)
Median response time (IQR), min	8.3 (6.0, 11.4)	8.4 (6.2, 11.6)	0.1 (0.06–0.25)
90th Percentile response time, min	15.4	15.7	0.3 (0.06–0.50)

Note: L&S, lights and sirens; TCI, time critical intervention; TP, true positive (L&S use with TCI); TN, true negative (no L&S use without TCI); FP, false positive (L&S use without TCI); FN, false negative (no L&S use with TCI); Accuracy , TP + TN/all responses.

them. Accuracy, by definition, incorporates all potential interactions between L&S use and the need for TCI. Other agencies may choose other measures.

Likewise, other agencies may choose to adopt alternative strategies for more appropriately matching L&S use with clinical need. For example, some agencies may choose to adopt a combination of clinical variables to set their response thresholds, including the use of abnormal vital signs, clinical impressions, and L&S transports. Each has potential upsides as well as downsides. Vital signs would seem to be helpful in identifying life-threatening emergencies, however, most large-scale analyses would use vital signs that have been imported into the chart from patient care monitors making them susceptible to artifactual values. As an example, SpO2 values are susceptible to inaccurate values when finger probes are dislodged. Likewise, heart rates can be impacted by displaced electrocardiogram electrodes or patient movement. Using L&S transports as a surrogate for patient acuity is appealing, but subjective and vulnerable to agency culture about using L&S for non-clinical reasons. Clinical impressions are also subject to challenges when used for dispatch purposes. For example, clinical impression of cardiac arrest is often used for patients who are found "dead on scene" and for whom resuscitation is not attempted. To the extent that MPDS can distinguish between patients needing and not needing resuscitation, the use of resuscitation interventions may be more accurate. Future work should utilize patient outcome data from hospital diagnoses and dispositions to further improve dispatch accuracy. Unfortunately, hospital outcome data were not available for this analysis.

Our methodology is dependent on clinical documentation and, as such, is vulnerable to documentation errors. Likewise, our criteria are calculated based on the dispatch call nature. While MPDS uses specific criteria to reach the call nature, it does involve human interaction and different dispatchers may reach different natures and determinants from similar calls. This is, however, the most objective process that is available.

Finally, the use of TCI is dependent upon clinician judgment. It is likely that there are some patients who might have benefited from TCIs who did not get them and other patients for whom TCIs were provided who did not need them.

5 | DISCUSSION

The use of L&S in EMS is common.[2,3] L&S use is largely based on historical tradition and is predicated on two assumptions: L&S significantly reduces response times and this time savings translates into life-saving care. Both assumptions have been questioned recently while recognition of the potential harms in L&S use have increased. The use of L&S increases the odds of crash with subsequent response and transport delay, as well as the potential for patient and clinician harm.[4] As a result, recent attention has focused on the need for a more rational approach to the use of L&S.[9–11]

Several studies have consistently shown that the use of L&S, on average, shortens response by 1.7–3.6 min and transport times by 0.7–3.8 min.[12] Several studies have investigated transports to the ED using L&S and found limited time-critical interventions were performed upon arrival within the time saved.[13–15] Making a judgment on the use of L&S for responses is difficult because little is known about how often TCIs are performed by EMS. A recent retrospective study using a large national EMS dataset demonstrated that less than 7% of L&S responses had a TCI performed at any time during the care provided by EMS and provided a methodology that could be used to match dispatch information to historical patient care reports to more objectively proscribe the use of L&S.[2]

We adopted a new response plan with our local agency as a local quality improvement effort, but our results may be helpful for other agencies seeking to rationally lower the use of L&S responses. Prior work using a national dataset to estimate that a similar methodology could reduce L&S use by between 47% with a 5% TCI threshold and 62% with a 10% TCI threshold.[2] In contrast to this, we found a smaller reduction (29%) in L&S use using a TCI threshold of 7%. While we used a similar methodology, we had a different baseline use of L&S. Our baseline use of L&S was substantially lower than the national dataset at 56%

compared with 86% L&S use in the national dataset.[2] As a result, our potential for L&S reduction was lower. Interestingly, our proportion of TCIs, even though our exact list of TCIs differed, was very similar to that found in the national dataset at 6.9% in both papers. This suggests wide variation in the use of L&S responses with little variation in clinical need across different systems.

We found a small increase of 6 s in median response time after implementation of our new response plan. Considering the potential dangers associated with L&S responses and the increase in dispatch accuracy following implementation of this strategy, this negligible increased response time is likely clinically irrelevant.

Finally, we wanted to further evaluate the increase in dispatch accuracy. We calculated the different components of accuracy, finding that most of the increased accuracy came from large increases in true negatives, from 43% to 70%, and large decreases in false positives, from 50% to 23%. There was a small decrease in true positives from 5.9% to 5.2% and an increase in false negatives from 0.9% to 2.4%. To further investigate the impact of this increase in false negatives, we further analyzed the TCIs and L&S transports among this group. We did note an increase in proportion of L&S transports among false negatives from 50% to 66%; however, the new dispatch protocol was unlikely to have impacted this, given the coincidental decrease in response times in this group from 18 to 14.7 min at the 90th percentile. This may have been because responding clinicians over-rode the dispatch priority based on call notes or because differences in times at the 90th percentile are more subject to large fluctuations because, by definition, they include a wider range of the distribution of values. The difference in median response times for these false negatives was only 24 s (8.5 vs. 8.1 min) compared to a difference at the 90th percentile of 198 s (3.3 min), which suggests that a few response times at the extremes of either group were responsible for the large difference.

Any increase in false negatives, while small, is worth noting. We are responding to 911 calls with limited information and no dispatch response plan can be perfect. Our goal should be over-triage, meaning we would prefer some number of false positives (L&S response that turns out to be unneeded) rather than false negatives (no L&S response that turns out to need a TCI). Future improvement efforts should focus on minimizing false negatives while maintaining overall accuracy.

L&S use can be objectively assigned to those calls in which time-critical interventions are most likely to occur. Doing so can reduce L&S use and increase dispatch accuracy with small marginal increases in response times.

AUTHOR CONTRIBUTIONS

All authors contributed significantly to this manuscript. Study conceptualization was by Jeffrey L. Jarvis, Mike Knipstein, Danny Johns, and Taylor Ratcliff. Data collection by Danny Johns. Data analysis by Jeffrey L. Jarvis and Sydney E. Jarvis. Manuscript preparation by Jeffrey L. Jarvis with significant contributions and critical review by all authors. Jeffrey L. Jarvis takes overall responsibility for the contents of this manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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