White Paper

Real World Application of an Aftermarket Driver Human Factors Real Time Auditory Monitoring and Feedback Device: An Emergency Service Perspective

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ABSTRACT

Ambulance transport has been demonstrated to be hazardous, however there is limited research on the effectiveness of technologies to minimize these risks. This study evaluates the effectiveness and human factors impact of an aftermarket ambulance driver monitoring device with real time auditory feedback. The device was evaluated in an urban/suburban EMS group (>150 drivers and 16 medical transport vehicles). Data were collected via an aftermarket onboard computer system monitoring vehicle parameters every second. Penalty counts were recorded for exceeding set parameters with real time auditory feedback to the driver of both warning and penalty tones. Data are downloaded wirelessly daily for analysis. Data collected over a 24 month period included: System miles traveled, miles between incident. Driver specific behavior and miles between incidents, by age and gender and total miles traveled. Response times and vehicle maintenance were tracked. Incidents that occurred appraised for cost and injuries sustained. Over 950,000 miles of vehicle operations were recorded. System wide performance improved in excess of two orders of magnitude over the study period. There was a 20% cost saving in vehicle maintenance within 6 months. There was no increase in response times. There was sustained improvement in safety proxies over 24 months, with no inservice or retraining after the initial introduction period. A gradual implementation, with rigorous attention to defray any potential concerns of any punitive approach was key.

This real world evaluation of an aftermarket electronic system wide safety technology demonstrated a marked improvement in ambulance transport safety and safety proxies in every measured area. These technologies should be encouraged for widespread implementation throughout the EMS system to optimize safety in addition to cost benefit.

INTRODUCTION

Ground Emergency Medical Service (EMS) vehicles are hazardous vehicles (Becker, Zaloshjna and Levick, 2003; CDC MMWR 2003; Maguire, Smith and Levick 2002; Levick 2002: Erich 2002; Levick 2001; Erich 2001; Kahn, Pirrallo and Kuhn, 2001; Weiss, Ellis, Ernst and Land 2001; Calle, Flonk and Buylaert, 1999; Biggers, Zacharia and Pepe, 1996; Saunders, Heye, 1994; Auerbach, Morris and Phillips, 1987). Numerous studies in the United States of America (USA) and internationally over recent years have identified, via both descriptive epidemiology (Becker et al. 2003; Maguire et al. 2002; Kahn et al. 2001; Saunders et al. 1994; Auerbach et al. 1987) and biomechanical aspects and crash and sled testing (Levick et al 2001; Levick, Li and Yannacconne, March and May 2000; Levick, Better and Grabowski 2000; Levick et al 1998; Best, Zivkovic and Ryan 1993), that there are clear and identifiable risks in ambulance transport, that are highly predictable (Becker et al 2003; Maguire et al 2002; Kahn et al 2001; Biggers et al 1996). These risks involve use of high speed, risky driving practice and lights and siren use, intersection crashes, and failure to use seat belts, in addition to unsecured equipment and suboptimal vehicle design to mention some of the more commonly cited hazards. Yet despite these hazards being convincingly identified, there are scant safety requirements, guidelines (EMSC/NHTSA 1999; General Services Administration KKK-E 2002) or regulations (Joint Standards Australia AS/NZS 4535:1999; European Standards CEN 1789:1999) and few scientifically demonstrated solutions to optimize transport safety in these vehicles (Best et al 1993; Levick et al 2002, 2001, 2000, 1998). In the USA it is estimated that there are ~5,000 ground EMS related vehicle crashes per year (National Highway Traffic Safety Administration (NHTSA), National Automotive Sampling System (NASS)/Crash Data Surveillance (CDS) 1998-2003), of which 10% are considered to be major crashes with either serious injury or fatality resulting. The risks that are predictable and preventable, involve both preventing the crash from occurring by addressing known risky driving practices (De Graeve, Deroo and Calle 2003; Calle, Lagaert, and Houbrechts, 1999) and minimizing the occupant injuries in the event of a crash. (Becker et al 2003; Levick et al 2002, 2001, 2000, 1998; Best et al, 1993). Prior studies have shown that EMS vehicle crashes are more often at intersections, and with another vehicle ($p<0.001$) (Kahn et al. 2001), that most serious and fatal EMS vehicle injuries occurred in the rear of the EMS vehicle (OR 2.7 vs front) and to improperly restrained occupants (OR 2.5 vs restrained) (Becker et al. 2003), that 82% of fatally injured EMS rear occupants were unrestrained (Becker et al 2003) and that >74% of all occupational fatalities for Emergency Medical Technicians (EMTs) are motor vehicle crash (MVC) related, with an occupational fatality rate approaching 4 fold the national mean (Maguire et al, 2002) and with cost estimates for emergency vehicle crashes being in excess of $500 million annually. Yet published studies identifying safety solutions remain scant. There is some injury biomechanics research published by this author on modalities for minimizing injury in the event of a crash (Levick 2002, 2001, 2000, 1998), however there is very little published that identifies how to prevent a crash or an injury causing event from occurring (De Gaeve et al 2003; Calle et al 1999).

This prospective study followed a prior study in the USA demonstrating the efficacy of a device, the primary purpose of which is to prevent a crash or an injury causing event from occurring by directly modifiying emergency vehicle driver behavior, and also in optimizing the use of seat belts.

OBJECTIVE

The purpose of the study was to enhance the safety of emergency vehicle transport. The objective was to determine if emergency vehicle driver behavior can be modified and improved with the installation of an on-board, computer based, monitoring device, with real time driver auditory feedback.

METHODS

This is a prospective study capturing real-time electronic field data from onboard computer recorders installed in ambulance vehicles over a 24 month period. The data was captured during three phases of implementation. A metropolitan EMS group situated within a mix of urban, suburban and semi rural environment, and with >150 drivers, installed the computer system in 20 ambulances in November 2004.

The environment in which this study was conducted was the Cetronia Ambulance Corps (CAC), in Allentown Pennsylvania, covering a region including urban, suburban and small metropolitan region. In 2006 CAC responded to 33,670 calls for service. CAC is the primary provider of emergency services to the following areas:
Whitehall (Pop. 24,296, Sq Miles 12.57), Coplay (Pop. 3,387, Sq Miles .63), South Whitehall (Pop. 18,028. Sq Miles 17.12) and Upper Macungie (Pop. 13,895 Sq Miles 26.24). Also portions of Lower Macungie (Pop. 19,220, Sq Miles 22.57), Weisenberg (Pop. 4,144, Sq Miles 26.82),

Lowhill (Pop. 1,869, Sq Miles 13.99), and Salisbury (Pop. 13,498, Sq Miles 11.02). These are all considered townships. CAC deploys 13 units daily with a mean response time of 11 minutes and covers 450,000 miles annually. CAC has 20 Emergency Vehicles and 11 Non-emergency Vehicles. There are 152 drivers which includes 17 Full-time Paramedics, and 26 Full-time EMT's, 10 Part-time Paramedics and 26 Part-time EMT's, as well as 14 Full-time, 6 Part-time Paratransit drivers, in addition to a number of casual part-timers and volunteers.

The study, in a similar fashion to the methodology of the prior pilot was divided into 3 Phases, however in contrast to the previous study - the duration of Phase II was extended to be 12 months - the rationale for this was to ensure familiarity with the system by all drivers including the extended fleet of infrequent part timers and also the volunteers, before embarking into Phase III.

Description of Implementation Phases - Phase I - from 11/1/04 to 4/30/05, 'Blind data', with no auditory feedback or driver identification were collected for 5 months initially. During Phase II - 5/1/05 to 6/30/06 - data for 13 months were captured with auditory feedback, but no driver identification implemented. In Phase III - 7/1/06 to 8/31/06, the system was fully operational with auditory feedback and driver identification.

<u>In summary:</u>
Phase I - Blind data - no tones, no ID capture,
11/1/04 to 4/30/05
Phase II - Warning and penalty tones only,
5/1/05 to 6/30/06
Phase III - Fully operational,
7/1/06 to 8/31/06

Table 1: Onboard Computer Device Settings used in this study

Speed Low Speed (LSCOUNT) High Speed HSCOUNT)	10 second warning period - 73 / 78 mph - >79 mph
Cornering Low Over Force (LFCOUNT) High Over Force HFCOUNT)	warning at 25% - 38% - 48%
Reverse Count (RVCOUNT)	- 1 count for each time the vehicle is placed in reverse without the reverse spotting switch being engaged.
Seat Belt Distance (SBCOUNT)	- 1/10ths mile (0.1 mile)

LSCOUNT = Low Speed Count (non emergency) - If the vehicle exceeds 73 MPH, the driver receives 10 seconds of warning beeps warning them to reduce their speed. If they fail to do so, one low speed count is recorded for each second the vehicle is between 73 & 78 MPH.
HSCOUNT = High Over speed Count - the system records an instant high over speed count every time the vehicle is driven in excess of 79 MPH.
LFCOUNT = Low Over force Count - total number of seconds the vehicle experienced a force greater than the Low Over force setting which varies from class of vehicle to class of vehicle. 38% is typical.
HFCOUNT = High Over force Count - total number of seconds the vehicle experienced a force greater than the High Over force setting, which varies from class of vehicle to class of vehicle. 48% is typical.
RVCOUNT = Unsafe Reverse Counts - One count is registered for every time a driver puts the truck in reverse without a spotter pressing the inside or outside spotter switch.
SBCOUNT = Seatbelt Counts - one count is registered for each 1/10 of a mile that the driver drives the vehicle without buckling the seatbelt.

These parameters differ slightly from the pilot study conducted by this principal authors team in Little Rock Arkansas in 2003-2004. The speed tolerances and seat belt tolerances are more stringent in this study. The speed warning period is 30% shorter, and the seat belt tolerance is 50% of the tolerance distance - thus twice as stringent. The rationale for embarking on this study were concerns about the need to enhance EMS transport safety, both related to the past safety experience of CAC, with at least one significant crash annually and numerous less severe crashes and the recent published literature which highlighted the seriousness of the risk and hazard in vehicle operations in EMS. There was also a management initiative to improve driver performance in an objective fashion, and a goal to save maintenance dollars and optimize the accident and incident investigation process.

Onboard Computer System Overview - The onboard computer system monitors a number of parameters every second (see table 1) and provides real time auditory feedback to the driver by way of different tones. The parameters monitored include: vehicle speed (against user set limits - both hot & cold), hard acceleration/braking, cornering velocity and g-forces, use of emergency lights and sirens, use of front seat belts, turn signals, parking brake and back up spotters. Each driver has individual key "fob". The key fob is a simple device, (Fig. 1) which must be keyed into a special contact lock on the vehicle dashboard at the time of the vehicle's ignition (Fig. 2), and thus identifies the driver of that vehicle. The computer system provides an audible real time feedback to the driver, by a system of warning growls and then penalty tones for when the pre set parameters are approached and exceeded (Table 1). The onboard computer continuously records penalty counts when drivers exceed certain set parameters.

The penalty count data recorded by the onboard computer for exceeding these parameters, are stored on the on-board computer and downloaded automatically to a base station on a daily basis for analysis and detailed electronic reports are generated. Management tracks trends and individuals.

System Implementation - It was anticipated that, (and supported by some other EMS services experiences) the logistics, style and process of implementation of this system may well have substantial impact on the acceptability or otherwise of this system amongst the EMS personnel. Extensive consultation was sought at all staffing levels with company meetings commencing in June 2004 to explain the technology and the rationale and potential benefit of its implementation. A three phase implementation path was selected. Phase I: Initial 'blind data' collection with no growls or tones switched on and no driver identification via identifying key fobs. Phase II: Growls and tones switched on but no identifying key fobs. Phase III: Full implementation, with growls and tones and identifying driver key fobs utilized. The time line for implementation of the system was: System installed in November 2004; 'Blind data' collection thru May 2005; Growls and tones turned on May 2005- however no key fobs utilized. The system was fully deployed in July 2006, with growls and tones and identifying key fobs fully implemented. There was added incentive of a priority choice of scheduling offered for the best perfoming drivers. It was clearly explained that no perfect drivers were expected, however that the focus was on driving as safely as possible whilst providing for prompt transport of the patient.

RESULTS

Implementation of the system was well received by the EMS personnel. There was no workplace disharmony nor rebellion regarding the system and its implementation and no interference with, or damage to the system or the monitoring or feedback equipment.

Table 2 - Performance improvement over the three phase periods

	Phase I 11/01/04-04/30/05	Phase II 05/01/05-06/30/06	Phase III 07/01/06-08/31/06
Distance -miles	193,210	682,320	75,957
LSCOUNT [LSCOUNT/mile]	89,250 [2.16]	100,195 [0.15]	96 [0.001]
HSCOUNT [HSCOUNT/mile]	12,936 [14.94]	14,448 [0.02]	2 [0.00003]
LFCOUNT [LFCOUNT/mile]	37,347 [0.19]	64,328 [0.09]	1.250 [0.02]
HFCOUNT [HFCOUNT/mile]	552 [0.003]	1.210 [0.002]	56 [0.001]
RVCOUNT [RVCOUNT/mile]	15,697 [12.31]	69,779 [0.10]	7,100 [0.09]
SBCOUNT [SBCOUNT/mile]	40,893 [4.72]	45,366 [0.07]	90 [0.001]

Over 950,000 miles of vehicle operations were recorded. The most dramatic performance improvement was in the reduction in high over speed penalty counts, with a reduction from 14.94 penalties/mile in Phase I to 0.00003 penalties/mile in Phase III. Seatbelt violation dropped from 4.72 violations/mile in Period I to 0.001 violations/mile traveled Period III to August 2006 and have been sustained at similar low rates to date, a 4,000 fold reduction in seat belt violations. Similar trends were seen in low over speed and over force parameters (Table 2). There was a cost saving in vehicle expenses: $271,091 in 2004, $242,965 in 2005 and $237,193 in 2006. There was no increase in average response times during the study period: 11:14 minutes in 2004, 10:36 in 2005, and 10:46 minutes in 2006, this data suggests a moderate overall improvement in response times during the study period. There were 19 vehicle incidents in 2004, 11 in 2005 and no major vehicle crash during the fully implemented phase of the study period. There was sustained improvement in safety proxies over 24 months, with no in-service or retraining after the initial introduction period. Similar to the previous study, there were cost savings in having a decreased number of serious crashes, decreased vehicle damage, and a decrease in the required investigations of those events, with resultant insurance savings also. There were fewer crashes and less severe crashes than over the preceding similar time periods. Additionally, detailed data was captured on the one crash that did occur during the study period. Overall performance improved dramatically from high rates of speed infringements, and high rates of seat belt use failures - to a number of orders of magnitude improvement in performance, the most dramatic being over speed.

Fig 1: Key fob for the EMS vehicle driver to engage onboard monitoring and feedback device

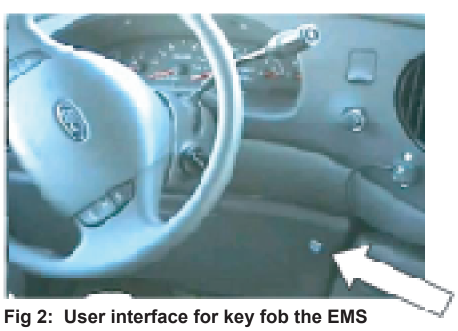

Fig 2: User interface for key fob the EMS vehicle driver

DISCUSSION

In stark contrast to other commercial and emergency vehicles on the road, formal safety performance standards, requirements and monitoring are lacking for ambulance transport in the USA. Additionally, the rear patient compartment of these vehicles is exempt from Federal Motor Vehicle Safety Standards, and these vehicles have been demonstrated to have high crash and injury rates per mile traveled. There are safety performance standards in Australia and Europe (Joint Standards Australia 1999; European Standards, CEN 1999), although real time monitoring is not uniform nor required by any of these nations. There are a number of modalities now being considered for enhancing ambulance transport safety. This study concurs with an earlier pilot that identified a sustained and dramatic improvement in safety performance and safety proxies with the use of this type of onboard driver monitoring and feedback device. Which is also in concordance with some preliminary data from Europe (De Graeve et al 2003; Calle et al 1999) using a similar technology. In Phase II, once the audible tones were switched on, there was a dramatic improvement in safety performance. In Phase III, once the driver identification via key fob was implemented, there was the most maximal and sustained improvement in safety performance.

There are some potential implementation issues with ensuring proper 'buy in' from staff, and the approach from a personnel and psychodynamic perspective appeared as successful in this study as in the previous pilot in Little Rock Arkansas. As identified in the previous study, there is the possibility of failure of staff cooperation with trading 'key fobs' or intentional damage to the equipment, which has been described anecdotally by some services in the USA. In addition it is possible in certain circumstances to 'trick' the current designed system, with some practices which are in fact risky, such as buckling the seat belt behind the driver, which would give the appearance of a decrease in violations or counts. However, once identified, it is possible to manage, monitor and to design out these practices.

The gold standard in true effectiveness is a decrease in both crash rate and near miss rate and a decreased injury rate. In other regions in the USA where this technology has been implemented there are reports of high rates of crash reduction (up to 90% reduction in crashes when compared to historical controls), and similar vehicle maintenance cost savings. Additional benefits to the use of this technology, from a systems perspective consideration that should be included in an evaluation of the impact of such a device as this technology on EMS system performance, is the reduction in administration time related to adverse event evaluation and management, in addition to mitigating resource loss and negative system response time impact that is the consequence of preventing a crash from occurring. Thus the positive impact of a reduction in crashes has a major positive flow on impact to the broader EMS system - as a result of decreased crash injuries, a decrease in loss of staff, no need for further EMS vehicles to be enlisted further to respond to an EMS crash scene and a decrease in administration down time and cost in reviewing and reconstructing as many crashes. None of these very real benefits have been included in the calculations of the over all cost benefit of the system in regards to improved safety. In vehicle maintenance cost savings alone, the improved performance has paid for the system implementation within 6 months. Detailed fiscal analysis is underway of all aspects of the direct cost of installing and maintaining the system, including the direct and indirect cost related to the monitoring of all the data gathered.

There is some administrative vigilance and time in oversight of this technology, however it is estimated to be far less time over all than would be consumed in management of the volume of adverse events in the absence of this technology. The data downloads automatically, and generates very clear graphical reports, which are far more time effective to review than previous administrative techniques and approaches, and yet far more comprehensive.

The limitations of this study include that the study was conducted in Allentown, which may not be considered a representative EMS environment for all of the USA. The study environment may also not be representative of the full spectrum of volunteer to professional, urban to rural and small to large EMS services, however in contrast to the Little Rock study some of the drivers in this study were volunteers. A more detailed analysis of driver performance addressing age, volunteer status and experience is underway. Additionally the device is not yet configured to monitor seat belt use in rear compartment, and the device is not yet linked to GIS for regional speed zones. It is important to note that this study suggests that the system implementation may well have had a positive impact on response times as there was a measured decrease in average response times with the system in place.

An important issue this study raises is the benefit of systems such as this for fleet safety management. A serious question raised is that if such systems can so effectively decrease adverse vehicle events and improve vehicle maintenance - then should these systems be implemented in all fleets particularly those that have high crash rates.

CONCLUSION

This study shows further evidence of a dramatic and sustained improvement in driver performance and vehicle safety in every measured area with this onboard computer monitoring and feedback system. Implementation of this system demonstrated to be a highly effective and sustainable approach to enhancing safety in ambulance transport, requiring minimal in-service training time and optimal safety outcome in addition to a cost savings in maintenance. Use of an on board computer system with real time monitoring and feedback should be encouraged for widespread implementation throughout the EMS system to optimize safety.

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