AN OPTIMAL SOLUTION FOR ENHANCING AMBULANCE SAFETY: IMPLEMENTING A DRIVER PERFORMANCE FEEDBACK AND MONITORING DEVICE IN GROUND EMERGENCY MEDICAL SERVICE VEHICLES

Nadine R. Levick, MD, MPH
Maimonides Medical Center
New York, NY

Jon Swanson
MetroEMS Executive Director
Little Rock, AR

ABSTRACT:

A prospective study was conducted to determine if emergency vehicle driver risk behavior could be improved with an onboard computer-monitoring device, with real time auditory feedback. Data were collected over 18 months from 36 vehicles in a metropolitan EMS group, with >250 drivers. In >1.9 million recorded miles, performance improved from a baseline low of 0.018 miles between penalty counts to a high of 15.8 miles between counts. Seatbelt violations dropped from 13,500 to 4. There was a 20% saving in vehicle maintenance costs within 6 months. This technology demonstrated sustained cost savings in regards to vehicle maintenance as well as minimal retraining of drivers.

BACKGROUND

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 here 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 sirens 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-D 1994) or regulations (Joint Standards Australia ASN/ZS 1999; European Standards CEN 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 ~ 8,500 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; Cook, Meador and Buckingham, 1991; 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 is the first of its type 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 modifying emergency vehicle driver behavior.

OBJECTIVE

The purpose of the study was to enhance the safety of emergency vehicle transport, and 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 an 18 month period. A metropolitan Emergency Medical Services (EMS) group with >250 drivers, installed the computer system in 36 ambulances in March 2003. 'Blind data', with no auditory feedback or driver identification were collected for 3 months initially. The system was fully operational with auditory feedback and driver identification from June 2003.

The environment in which this study was conducted was the Metro Emergency Medical Service (MEMS) of Little Rock, Arkansas. MEMS is a public, non-profit entity, created by the City of Little Rock in May, 84. Established by city charter as a Public Facilities Board. MEMS is governed by the Little Rock Ambulance Authority (LRAA) with 5 members from Little Rock and 2 from North Little Rock. Since 1984, MEMS has expanded into neighboring cities and counties. It now serves unincorporated Pulaski, Grant & Faulkner Counties and the cities of Maumelle, Lonoke, Sheridan & Conway, covering approximately 2400 square miles and a population of

500,000 people in Little Rock area with 58,000 total EMS calls in 2004. MEMS deploy 29 units daily with a mean response time of 6 minutes and covers 1.9 million miles annually. MEMS employs approximately 110 fulltime paramedics, 90 fulltime EMTs, and 101 other staff. MEMS has National Commission on Accreditation of Ambulance Services (CAAS) accreditation in 2001 and re-accreditation in 2004, and is funded entirely through fee for service – MEMS receives no local tax subsidies. MEMS serves as secondary Public Safety Answering Point (PSAP) to area 911 agencies – and provides all medical pre-arrival instructions directly to 911 callers. All ambulances are dispatched by MEMS own dispatch center. MEMS have started its own training academy for both paramedics and EMTs. Paramedic's attend paid, full-time 6 month program taught by University of Arkansas Medical School at MEMS. EMTs recruited with no prior training or experience taught by MEMS staff in a paid, full-time 6 week course at their facility.

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 MEMS, with at least one major serious crash annually and numerous less severe crashes and the recent published literature. 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.

HOW THE ONBOARD COMPUTER SYSTEM WORKS - The onboard computer system monitors a number of parameters every second (see table 1) and provides real time auditory feedback to the driver. 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", which is a simple device, which must be keyed into a special contact lock on the vehicle dashboard at the time of the vehicles ignition, 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. The onboard computer 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.

Table 1. Study Onboard Computer Device Settings

The MEMS Device Settings used in this pilot were:

Speed Cold (non emergency) Hot (emergency with lights and sirens)	15 second warning period - 74 / 78 mph - 84 / 88 mph
Cornering Low Over Force High Over Force	warning at 25% - 39% - 55%
Seat Belt Distance	- 2/10ths mile (.2 mile)

The monitoring/feedback system used by MEMS utilizes a 10 level scoring system (see table 2). The performance goal that was set for this pilot study was to aim for an average of 4 miles between penalty counts, a level 4 Average Between Counts (ABC) miles.

Table 2. Device Scoring System

Scoring System: ABC – Average Between Counts (ABC) miles			
Level	ABC	Level	ABC
1	< 1	6	16
2	1	7	32
3	2	8	64
4*	4	9	125
5	8	10	250

*Recommended goal based on system suppliers historical data in conjunction with Executive Director, MEMS – baseline ABC at MEMS was 0.018 miles

<u>System Implementation</u> **-** 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 November 2002 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 March 2003; ‘Blind data’ collection

thru mid April 2003; Growls and tones turned on mid April 2003 – however no key fobs utilized; The system was fully deployed in June 2003, with growls and tones and identifying key fobs fully implemented. The company was divided into two teams to foster some competitive spirit, and there was added incentive of a free lunch being offered for the best performing team. 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. Over 1.9 million miles of vehicle operations were recorded. Seatbelt violations dropped from 13,500 in April 2003 to 4 violations in August 2003 and were sustained at low rates thru to June 2004, a 3,375 fold reduction in seat belt violations. Similar trends were seen in over speed and over force parameters (see Figures 3 and 4). There was a 20% cost saving in vehicle maintenance within 6 months, with 10 - 20% less brake and tire wear and reduced oil consumption. This cost saving completely covered the implementation costs of the total system. There was no increase in response times, although call volume had increased substantially over the study period (see Figure 5). There was only one vehicle mishap in >1.9 million miles of operations and it was of a minor severity compared with the historical vehicle crash experience (see Figure 6 and 7). There was sustained improvement in safety proxies over 18 months, with no in-service or retraining after the initial introduction period. The system paid for itself in savings in maintenance costs alone with in 6 months, not including any of the cost savings in having a decreased number of crashes, decreased vehicle damage, and a decrease in the required investigations of those events. There were fewer crashes and less severe crashes than over the preceding similar time periods. Additionally, detailed data was captured in the one crash that occurred during the study period, and also the company was able to refute an allegation that a vehicle had stopped at a McDonald's enroute to the hospital and verify that the vehicle made no unscheduled stops enroute to the hospital. Overall performance improved from a baseline low of 0.018 miles between penalty counts (>56 counts/mile) to a high of 15.8 miles between each count, an 878 fold safety proxy improvement (see Figure 8).

Figure 1. The user interface for key fob the EMS vehicle driver

There were two steep declines in performance, despite the overall major improvements in performance – one in October 2003 and one in March 2004 (see Figure 8) – with a general decrease to a mean performance of approximately 4 miles between counts April 2004 to June 2004. The October 2003 trough in performance pertained to one driver alone who had been identified as performing poorly, and was to be reassigned but remained a driver into the following 4 week period and the performance data was only being reviewed monthly after that designation. The March trough was attributable to two events, 'back up spotters' when introduced into the data captured and also the vehicles went out for maintenance and were being driven by the mechanics.

Preliminary data subsequent to June 2004 is being analyzed currently with trends towards improved ABC miles with values above Level 4

Figure 2. March 2003 to June 2004 Seatbelt violation trend

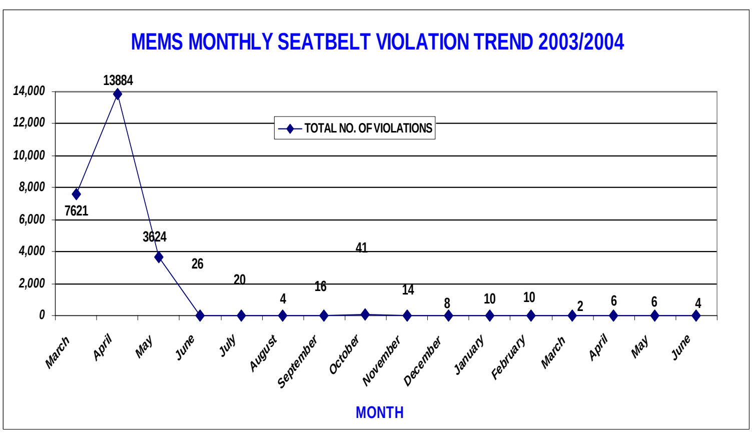


Figure 3. March 2003 to June 2004 Over speed violation trend

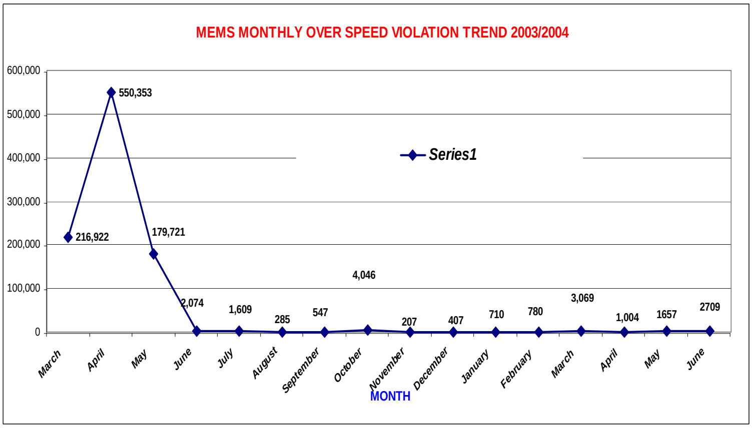


Figure 4. March 2003 to June 2004 Over force violation trend

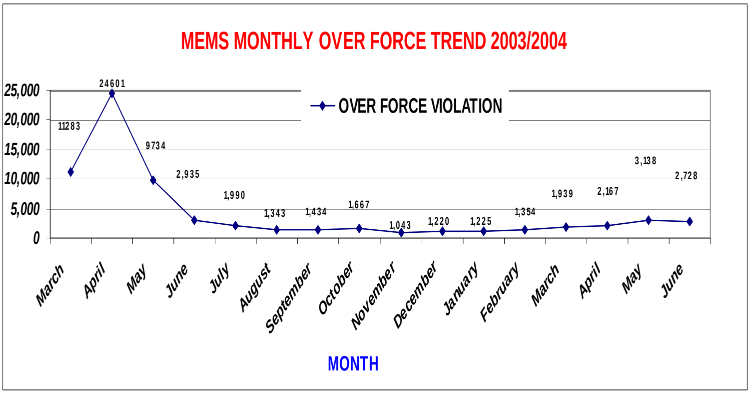


Figure 5. March 2003 to June 2004 Total Miles driven monthly trend

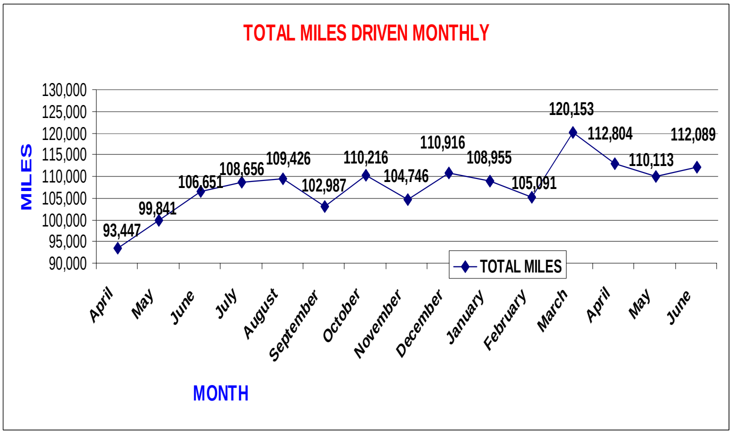


Figure 6. Vehicle crash data, recorded device parameters

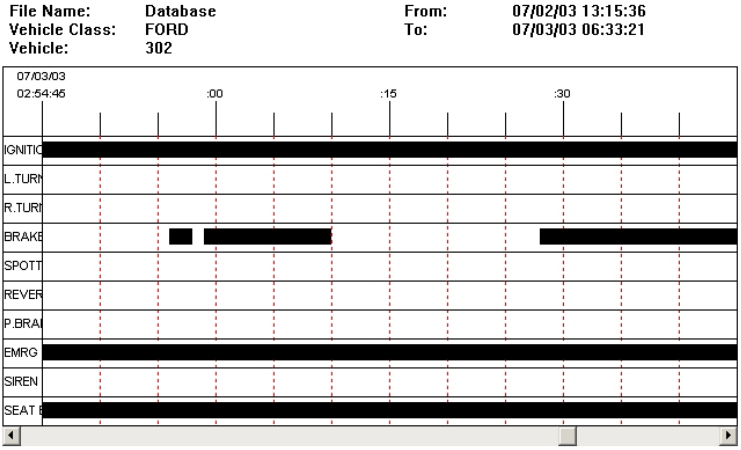


Figure 7. Vehicle crash data: speed

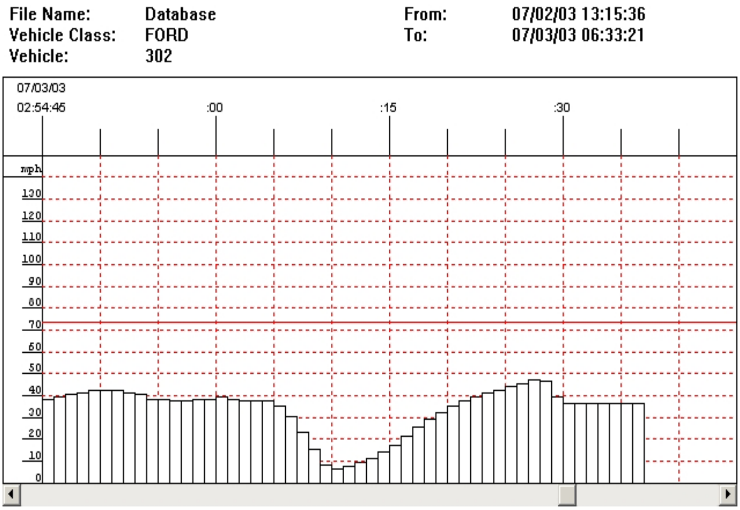
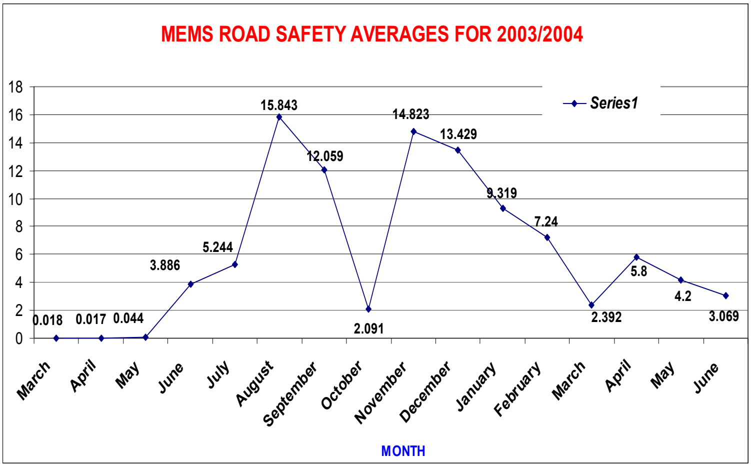


Figure 8. Safety performance: Average Btw Count Miles 2003-04



DISCUSSION

In contrast to most other vehicles on the road, formal safety performance standards, requirements and monitoring are lacking for ambulance transport in the USA. The rear patient compartment of these vehicles is exempt from Federal Motor Vehicle Safety Standards. 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 identifies a sustained and dramatic improvement in safety performance and safety proxies in this study, which is in concordance with some preliminary data from Europe (De Graeve et al 2003; Calle et al 1999) using a similar technology. The initial general trend in this study demonstrated a type of Hawthorne effect. During the first 4 weeks, the device was collecting silent 'blind data.' When comparing the first month (March 2003) of 'blind data' capture to the second month (April 2003) during Phase I, it appeared that the number of violations increased (see figures 2, 3, 4). It is assumed that in the first month, at commencement of data collection the drivers were initially very aware about the installation of the system as it had just been discussed extensively. Even though the system was 'silent' the drivers' behavior appeared to be influenced by this awareness which resulted in better performance than what would be expected prior to installation of the system. After 4 weeks and at the end of Phase I, with the device remaining silent, it appears the drivers became less attuned to its presence, driver performance had deteriorated markedly, and the Hawthorne effect appeared to have decreased substantially (see Figures 2,3,4) with the results showing a large peak in the number of violations in all parameters measured. It is assumed at the end of Phase I, the drivers returned more to their normal 'baseline' driving and safety habits having become less aware or somewhat less attentive to the system's presence and given that the system was silently recording data. 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 (see Figures 2, 3, 4).

To clarify the two recorded 'dips' in the data, October 2003 (2.091 ABC miles) and March 2004 (2.392 ABC miles) – The data was recalculated for these two data points, excluding the one driver for the October 2003 data, and excluding the mechanics for March 2003 The ABC resulting from this recalculation for October 2003 was 9.94 ABC miles, demonstrating the impact of the one driver on the ABC miles being in excess of 7 ABC miles. The recalculation for March 2003 resulted in a value of 6.9 ABC miles, demonstrating that the mechanics impact was 4.5 ABC miles.

There are some potential implementation issues with ensuring proper 'buy in' from staff, and the approach from a personnel and psychodynamic perspective appeared most successful in this 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 circumstance 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 and to design out these circumstances.

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 cost maintenance cost savings.

Other 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 a crash 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 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 Arkansas, 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. 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.

Also an increase in EMS call volume over the study period may have increased the expected actual baseline response times, thus a response time increase would have been anticipated in this study, which did not occur - which suggests that the system implementation may well have had a positive impact on response times as although there was no decrease in response times with the system in place an expected volume related increase in response times appeared to be mitigated.

An important issue this study raises is “Is it ethical to do any further studies?” of this type and even more importantly, given the now well described morbidity and mortality associated with EMS transport, and the dramatic improvement in safety with the use of this system

“Is it ethical NOT to have these devices in all EMS vehicles?”, given the safety benefit and cost savings demonstrated in this study.

CONCLUSION

There has been a dramatic and sustained improvement in driver performance in every measured area with this onboard computer monitoring and feedback system. Implementation of this system demonstrated to be 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 feedback and monitoring should be encouraged for widespread implementation throughout the EMS system to optimize safety.

ACKNOWLEDGEMENTS

Much appreciation to Mr. David Mener and Mr. Antonios Likourezos for their contributions to preparing the manuscript.

REFERENCES:

Auerbach PS., Morris JA., Phillips JB., Redlinger SR., Vaughn WK An Analysis of Ambulance Accidents in Tennessee. JAMA, **258** (11): 1487-90; 1987.

Becker LR., Zaloshnja E., Levick N., Miller TR. Relative Risk of Injury and Death in Ambulances and Other Emergency Vehicles. Accident Analysis and Prevention, **35:** 941-8; 2003.

Best GH., Zivkovic G., Ryan GA. Development of an Effective Ambulance Patient Restraint. Society of Automotive Engineering Australasia Journal, **53** (1): 17-21; 1993.

Biggers WA., Zachariah BS., Pepe PE. Emergency Medical Vehicle Collisions in an Urban System. Prehospital and Disaster Medicine, July-Sept., 1996.

Calle P., Fonck K., Buylaert W. Collisions Involving Mobile Intensive Care Units in Flanders, Belgium. European Journal of Emergency Medicine, **6**(4): 349-353; 1999.

Calle PA., Lagaert L., Houbrechts H., Vanhaute O., Vanoverschelde H., Buylaert WA. Evaluation of a Training Course for Emergency Medical Dispatchers in Belgium: A Prospective Intervention Study. Pre-hospital Immediate Care, **3**: 196-202; 1999.

Center for Disease Control, MMWR. Ambulance Crash-Related Injuries Among Emergency Medical Services Workers - United States, 1991—2002. **52**(8): 154-6; 2003.

Cook RT., Meador SA., Buckingham BD., Groff LV. Opportunity for Seatbelt Usage by ALS Providers. Prehospital and Disaster Medicine, **6**(4): 469-71; 1991.

De Graeve K., Deroo KF., Calle PA., Vanhaute OA., Buylaert WA. How to Modify the Risk-taking Behaviour of Emergency Medical Services' Drivers? European Journal of Emergency Medicine, **10**(2): 111-116; 2003.

Emergency Medical Services of Children (EMSC)/Nationla Highway Traffic Safety Administration (NHTSA) Federal Guidelines Child Restraint for Ambulance Transport, Do's and Don't's of Transporting Children in Ambulances. http://www.nhtsa.dot.gov, or http://www.ems-c.org. published - December 1999.

European Ambulance Restraint Systems Standards CEN, European Committee for Standardization, EN **1789**:1999.

General Services Administration, Federal Ambulance Specification KKK-A- 1822D, Automotive Commodity Center, Federal Supply Service. Nov 1994.

Joint Standards Australia/Standards New Zealand Committee ME/48 on Restraint Systems in Vehicles, Standards for Ambulance Restraint Systems, ASN/ZS **4535:**1999.

Erich J. Ambulance Safety: What's New, What's Needed. Emergency Medical Services Magazine, http://www.emsmagazine.com/issues/ambulancesafety.html. June 2002.

Erich J. Wheels of Fortune, Vehicle Safety in EMS. Emergency Medical Services Magazine, http://www.emsmagazine.com/articles/emsarts/wheel.html. April 2001.

Kahn CA., Pirrallo RG., Kuhn EM. Characteristics of Fatal Ambulance Crashes in the United States: An 11-Year Retrospective Analysis. Prehospital Emergency Care, **5**(3):261-9; 2001.

Levick NR. A Crisis in Ambulance Safety. Emergency Response and Disaster Management, **4**: 20-22; 2002

Levick NR, Editorial, - New Frontiers in Optimizing Ambulance Transport Safety and Crashworthiness. UK Journal-The Paramedic, **4**: 36-39; 2002.

Levick NR., Better AI., Grabowski JG., Li G., Smith G. Injury Hazards in Pediatric Ambulance, Poster Presentation: Pediatric Academic Societies and American Academy of Pediatrics Joint Meeting, Boston, May 2000.

Levick NR., Donnelly BR., Blatt A., Gillespie G., Schultze M. Ambulance Crashworthiness and Occupant Dynamics in Vehicle-to-Vehicle Crash Tests: Preliminary Report, Enhanced Safety of Vehicles, Technical Paper Series. Paper # 452. http://www-nrd.nhtsa.dot.gov/pdf/nrd-01/esv/esv17/proceed/00012.pdf. May 2001.

Levick NR., Li G., Yannaccone J. Biomechanics of the Patient Compartment of Ambulance Vehicles Under Crash Conditions: Testing Countermeasures to Mitigate Injury, Society of Automotive Engineering, Technical Paper Series. Paper 2001-01-1173. http://www.sae.org March 2001.

Levick NR., Li G., Yannaccone J. Development of a Dynamic Testing Procedure to Assess Crashworthiness of the Rear Patient Compartment of Ambulance Vehicles. Enhanced Safety of Vehicles, Technical Paper Series. Paper # 454. http://www-nrd.nhtsa.dot.gov/pdf/nrd-01/esv/esv17/proceed/00053.pdf. May 2001.

Levick NR., Winston F., Aitken S., Freemantle R., Marshall F., Smith G. Development and Application of a Dynamic Testing Procedure for Ambulance Pediatric Restraint Systems. Society of Automotive Engineering Australasia, **58**(2): 45-51; 1998.

Maguire BJ., Hunting KL., Smith GS., Levick NR., Occupational Fatalities in Emergency Medical Services: A Hidden Crisis. Annals of Emergency Medicine, **40**: 625-32; 2002.

National Highway traffic Safety Administration (NHTSA), Fatality Analysis Reporting System (FARS), 1987-2003

Saunders CE., Heye CJ. Ambulance Collisions in an Urban Environment. Prehospital and Disaster Medicine, **9**(2): 118-124; 1994

Traffic Safety Facts 1998-2003: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System. U.S. Department of Transportation/National Highway Traffic Safety Administration.

Weiss SJ., Ellis R., Ernst AA., Land RF., Garza A. A Comparison of Rural and Urban Ambulance Crashes. American Journal of Emergency Medicine, **19**:52-56; 2001