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Cardiac arrest survival did not increase in the Resuscitation Outcomes Consortium after implementation of the 2005 AHA CPR and ECC guidelines

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Abstract

Introduction—We examined the effect of the 2005 American Heart Association guidelines on survival in the Resuscitation Outcomes Consortium (ROC) Cardiac Arrest Epistry.

Methods—We surveyed 174 EMS agencies from 8 of 10 ROC sites to determine 2005 AHA guideline implementation, or crossover, date. Two sites with 2005 compatible treatment algorithms prior to guideline release, and agencies that did not adopt the new guidelines during the study period were excluded. Non-traumatic adult cardiac arrests that were not witnessed by EMS, and did not have do not resuscitate orders were included. A linear mixed effects model was applied for survival controlling for time and agency. The "crossover" date was added to the model to determine the effect of the 2005 guidelines.

Results—Of 174 agencies, 85 contributed cases to both cohorts during the 18 month period between 2005/12/01 and 2007/05/31. Of 7779 cases, 5054 occurred during the 13 month (median) interval before crossover and 2725 occurred in the five month (median) interval after crossover. The overall survival rate was 6.1%; 5.8% in the old cohort vs 6.5%, p=0.23. For VF/VT patients, survival was 14.6% vs 18.0%, p=0.063. Our model estimated no increase in survival over time (monthly OR 1.014, 95% CI 0.988, 1.041, p=0.28).

Conclusion—This study found no significant change in survival rate over time in the early months after implementation. Further longitudinal study is needed to determine the full impact of the guidelines on survival and methods to translate knowledge quickly and effectively in EMS.

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Introduction

Cardiac arrest is a leading cause of death around the world[1]. To improve survival following cardiac arrest, the International Liaison Committee on Resuscitation (ILCOR) systematically reviews the evidence involving resuscitation and publishes consensus recommendations every five years[2]. In 2005, the American Heart Association and Heart and Stroke Foundation of Canada released updated cardiac arrest guidelines based on these recomendations[3]. These updated guidelines replaced stacked defibrillator shocks with single shocks, increased CPR intervals from 1 to 2 minutes, and removed post-shock pulse checks, all in an effort to increase the proportion of time spent performing CPR. Whether these evidence-based guidelines result in improved patient care and outcomes is largely unmeasured.

It is well known that only about half of all patients are treated with evidence-based medicine[4]. This disconnect between published science and pragmatic adoption into clinical practice is the nemesis that has sparked knowledge translation research[5]. Knowledge translation in EMS systems has been identified to be particularly challenging[6, 7], yet is critical to address as EMS providers are the first to encounter most cardiac arrest patients. We have previously evaluated knowledge translation of the 2005 guidelines among EMS agencies participating in the Resuscitation Outcomes Consortium (ROC)[8], a clinical trials network that studies prehospital interventions for cardiac arrest care[9]. Surveyed EMS agencies implemented 2005 guidelines into field practice an average 14 months after the guidelines were published, though the time required to implement was highly variable across agencies (range of 49-750 days, mean of 416 days and SD 174 days).

We sought to evaluate if survival to hospital discharge improved in the months following 2005 guideline implementation in ROC EMS agencies.

Methods

Study Design, Setting, and Subjects

We conducted a prospective cohort study of persons suffering out-of-hospital cardiac arrest between December 1, 2005 and May 31, 2007 who were treated by EMS agencies participating in ROC. ROC consists of 10 coordinating centers covering 11 regions across North America and was created to study out-of-hospital cardiac arrest and life threatening trauma[9]. Three of the regions are Canadian while 8 are American. These 10 coordinating centers have 264 separate EMS agencies participating in a population based registry and clinical trials[9]. We excluded two centres because their EMS agencies were employing cardiac arrest protocols similar to the 2005 guidelines prior to the release of the guidelines. We excluded air transport agencies and agencies that did not contribute cases to both cohorts.

We excluded traumatic cardiac arrest, EMS witnessed cardiac arrests, patients <18 years of age, and patients with do-not-resuscitate orders. We excluded cases occurring after May 31, 2007 because of the roll-out of a ROC randomized controlled trial[10, 11]. This study was approved by the appropriate institutional review boards.

Defining pre- and post-2005 guideline implementation

We invited 178 EMS agencies in the remaining eight centers to participate in a brief telephone survey, described previously, regarding cardiac arrest guideline implementation to determine the month and year field providers began treating patients with algorithms consistent with the 2005 guidelines[8]. We defined the implementation date as the date an agency reported comprehensive implementation of the 2005 AHA guidelines for CPR and

Emergency Cardiovascular Care had occurred (either the “go-live” date or the end of a “rolling start” after sequential training of providers). We chose the first day of the month when only a month was given by the respondent. Each patient was placed into the “old” guidelines cohort (treated with the previously published guidelines from 2000) or the 2005 guidelines cohort based on the date of their cardiac arrest and the implementation date of the agency that treated them.

Outcome and covariates

The primary outcome was survival to hospital discharge regardless of neurologic status. We used the ROC Epistry – Cardiac Arrest to determine survival status as well as information regarding core Utstein data elements [12]. Information was collected about patient demographics, arrest circumstances, and prehospital care using a standard set of data definitions and collection forms.

Statistical Analysis

Characteristics and outcome were summarized overall and according to guideline cohort using descriptive statistics. Differences in proportions of death were compared using likelihood ratio chi-square tests. For the primary analysis, a generalized linear mixed model was fit with survival to hospital discharge as the outcome. This model was chosen a priori, as the most straightforward and appropriate model that could capture changes in survival associated with calendar time and associated with the implementation of the 2005 guidelines, while accounting for potential confounding due to EMS agency. Fixed effects included time, guideline use, and an interaction between these two. Random effects included an intercept term for the agency. This model fits the log-odds of survival as a function of the main effects of time and guideline implementation while accounting for multiple agencies. An alpha of 0.05 was considered statistically significant; no adjustments were made for multiple comparisons. The data analysis for this paper was generated using SAS software, Version 9.1 of the SAS System for Windows (SAS Institute Inc., Cary, NC, USA.).

Results

We contacted 178 EMS agencies and received responses from 176 agencies (99%). Two agencies had not implemented the AHA guidelines (1%) and were excluded. Of the remaining174 agencies, 83 contributed cases to both cohorts during the 18 month period between 2005/12/01, when ROC data collection began, and 2007/05/31, when clinical trials were rolled out. Characteristics of these agencies are reported in Table 1. Of 7779 cases occurring in these 85 agencies, 5054 occurred during the 13 month (median) interval before guideline implementation and 2725 occurred in the five month (median) interval after implementation.

Summary statistics of subjects are presented in Table 2. The overall survival rate was 6.1%. Survival in the “old” guideline cohort was 5.8% (294/5054) and 6.5% (177/2725) in the 2005 guideline cohort (p=0.23). Our regression model estimated no change in survival over time (monthly OR 1.014, 95% CI 0.988, 1.041, p=0.28). Results did not differ for the subgroup of VF/VT patients (14.6%, 165/1129 in the old cohort and 18.0%, 116/645, in the 2005 cohort, p=0.063).

Discussion

In this cohort investigation of out-of-hospital cardiac arrest, we did not observe statistically significant survival improvement during the first 5 months following implementation of the 2005 guidelines among ROC EMS systems. While the VF/VT cohort did have an absolute

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survival increase of 3.4%, an increase we consider clinically significant, statistical significance was not reached.

Two stages to knowledge transfer in EMS: System and Individual

While ILCOR and the Resuscitation Councils have developed evidence based guidelines, the process of translating the guidelines into practice is challenging. The 2005 guidelines were published on December 13, 2005. ROC EMS organizations reported implementing the guidelines an average of 416 days later[8]. Further, there was no statistically significant change in survival for five months following system implementation, suggesting that clinical practice may not have changed in accordance to the guidelines within this short timeframe.

Barriers to system implementation have been identified by our previous qualitative research; training barriers and delays to upgrade defibrillators were experienced in more than one third of EMS services and nearly half reported decision-making delays from regulators, base hospitals, ROC research efforts or allied response agencies[7]. Delays associated with coordinating implementation across allied resources (i.e. fire and police agencies) and regulator decision-making have been identified in Europe as well[13]. Also in Europe, language translation of the guidelines delayed the initiation of provider training[13]. Sasson has further identified several operational barriers that hamper implementation of research in the EMS setting including a lack of communication between medical directors, online patch physicians and field providers[36].

Our data suggest that the second stage of implementation, at the level of the individual clinician, may contribute to similar survival rates in both time intervals. Despite system-level implementation of the guidelines by training prehospital care providers to follow protocols, we did not observe a statistically significant survival increase in the 5 month period post-implementation. One explanation that should not be discounted is that the guidelines have no effect on survival. Few studies cited by the Guidelines are randomized controlled trials, and many of the recommendations made in the Guidelines are based on retrospective reviews, animal data and expert consensus. Second, we did find a clinically significant difference of 10% in all rhythms, and 23% in VF/VT rhythms, but failed to reach statistical significance in our underpowered sample. Further multicentre surveillance has the potential to allow for adequately powered studies in the future.

However, several studies have observed an increase in survival after implementation of EMS resuscitation protocols compatible with the 2005 Guidelines. Sayre identified improved CPR quality during a two year period after implementation of the 2005 guidelines, which was associated with improved survival compared to the pre-2005 guideline era (6.1% vs 9.4%, OR 1.6, CI 1.1-2.4)[37]. Rea's observational study found that survival rates among bystander witnessed VF cardiac arrests increased from 33% to 46% (p=0.008)[14]. A retrospective review by Garza found that survival after EMS treated cardiac arrest increased from 7.5% to 13.9% (CI 1.2-2.7)[15]. Bobrow conducted a before-after study and observed an increase in EMS treated cardiac arrest survival from 1.8% to 5.4% (CI 1.1-8.6) and an increase in witnessed VF cardiac arrest survival from 4.7% to 17.6% (CI 1.0-19.1)[16].

Another explanation for the current null finding is that the effectiveness of the new guidelines may require time for providers to become practiced and proficient so that the guideline changes can produce robust changes in field care and in turn translate to better survival. Berdowski et al used CPR process data to analyze out-of-hospital cardiac arrests occurring peri-implementation and reported that 80% of cardiac arrests were compliant with the new guidelines five months after the start of new guideline training[13]. This training did not begin until twelve months after release of the guidelines, similar to our findings in North

America. This means that seventeen months elapsed between guideline publication and achieving a guideline compliance rate of 80%.

Berdowski found that one year after training, guideline compliance rates were still below 90%. Unfortunately, not all ROC sites were capable of routinely collecting CPR process data during our study period and we cannot assess if non-compliance at this level of measurement contributed to the lack of observed difference in the survival rate of our study population. However, we hypothesize that the 2005 guidelines required a rechoreography of cardiac arrest care and this may have initially confused providers and contributed to a reduction in the quality of their resuscitation efforts shortly after retraining. Most providers see few cardiac arrests each year. Perhaps over time, once they achieved efficiency in motion, kinetic synchrony and high quality compressions, increase in survival may surpass the rate observed in the years served by the 2000 guidelines as it seems to have in other studies examining survival over longer periods of time. Improved training or simulation exercises ("mock codes") could improve provider competency in this context. Consequently, strategies that enhance provider performance of CPR and cardiac arrest care should continue to be an important area of investigation.

The Impact of Delayed Implementation

Nichol has previously calculated that as many as 294,851 EMS-assessed cardiac arrest cases occur each year in the United States, and a further 32,160 cases occur in Canada[17]. Using these data, during the 18 month period after the release of the AHA guidelines, 490,517 North Americans suffered an EMS-assessed cardiac arrest (294,851 + 32,160 × (18 / 12)). If we extrapolate using the survival rate of Bobrow's pre-implementation period, 8829 patients would have survived during these 18 months (490,517 × 0.018). Applying the survival rate from Bobrow's 2 year post-implementation period, 27,959 (463,266 × 0.057) patients would have lived, representing 19,000 additional lives saved. While this extrapolation is limited, it highlights the importance of quickly translating scientific knowledge into clinical practice to achieve better health outcomes.

From Knowledge to Action in EMS: What can be done to improve care?

Knowledge translation research in the EMS field is lacking[6] despite reports that evidence-based guidelines are often not followed. For example, one study found that fewer than 30% of EMS providers were aware of pediatric defibrillation guidelines and only one third had access to pediatric defibrillation pads[18]. This challenge is not specific to EMS and perhaps our survival rate related findings are generalizeable to other health care settings such as hospitals and long term care facilities where poor adherence to resuscitation guidelines by clinicians working in hospitals has already been observed[19, 20]. Nor is the challenge specific to cardiac arrest resuscitation. In emergency departments, overall advanced trauma life support protocol adherence was measured to be 42%[21], and post arrest therapeutic hypothermia is still underused in patients who achieve circulatory stability[22, 23] and a large retrospective study found that only half of all acutely ill patients are treated in accordance with scientific evidence[4]. New evidence will not improve health outcomes unless EMS systems, organizations and providers agree with the science and adopt it[24].

Graham has identified that organizations that develop guidelines often neglect to evaluate the dissemination or clinical effects of guidelines[25]. While our prior work has discussed facilitating system-level implementation using classic theories of knowledge translation, strategies to improve individual clinician behaviour are less clear and require further study[24, 26]. In Graham's "knowledge to action" cycle, there is a stage to "monitor knowledge use" prior to evaluating outcomes. Here, defined changes in behavior and practice that may have a clinical effect are measured; once compliance is reached, outcomes can be assessed[27]. Both qualitative and quantitative methods may be employed to measure attitudes, behaviour, agreement, adoption and knowledge use[28] but research on strategies to improve compliance and relevant clinical outcomes is sparse.

The amount of time required for providers to become proficient in applying cardiac arrest guidelines is not clear and requires further research. It is likely that improved high fidelity simulation training will improve competency. To accomplish further adherence to guidelines in the hectic prehospital setting, real-time feedback of biometrics such as compression depth, compression rate, ventilation rate and end-tidal carbon dioxide values may be helpful[29-32] in achieving guideline compliance. Further, the use of checklists has been successful in other medical settings and may be applicable to EMS[33, 34] to improving adoption and adherence to guideline recommendations as routine practice.

Limitations

Our study has several limitations. We were unable to reach a sample size with adequate power due to the start of randomized trials in the ROC network, and thus have a convenience sample with an approximate power of 0.24 for our comparison of two proportions (2 sided significance of 0.05, absolute difference of 0.07%). For VF/VT cases, the power is approximately 0.47. Further longitudinal study over a greater period of time may be required to determine the full impact of the guidelines on survival. We know that there is significant site variation in resuscitation outcomes across ROC sites and EMS agencies[17]. We suspect these confounders were not completely accounted for in our mixed-effects regression model and would ideally be controlled for in a randomized trial design. ROC EMS agencies may be systematically different from other agencies because of their participation in the consortium and their association with academic hospitals, which may be more proactive implementing evidence-based guidelines. The Hawthorne effect of participating in a trial consortium may have affected performance in both the before and after cohort[35]. Media reports of the 2005 guidelines, particularly the new 30:2 compression:ventilation ratio, may have affected patient care in the “before” cohort. Lastly, we were not able to assess quality of the resuscitations to understand what was actually done; the lack of consistent CPR process data throughout the time frame of comparison does not allow us to assess this level of compliance to guidelines.

Conclusion

Survival from EMS treated cardiac arrest did not significantly improve in the five months following implementation of the 2005 AHA guidelines in ROC EMS agencies. Resuscitation science is a fast-paced field; the ability to rapidly and diligently implement scientific guidelines into practice is needed. Knowledge translation strategies must be creatively developed, rigorously tested, easy to implement and widely distributed to ensure every patient is treated in line with the best available science and to evaluate the true impact of new guidelines on health outcomes.

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References

1. Zheng ZJ, Croft JB, Giles WH, Mensah GA. Sudden cardiac death in the United States, 1989 to 1998. Circulation. 2001; 104(18):2158–2163. [PubMed: 11684624]
2. 2005 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. Part 1: introduction. Resuscitation. 2005; 67(2-3): 181–186. [PubMed: 16324987]
3. 2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2005; 112(24 Suppl):IV1–203. [PubMed: 16314375]
4. McGlynn EA, Asch SM, Adams J, Keesey J, Hicks J, DeCristofaro A, Kerr EA. The quality of health care delivered to adults in the United States. N Engl J Med. 2003; 348(26):2635–2645. [PubMed: 12826639]
5. Lang ES, Wyer PC, Eskin B. Executive summary: Knowledge translation in emergency medicine: establishing a research agenda and guide map for evidence uptake. Acad Emerg Med. 2007; 14(11): 915–918. [PubMed: 17923716]
6. Cone DC. Knowledge translation in the emergency medical services: a research agenda for advancing prehospital care. Acad Emerg Med. 2007; 14(11):1052–1057. [PubMed: 17761547]
7. Bigham BL, Aufderheide TP, Davis DP, Powell J, Donn S, Suffoletto B, Nafziger S, Stouffer J, Morrison LJ. Knowledge translation in emergency medical services: a qualitative survey of barriers to guideline implementation. Resuscitation. 2010; 81(7):836–840. [PubMed: 20398994]
8. Bigham BL, Koprowicz K, Aufderheide TP, Davis DP, Donn S, Powell J, Suffoletto B, Nafziger S, Stouffer J, Idris A, Morrison LJ. Delayed prehospital implementation of the 2005 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiac care. Prehosp Emerg Care. 2010; 14(3):355–360. [PubMed: 20388032]
9. Davis DP, Garberson LA, Andrusiek DL, Hostler D, Daya M, Pirrallo R, Craig A, Stephens S, Larsen J, Drum AF, Fowler R. A descriptive analysis of Emergency Medical Service Systems participating in the Resuscitation Outcomes Consortium (ROC) network. Prehosp Emerg Care. 2007; 11(4):369–382. [PubMed: 17907019]
10. Aufderheide TP, Kudenchuk PJ, Hedges JR, Nichol G, Kerber RE, Dorian P, Davis DP, Idris AH, Callaway CW, Emerson S, Stiell IG, Terndrup TE. Resuscitation Outcomes Consortium (ROC) PRIMED cardiac arrest trial methods part 1: rationale and methodology for the impedance threshold device (ITD) protocol. Resuscitation. 2008; 78(2):179–185. [PubMed: 18487005]
11. Stiell IG, Callaway C, Davis D, Terndrup T, Powell J, Cook A, Kudenchuk PJ, Daya M, Kerber R, Idris A, Morrison LJ, Aufderheide T. Resuscitation Outcomes Consortium (ROC) PRIMED cardiac arrest trial methods part 2: rationale and methodology for "Analyze Later vs. Analyze Early" protocol. Resuscitation. 2008; 78(2):186–195. [PubMed: 18487004]
12. Morrison LJ, Nichol G, Rea TD, Christenson J, Callaway CW, Stephens S, Pirrallo RG, Atkins DL, Davis DP, Idris AH, Newgard C, Investigators ROC. Rationale, development and implementation of the Resuscitation Outcomes Consortium Epistry-Cardiac Arrest. Resuscitation. 2008; 78(2):161–169. [PubMed: 18479802]
13. Berdowski J, Schmohl A, Tijssen JG, Koster RW. Time needed for a regional emergency medical system to implement resuscitation Guidelines 2005--The Netherlands experience. Resuscitation. 2009; 80(12):1336–1341. [PubMed: 19766376]
14. Rea TD, Helbock M, Perry S, Garcia M, Cloyd D, Becker L, Eisenberg M. Increasing use of cardiopulmonary resuscitation during out-of-hospital ventricular fibrillation arrest: survival implications of guideline changes. Circulation. 2006; 114(25):2760–2765. [PubMed: 17159062]
15. Garza AG, Gratton MC, Salomone JA, Lindholm D, McElroy J, Archer R. Improved patient survival using a modified resuscitation protocol for out-of-hospital cardiac arrest. Circulation. 2009; 119(19):2597–2605. [PubMed: 19414637]
16. Bobrow BJ, Clark LL, Ewy GA, Chikani V, Sanders AB, Berg RA, Richman PB, Kern KB. Minimally interrupted cardiac resuscitation by emergency medical services for out-of-hospital cardiac arrest. JAMA. 2008; 299(10):1158–1165. [PubMed: 18334691]

17. Nichol G, Thomas E, Callaway CW, Hedges J, Powell JL, Aufderheide TP, Rea T, Lowe R, Brown T, Dreyer J, Davis D, Idris A, Stiell I. Regional variation in out-of-hospital cardiac arrest incidence and outcome. JAMA. 2008; 300(12):1423–1431. [PubMed: 18812533]
18. Haskell SE, Kenney MA, Patel S, Sanddal TL, Altenhofen KL, Sanddal ND, Atkins DL. Awareness of guidelines for use of automated external defibrillators in children within emergency medical services. Resuscitation. 2008; 76(3):354–359. [PubMed: 17936491]
19. Abella BS, Alvarado JP, Myklebust H, Edelson DP, Barry A, O'Hearn N, Vanden Hoek TL, Becker LB. Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. JAMA. 2005; 293(3):305–310. [PubMed: 15657323]
20. Abella BS, Sandbo N, Vassilatos P, Alvarado JP, O'Hearn N, Wigder HN, Hoffman P, Tynus K, Vanden Hoek TL, Becker LB. Chest compression rates during cardiopulmonary resuscitation are suboptimal: a prospective study during in-hospital cardiac arrest. Circulation. 2005; 111(4):428–434. [PubMed: 15687130]
21. Spanjersberg WR, Bergs EA, Mushkudiani N, Klimek M, Schipper IB. Protocol compliance and time management in blunt trauma resuscitation. Emerg Med J. 2009; 26(1):23–27. [PubMed: 19104091]
22. Bigham BL, Dainty KN, Scales DC, Morrison LJ, Brooks SC. Predictors of adopting therapeutic hypothermia for post-cardiac arrest patients among Canadian emergency and critical care physicians. Resuscitation. 2009; 81(1):20–24. [PubMed: 19913981]
23. Kennedy J, Green RS, Stenstrom R. The use of induced hypothermia after cardiac arrest: a survey of Canadian emergency physicians. CJEM. 2008; 10(2):125–130. [PubMed: 18371250]
24. Graham ID, Tetroe J, Group KTTR. Some theoretical underpinnings of knowledge translation. Academic Emergency Medicine. 2007; 14(11):936–941. [PubMed: 17967955]
25. Graham ID, Beardall S, Carter AO, Tetroe J, Davies B. The state of the science and art of practice guidelines development, dissemination and evaluation in Canada. J Eval Clin Pract. 2003; 9(2): 195–202. [PubMed: 12787183]
26. Graham ID, Tetroe J. Whither knowledge translation: an international research agenda. Nurs Res. 2007; 56(4 Suppl):S86–88. [PubMed: 17625480]
27. Graham ID, Logan J, Harrison MB, Straus SE, Tetroe J, Caswell W, Robinson N. Lost in knowledge translation: time for a map? J Contin Educ Health Prof. 2006; 26(1):13–24. [PubMed: 16557505]
28. Straus SE, Holroyd-Leduc J. Knowledge-to-action cycle. Evid Based Med. 2008; 13(4):98–100. [PubMed: 18667658]
29. Abella BS, Edelson DP, Kim S, Retzer E, Myklebust H, Barry AM, O'Hearn N, Hoek TL, Becker LB. CPR quality improvement during in-hospital cardiac arrest using a real-time audiovisual feedback system. Resuscitation. 2007; 73(1):54–61. [PubMed: 17258853]
30. Beckers SK, Skorning MH, Fries M, Bickenbach J, Beuerlein S, Derwall M, Kuhlen R, Rossaint R. CPREzy improves performance of external chest compressions in simulated cardiac arrest. Resuscitation. 2007; 72(1):100–107. [PubMed: 17079067]
31. Kramer-Johansen J, Myklebust H, Wik L, Fellows B, Svensson L, Sorebo H, Steen PA. Quality of out-of-hospital cardiopulmonary resuscitation with real time automated feedback: a prospective interventional study. Resuscitation. 2006; 71(3):283–292. [PubMed: 17070980]
32. Leary M, Abella BS. The challenge of CPR quality: improvement in the real world. Resuscitation. 2008; 77(1):1–3. [PubMed: 18325434]
33. Haynes AB, Weiser TG, Berry WR, Lipsitz SR, Breizat AH, Dellinger EP, Herbosa T, Joseph S, Kibatala PL, Lapitan MC, Merry AF, Moorthy K, Reznick RK, Taylor B, Gawande AA. A surgical safety checklist to reduce morbidity and mortality in a global population. N Engl J Med. 2009; 360(5):491–499. [PubMed: 19144931]
34. Verdaasdonk EG, Stassen LP, Widhiasmara PP, Dankelman J. Requirements for the design and implementation of checklists for surgical processes. Surg Endosc. 2009; 23(4):715–726. [PubMed: 18636292]
35. Campbell JP, Maxey VA, Watson WA. Hawthorne effect: implications for prehospital research. Ann Emerg Med. 1995; 26(5):590–594. [PubMed: 7486367]

Table 1

Summary statistics of included EMS agencies.

	N	Mean days to crossover[1]
Organizational structure[2]		
Fire Department	51	338
Governmental, Non-Fire	20	338
Private, Non-Hospital	7	327
Other	4	215
Number of vehicles[3]		
1 - 5	11	244
6 – 10	15	381
11 - 50	49	338
51+	7	336

[1]Mean days to crossover based on last day of month.

[2]p-value = 0.28 for ANOVA test of equality of means.

[3]p-value = 0..04 for ANOVA test of equality of means. Tukey's multiple comparison procedure gives a p-value <0.05 for comparing the means of the first two categories.

Table 2

Summary statistics of subject and episode characteristics*.

	Overall	Before	After	p-value
Number of events	7403	4897	2506	NA
Age – mean (sd)	65.3 (16.9)	65.0 (16.8)	65.8 (16.9)	0.038
Male – N (%)	4873 (62.7)	3179 (63.0)	1694 (62.3)	0.54
Public Location – N (%)	1196 (15.4)	759 (15.0)	437 (16.1)	0.23
Home – N (%)	5582 (71.8)	3658 (72.4)	1924 (70.7)	0.10
Response time – mean (sd)	5.8 (8.9)	5.8 (10.7)	5.7 (3.7)	0.54
ALS among responders – N (%)	7270 (93.5)	4622 (91.5)	2648 (97.2)	<0.0001
Bystander witnessed – N (%)	3117 (46.5)	1999 (45.4)	1118 (48.6)	0.012
Bystander CPR – N (%)	2395 (30.8)	1449 (28.7)	946 (34.7)	<0.0001
Initial EMS rhythm VT/VF – N (%)	1774 (23.5)	1129(23.1)	645 (24.2)	0.28
EMS schocked – N (%)	2637 (33.9)	1669 (33.1)	968 (35.5)	0.03

* For continuous variables mean and standard deviation are of those with non-missing values. For discrete variables the number and percent are of subjects with non-missing values.