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Clinical Paper

Volume versus outcome: More emergency medical services personnel on-scene and increased survival after out-of-hospital cardiac arrest☆

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ABSTRACT

Background and aim: : The large regional variation in survival after treatment of out-of-hospital cardiac arrest (OHCA) is incompletely explained. Communities respond to OHCA with differing number of emergency medical services (EMS) personnel who respond to the scene. The effect of different numbers of EMS personnel on-scene upon outcomes is unclear. We sought to evaluate the association between number of EMS personnel on-scene and survival after OHCA.
Methods: We performed a retrospective review of prospectively collected data on 16,122 EMS-treated OHCA events from December 1, 2005 to May 31, 2007 from a combined population over 21 million people residing in an area of over 33,000 square miles in Canada and the United States. Number of EMS personnel on-scene was defined as the number of EMS personnel who responded to the scene of OHCA within 15 min after 9-1-1 call receipt and prior to patient death or transport away from the scene. Associations with survival to hospital discharge were assessed by using generalized estimating equations to construct multivariable logistic regression models.
Results: Compared to a reference number of EMS personnel on-scene of 5 or 6, 7 or 8 EMS personnel on-scene was associated with a higher rate of survival to hospital discharge, adjusted odds ratio [OR], 1.35 (95% CI: 1.05, 1.73). There was no significant difference in survival between 5 or 6 personnel on-scene versus fewer.
Conclusion: More EMS personnel on-scene within 15 min of 9-1-1 call was associated with improved survival of out-of-hospital cardiac arrest. It is unlikely that this finding was mediated solely by earlier CPR or earlier defibrillation.

1. Introduction

More than 400,000 out-of-hospital cardiac arrests (OHCA) occur annually in the U.S., representing 20% of all heart disease deaths.[1–3] Though there has been no uniform reporting mandate, significant and important variations in rates of survival to hospital discharge across communities have been observed.[2] Within the Resuscitation Outcomes Consortium (ROC) communities for whom OHCA

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data have been uniformly collected since December 2005, survival after OHCA ranged from 3.0% to 16.3%. For the subset who presented with ventricular fibrillation (VF) or ventricular tachycardia (VT), survival ranged from 7.7% to 39.9%.[2] Much of this variation in survival remains incompletely explained. In 2010, Rea and colleagues observed that the core Utstein data elements, a set of internationally recognized OHCA process of care variables believed to be associated with survival and explain geographic differences in outcome, collectively accounted for only 43.7% of the between-community survival difference among EMS-treated cardiac arrest.[4,5]

One way that community response to OHCA differs is in the number of emergency medical services (EMS) personnel dispatched to provide on-scene treatment.[6] This generally depends on EMS organizational structure. Accordingly, we sought to examine patterns of association between number of EMS personnel on-scene and survival to hospital discharge in adults with EMS-treated.

2. Methods

2.1. Design

We performed a retrospective review of prospectively collected data from 193 unique EMS agencies participating in the ROC Epistry-Cardiac Arrest, a multi-community registry of patients with OHCA. The study design and data collection of the ROC Epistry have been previously described.[7] An EMS-treated OHCA was defined as any patient with unresponsiveness, apnea, and the absence of a central pulse whom EMS responders attempted to revive. All data were abstracted by dedicated personnel from EMS records, hospital records, and death certificates. To encourage uniform reporting, definitions of data elements were referenced whenever possible to existing standardized National EMS Information System (NEMSIS) and Utstein reporting templates for cardiac arrest.[5,8] The accuracy of the data was ensured by training of personnel, data entry software with numerous built in data checks for missing or outlying values, and a centralized review of randomly selected records to confirm accuracy and consistency. The coordinating center also conducts annual site visits to spot check a portion of entered records, the data capture processes, and site specific measures of quality assurance.[7]

2.2. Population

Our study included EMS-treated OHCA events from December 1, 2005 to May 31, 2007 among adults from a combined population over 21 million people residing in an area of over 33,000 square miles in Canada and the United States. We excluded OHCA with traumatic injury as the primary cause, OHCA having occurred after EMS arrival to the patient, OHCA for which the number of EMS personnel on-scene was unavailable, OHCA with primary outcome unavailable, and OHCA for which the first arriving EMS vehicle was from an agency not participating in the ROC Epistry.

2.3. Measurements

The primary exposure of interest was the number of EMS personnel on-scene, which was pre-specified as the number of EMS personnel who responded to the scene of OHCA within 15 min after 9-1-1 call receipt and prior to patient death or transport away from the scene. The 15 min time frame was chosen with consideration for average EMS response times and published data regarding survival associations.[9–11] Number of EMS personnel on-scene was classified by categories: 0 personnel, 1 or 2 personnel, 3 or 4 personnel, 5 or 6 personnel, 7 or 8 personnel, and >8 personnel.

2.4. Statistical analysis

Baseline characteristics among categories of number of EMS personnel on-scene were summarized descriptively. To evaluate the association between number of EMS personnel on-scene and survival to hospital discharge, we constructed multivariable logistic regression models. Generalized estimating equations (GEE) with logit link, exchangeable correlation matrix, and a Huber–White robust variance estimator, were used to examine the association between number of EMS personnel on-scene and survival to hospital discharge, adjusted for patient and event characteristics and within-EMS agency correlation of OHCA cases.[12,13] For our independent variable, we chose the category of 5 or 6 personnel as our reference category, as it included the overall median and was the most frequent category observed. Effects were reported as odds ratios with 95% confidence intervals. *P*-values of less than or equal to 0.05 were considered to be significant. Analyses were performed using R, version 2.14.0 (R Foundation for Statistical Computing) or SAS, version 9.3 (SAS Institute, Cary, NC).

Covariates included in the adjusted models were chosen a priori based on their association with survival from prior studies of OHCA, biologic plausibility, and adequate ascertainment. Covariates missing more than 0.5% of values were assessed for differential distribution of missing data among categories of number of EMS personnel on-scene. Continuous covariates were included in the adjusted models either continuously or as categorical variables based on our a priori scientific understanding of the relationship between the covariates and the primary outcome.

Patient/event level covariates included were: age (years), sex, median income of census tract where cardiac arrest occurred, whether the arrest occurred in a public setting, whether the arrest was witnessed by bystanders, whether cardiopulmonary resuscitation was initiated by bystanders, first recorded rhythm (automated external defibrillator [AED] with no shock advised, asystole, pulseless electrical activity [PEA], ventricular fibrillation [VF], pulseless ventricular tachycardia [VT], cannot determine), and time (minutes) from 9-1-1 call receipt to first EMS vehicle arrival, and first arriving EMS agency. The following patient/event level covariates were excluded a priori from the primary regression model on the basis of their potential to mediate the association between number of EMS personnel on-scene and patient survival: time from arrival of first EMS agency to EMS CPR, time from arrival of first EMS agency to EMS defibrillation shock (for shockable cardiac rhythms), whether an advanced airway was used, and total dose (milligrams) of epinephrine administered during EMS resuscitation efforts.

EMS agency level covariates were included for each cardiac arrest's first responding EMS agency. These were: population density served, annual EMS runs per ALS capable vehicle, paid ALS full-time equivalents (FTE) per 100k service population, and paid basic life support (BLS) FTE per 100k service population. Median EMS personnel number per EMS vehicle was excluded a priori from the primary regression model on the basis of its anticipated collinearity with other variables of interest.

A secondary analysis was performed by repeating the above analyses, stratified by whether the first identifiable rhythm was shockable (VF or pulseless VT) or non-shockable (asystole or PEA). Additional secondary analyses were performed using three alternate independent variables: EMS personnel on-scene within 10 min of the 9-1-1 call, EMS personnel on-scene beyond 30 min after the 9-1-1, and EMS personnel on-scene any time prior to patient death or transport.

Potential effect modification by the first responding EMS agency's overall survival statistic ranking was assessed, since it was intuitive to the authors that any positive association found between OHCA survival and number of EMS personnel on-scene could be

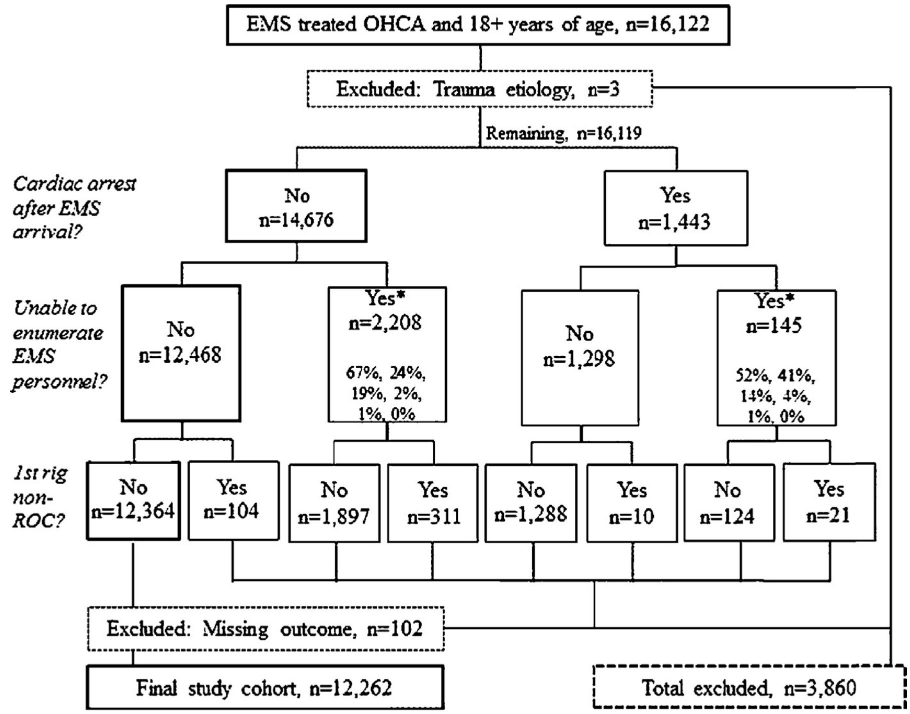

Fig. 1. Study cohort. Of the initial 16,122 out-of-hospital cardiac arrest events in the Resuscitation Outcomes Consortium cardiac arrest registry, 12,262 eligible patients were included in the final study population. *Percentages reported above are with respect to the *n* reported for the following specific reasons, where a case could be included more than once: (1) site had inconsistent reporting; (2) first rig arrival time missing; (3) number of personnel of first arriving rig missing; (4) 911 call receipt time missing; (5) inappropriately high number of personnel reported on one or more rigs; and (6) first rig arrival before 911 call time.

more apparent within EMS agencies with better overall survival outcomes.

3. Results

After exclusion criteria were applied to 16,122 EMS-treated OHCA, our final study cohort eligible for analysis was 12,262 OHCA (Fig. 1). Baseline characteristics of OHCA events among categories of number of EMS personnel on-scene within 15 min of 9-1-1 call are presented in Table 1, along with characteristics of the 193 first responding EMS agencies (i.e., first EMS vehicle to arrive).

Survival to hospital discharge occurred in 871 (7.1%) of the 12,262 patients. In the subgroup of patients with non-shockable initial cardiac rhythms – who accounted for 71.4% of study population and 23.5% of the survivors – survival to hospital discharge was achieved in 205 (2.3%). In the subgroup of patients with shockable initial cardiac rhythms – who accounted for 24.5% of the study population and 68.7% of the survivors – survival to hospital discharge was achieved in 598 (19.9%). The proportion of patients surviving to hospital discharge by category of number of EMS personnel on-scene is presented in Fig. 2. Compared to the reference number of EMS personnel on-scene of 5 or 6, 7 or 8 EMS personnel on-scene was associated with a higher rate of survival to hospital discharge, adjusted odds ratio [OR], 1.35 (95% CI: 1.05, 1.73). Whether the initial cardiac rhythm was shockable or non-shockable did change significantly the effect of our main exposure (number of EMS personnel on-scene) on survival to discharge. Among cardiac arrests due to shockable rhythms (Fig. 3), 7 or 8 EMS personnel on-scene was associated with a higher rate of survival compared to 5 or 6 EMS personnel, adjusted OR 1.48 (95% CI: 1.11, 1.99). For cardiac arrests due to non-shockable rhythms (Fig. 4), 7 or 8 EMS personnel on-scene was not associated with a statistically higher rate of survival compared to 5 or 6 EMS personnel, adjusted OR 1.09 (95% CI: 0.75, 1.57). Fewer than 5 EMS personnel on-scene was not associated with significantly different survival.

The results of secondary analyses that assessed alternate hypotheses are presented in Appendix Figs. A1–A3. Regarding number of EMS personnel on-scene within 10 min of 9-1-1 call, compared to the reference of 5 or 6 EMS personnel on-scene, 1 or 2 EMS personnel was associated with a lower rate of survival to hospital discharge, adjusted OR 0.67 ([95% CI: 0.50, 0.89], Appendix Fig. A1). Regarding number of EMS personnel on-scene beyond 30 min after 9-1-1 call, there were no significant differences in survival observed. Regarding EMS personnel on-scene any time after 9-1-1 call and prior to patient death or transport, 7 or 8 EMS personnel on-scene was associated with a higher rate of survival to hospital discharge, adjusted odds ratio [OR], 1.29 (95% CI: 1.04, 1.61). When first responding EMS agencies were ranked by the proportion of their patients surviving to hospital discharge and divided into quartiles, quartile of survival success did not change significantly the effect of our main exposure (number of EMS personnel on-scene) on survival to discharge [interaction p-value = 0.71]. When assessing survival trends by EMS personnel within ROC sites, we found trends within site were consistent with the overall trend.

4. Discussion

EMS personnel staffing is a complex task and there are no widely recognized guidelines for EMS staffing. In this large North American registry of patients with OHCA, we found that more compared to fewer EMS personnel on-scene within 15 min of 9-1-1 call was associated with improved survival. OHCA presenting with a shockable cardiac rhythm appear to have contributed greater to this observation. These findings were robust to stratification by EMS agency quartile rank of resuscitation success. This suggests that interpretation of our findings can be applied across all levels of EMS agency performance.

Number of EMS personnel on-scene depends on characteristics of EMS structure design, such as geographic distribution of base

Table 1
Baseline characteristics of 12,226 out-of-hospital cardiac arrest events by category of number of EMS personnel on-scene within 15 min of 9-1-1 call.

Characteristic	Number of EMS personnel on-scene within 15 min of 9-1-1 call					
	0	1–2	3–4	5–6	7–8	>8
n	216	1638	1576	5328	2776	728
Age, no. (%)						
18–39 years	16 (7.4)	102 (6.2)	110 (7.0)	353 (6.6)	213 (7.8)	48 (6.6)
40–59 years	67 (31.5)	400 (24.6)	425 (27.2)	1523 (28.7)	761 (27.6)	199 (27.6)
60–79 years	85 (39.9)	667 (41.1)	619 (39.7)	2105 (39.7)	1098 (39.8)	295 (40.9)
≥80 years	45 (21.1)	454 (28.0)	407 (26.1)	1323 (24.9)	686 (24.9)	180 (24.9)
Male sex, no. (%)	143 (66.8)	1013 (61.9)	1026 (65.2)	3425 (64.4)	1765 (63.6)	484 (66.6)
Public location of cardiac arrest, no. (%)	44 (20.4)	241 (14.7)	276 (17.5)	772 (14.5)	453 (16.3)	148 (20.3)
Bystander witness cardiac arrest, no. (%)						
Witnessed	97 (44.9)	668 (40.8)	692 (43.9)	2421 (45.4)	1182 (42.6)	324 (44.5)
Not witnessed	108 (50.0)	903 (55.1)	816 (51.8)	2590 (48.6)	1538 (55.4)	390 (53.6)
Unknown or not noted	11 (5.1)	67 (4.1)	68 (4.3)	317 (5.9)	56 (2.0)	14 (1.9)
Bystander CPR, no. (%)	82 (38.0)	481 (29.4)	536 (34.0)	1861 (34.9)	1141 (41.1)	330 (45.3)
Time from 9-1-1 call to arrival of 1st EMS vehicle, mean (sd)	20.0 (9.3)	7.2 (3.2)	6.2 (2.5)	5.3 (2.0)	5.4 (1.8)	4.8 (1.6)
Initial EMS-detected cardiac rhythm, no. (%)						
Ventricular fibrillation/ventricular tachycardia	30 (14.8)	352 (22.1)	375 (24.6)	1325 (25.5)	707 (26.1)	216 (30.6)
Pulseless electrical activity	35 (17.2)	314 (19.7)	290 (19.0)	987 (19.0)	459 (16.9)	156 (22.1)
Asystole	90 (44.3)	674 (42.3)	652 (42.8)	2362 (45.5)	1183 (43.6)	292 (41.4)
AED – no shock and no strip	45 (22.2)	231 (14.5)	186 (12.2)	447 (8.6)	329 (12.1)	29 (4.1)
Cannot determine	3 (1.5)	24 (1.5)	20 (1.3)	68 (1.3)	35 (1.3)	12 (1.7)
Advanced airway used	148 (69.5)	1188 (74.1)	1236 (80.1)	4309 (82.0)	2329 (85.2)	605 (84.7)
Characteristics of first responding EMS agency						
Population density served, mean (SD), population/square mile	2006 (2768)	1334 (2139)	2497 (2983)	4006 (3403)	4279 (3596)	4847 (2744)
Area served, mean (SD), square miles	905 (723)	871 (619)	643 (634)	308 (422)	384 (562)	250 (375)
Responses per year, mean (SD), 1000	81 (91)	50 (68)	51 (71)	42 (52)	51 (71)	41 (35)
Providers per unit (e.g. rig), mean (SD)	2.4 (0.7)	2.1 (0.8)	2.6 (1.6)	3.3 (1.6)	3.1 (1.0)	3.5 (0.8)
ALS capable units per 100k population, mean (SD)	5.9 (11.3)	7.1 (9.5)	5.4 (6.5)	4.0 (4.9)	2.4 (5.4)	2.7 (4.1)
Paid ALS FTE per 100k population, mean (SD)[a]	19.7 (30.6)	18.6 (19.9)	17.9 (24.0)	16.2 (19.8)	9.6 (25.2)	11.7 (14.6)

[a] Greater than 3% missing: age (5.8%), household adjusted median income (7.0%), paid ALS FTE per 100k population (9.9%), time from arrival of 1st EMS vehicle to first EMS CPR (9.8%), time from arrival of 1st EMS vehicle to first EMS shock, among shockable rhythms without bystander AED application (5.0%).

stations, number of personnel per vehicle, number of personnel on-shift at a time, and dispatcher protocols. As they are constrained by operating budgets, EMS agencies must make difficult choices as they allocate resources.

Other investigators have taken interest in understanding any association between on-scene EMS personnel number and patient outcomes after OHCA. Most recently, Kajino et al. observed a higher rate of survival with favorable neurological outcome among bystander-witnessed OHCA patients in Osaka City, Japan, attended to by three emergency life-saving technicians (ELSTs) compared to one ESLT.[15] Eschmann et al. observed no difference in survival when a crew including three or more paramedics arrived on-scene to OHCA cases in Milwaukee County, Wisconsin, compared with crews including two paramedics.[16] In a simulator-based study of the initial 8 min of simulated cardiac arrest, no difference was found in effectiveness of CPR or in time to performance of procedures among an all-paramedic crews of two, three, or four paramedics.[17] Each of these studies focused on the number of advanced life support (ALS) trained personnel on-scene. By contrast, our study did not differentiate between level of training certification among EMS providers. The stronger evidence-based determinants of survival after OHCA are chest compressions initiated early and effectively and early defibrillation for shockable rhythms. At least in North America, both of those activities are commonly performed by BLS trained personnel.

The underlying mechanism of our primary observation, that 7 or 8 EMS personnel on-scene within 15 min was associated with increased patient survival compared to the most common category, 5 or 6 EMS personnel, should be considered. First, it is possible that a greater number of personnel on-scene facilitated a shorter time between the arrival of the first EMS vehicle and the initiation of EMS CPR, or between the arrival of the first EMS vehicle and the EMS application of a defibrillation shock to a shockable cardiac rhythm. However, adding these two time variables into our primary model did not alter the direction or magnitude of the relationship between number of personnel and survival. Other possible underlying mechanisms include quality of chest compressions when more personnel are able to rotate into that role, improved interaction between chest compressions and defibrillation shocks, more BLS assistance available for ALS level activities such as definitive airway management

EMS personnel on-scene	No. of patients (%)	Unadjusted survival to discharge No. (%)	Unadjusted Odds Ratio for Survival (95%CI)	Adjusted Odds Ratio for Survival (95%CI)*
0	216 (1.8)	5 (2.3)	0.35 (0.17, 0.75)	0.40 (0.14, 1.17)
1-2	1638(13.4)	71 (4.3)	0.69 (0.55 0.88)	0.84 (0.62, 1.15)
3-4	1576 (12.9)	100 (6.3)	0.93 (0.73, 1.19)	0.96 (0.73, 1.25)
5-6	5328 (43.6)	358 (6.7)	1(ref.)	1(ref.)
7-8	2766 (22.7)	257 (9.3)	1.28 (1.08, 1.53)	1.35(1.05, 1.73)
>8	728 (6.0)	80 (11.0)	1.26 (1.00, 1.60)	1.21 (0.89, 1.64)
Total	12,262 (100)			

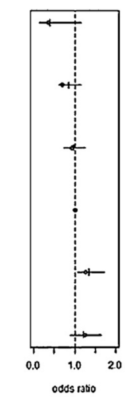

Fig. 2. Survival to hospital discharge by category of number of EMS personnel on-scene within 15 min of 9-1-1 call receipt and prior to patient death or transport. *Adjusted for age (years), sex, median income of census tract where cardiac arrest occurred, whether the arrest occurred in a public setting, whether the arrest was witnessed by bystanders, whether resuscitation was attempted by bystanders, initially detected cardiac rhythm (automated external defibrillator [AED] with no shock advised, asystole, pulseless electrical activity [PEA], ventricular fibrillation [VF], pulseless ventricular tachycardia [VT], cannot determine), and time (minutes) from 9-1-1 call receipt to first EMS vehicle arrival, and first arriving EMS agency. EMS agency level variables included for each cardiac arrest's first responding EMS agency were: population density served, annual EMS runs per Advanced Life Support (ALS) capable vehicle, paid ALS full-time equivalents (FTE) per 100k service population, and paid BLS FTE per 100k service population.

and IV medication delivery, earlier or improved "packaging" of the patient for transport to a hospital, and greater overall situational management (e.g., interfacing with a patient's family, moving furniture, etc.), and other characteristics of teamwork that are difficult to measure.

Any attempt to explain why 7–8 EMS personnel on-scene was associated with improved survival after cardiac arrest would need to account for the lack of relative association observed between >8 EMS personnel on-scene and survival compared to 5 or 6 EMS personnel on-scene. It is possible that the comparison involving the >8 EMS personnel category lacked statistical power to reach significance despite the point estimate suggesting a positive correlation between that that personnel category and survival. It is also possible that additional personnel beyond eight may be unnecessary, in a manner akin to "too many cooks spoiling the broth".

EMS personnel on-scene	No. of patients (%)	Unadjusted survival to discharge No. (%)	Unadjusted Odds Ratio for Survival (95%CI)	Adjusted Odds Ratio for Survival (95%CI)**
0	30 (1.0)	3 (10.0)	0.46 (0.16, 1.29)	0.67 (0.16, 2.81)
1-2	352 (11.7)	47 (13.4)	0.71 (0.53, 0.93)	0.88 (0.61, 1.25)
3-4	375 (12.5)	62 (16.5)	0.82 (0.58, 1.16)	0.84 (0.60, 1.18)
5-6	1325 (44.2)	247 (18.6)	1(ref.)	1(ref.)
7-8	707 (23.6)	184 (26.0)	1.41 (1.14, 1.74)	1.48 (1.11, 1.99)
>8	216 (7.2)	55 (25.5)	1.21 (0.86, 1.71)	1.36 (0.93, 1.99)
Total	3005 (100)			

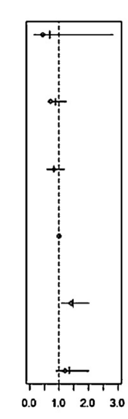

Fig. 3. Survival to hospital discharge by category of number of EMS personnel on-scene within 15 min of 9-1-1 call and prior to patient death or transport, among shockable initial rhythms. Shockable rhythms represent 24.6% of the study population and 68.7% of the survivors. *Adjusted for age (years), sex, median income of census tract where cardiac arrest occurred, whether the arrest occurred in a public setting, whether the arrest was witnessed by bystanders, whether resuscitation was attempted by bystanders, and time (minutes) from 9-1-1 call receipt to first EMS vehicle arrival, and first arriving EMS agency. EMS agency level variables included for each cardiac arrest's first responding EMS agency were: population density served, annual EMS runs per Advanced Life Support (ALS) capable vehicle, paid ALS full-time equivalents (FTE) per 100k service population, paid BLS FTE per 100k service population.

EMS personnel on-scene	No. of patients (%)	Unadjusted survival to discharge No. (%)	Unadjusted Odds Ratio for Survival (95%CI)	Adjusted Odds Ratio for Survival (95%CI)**
0	170 (1.9)	0 (0.0)	(omitted)	(omitted)
1-2	1219 (14.0)	19 (1.6)	0.87 (0.57, 1.32)	0.92 (0.56, 1.53)
3-4	1128 (12.9)	32 (2.8)	1.41 (0.91, 2.18)	1.27 (0.78, 2.06)
5-6	3796 (43.5)	82 (2.2)	1(ref.)	1(ref.)
7-8	1971 (22.6)	54 (2.7)	1.24 (0.91, 1.67)	1.09 (0.75, 1.57)
>8	477 (5.5)	18 (3.8)	0.84 (0.46, 1.53)	0.83 (0.53, 1.30)
Total	8761 (100)			

Adjusted Odds Ratio for Survival (95%CI) Plotted

(○ = unadjusted OR)

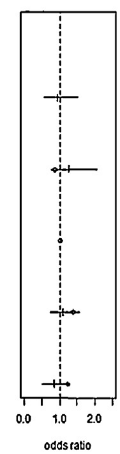

Fig. 4. Survival to hospital discharge by category of number of EMS personnel on-scene within 15 min of 9-1-1 call receipt and prior to patient death or transport, among non-shockable initial rhythms. Non-shockable rhythms accounted for 71.4% of study population and 23.5% of the survivors. *Adjusted for age (years), sex, median income of census tract where cardiac arrest occurred, whether the arrest occurred in a public setting, whether the arrest was witnessed by bystanders, whether resuscitation was attempted by bystanders, initially detected cardiac rhythm (automated external defibrillator [AED] with no shock advised, asystole, pulseless electrical activity [PEA], cannot determine), and time (minutes) from 9-1-1 call receipt to first EMS vehicle arrival, and first arriving EMS agency. EMS agency level variables included for each cardiac arrest's first responding EMS agency were population density served, annual EMS runs per Advanced Life Support (ALS) capable vehicle, paid ALS full-time equivalents (FTE) per 100k service population, and paid BLS FTE per 100k service population.

Our work should be interpreted in the context of the following strengths. First, the strengths of the ROC registry are numerous: it is a large registry of OHCA events that collects clinical level information rather than administrative data. By using common inclusion criteria, variable definitions, outcome ascertainment, and ongoing monitoring to identify missing cases, observed differences between EMS agencies within the ROC are less likely to be due to selection bias. Second, our statistical methods were able to account for clustering of cardiac arrest events within EMS agencies. Third, the nature of our research question avoids a common problem in observational research, confounding by indication: we are aware of no EMS dispatch protocols for cardiac arrest that vary EMS personnel allocation by a reported prognostic factor.

Our work should be interpreted in the context of the following limitations. First, we were unable to adjust for patient-level information on comorbidities or pre-arrest medication use, two characteristics that may cluster differently between populations served by EMS agencies with different staffing norms. However, the magnitude of variation in comorbidity and medication use is likely to be much less than the approximately 5-fold variation in cardiac arrest survival among ROC sites and therefore also less likely to have large confounding effects within this study.[2] Second, unmeasured EMS characteristics of importance are likely to vary ROC site to ROC site within our study cohort. We believe we maximally accounted for that using sensitivity analyses. Third, time data were self-reported by EMS agencies and inaccuracies may exist. However, such inaccuracies in time data would be expected to be non-differential and to bias our observations toward the null hypothesis. Fourth, we only had data for the first four arriving EMS vehicles. However, in only about 2% of the episodes did the first four arriving EMS vehicles together carry fewer than 8 personnel, which did not have an identifiable impact on the final results. Fifth, we were unable to adjust for potentially effective post-resuscitation care such as targeted temperature management.[18,19] Sixth, our results may not be generalizable to other populations (e.g., children) or locations with less community interest in improving the care of cardiac arrest patients than is represented in the Resuscitation Outcome Consortium communities. Seventh, there is no prior evidence to link the number of EMS personnel on-scene to CPR quality beyond the recognition that the American Heart Association recommends alternating personnel who perform chest compressions in order to avoid provider fatigue.

Such limitations make policy implications of our work uncertain. Furthermore, there are other life threatening conditions that are sensitive to EMS care besides OHCA, such as trauma, and we are not aware of similar research on EMS personnel number and outcomes for other conditions. Cost implications of providing patients with greater number of on-scene EMS personnel would partly depend on personnel level-of-training. We do believe more research is needed regarding on-scene EMS personnel number and clinical outcomes after OHCA and other conditions. Clinical trial randomization would be feasible at the dispatcher level.

In summary, we found that more EMS personnel on-scene within 15 min of 9-1-1 call was associated with improved survival compared with fewer EMS personnel, and that within each site there was a consistent relationship between survival and number of providers on scene. It is unlikely that these findings were mediated solely by earlier CPR or earlier defibrillation.

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Disclosures

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Author contributions

S.A.W. had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Acquisition of data: S.A.W., D.K.P., E.H., T.D.R., G.N.

Statistical analysis and interpretation of data: S.A.W., D.K.P., E.H., T.D.R., G.N.

Drafting of the manuscript: S.A.W., D.K.P., E.H., G.N.

Critical revision of the manuscript for important intellectual content: S.A.W., D.K.P., D.L.A., S.D., L.J.M., G.M.V., G.N.

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Foremost, Patients. In this era rich with opinions regarding sharing our personal "data", there remains a trust provided to medical researchers from medical patients that their personal data be used toward a collective goal of better health, and in a way that does not compromise patient privacy. We take that trust with gratitude and great seriousness.

Appendix A.

Figs. A1–A3.

EMS personnel on-scene	No. of patients (%)	Unadjusted survival to discharge No. (%)	Unadjusted Odds Ratio for Survival (95%CI)	Adjusted Odds Ratio for Survival (95%CI)*	Adjusted Odds Ratio for Survival (95%CI) Plotted (○ = unadjusted OR)
0	864 (7.1)	27 (3.1)	0.39 (0.29, 0.53)	0.69 (0.47, 1.00)	
1-2	1934 (15.8)	94 (4.9)	0.61 (0.49, 0.77)	0.67 (0.50,0.89)	
3-4	2330 (19.1)	163 (7.0)	0.83 (0.69, 1.01)	0.91 (0.73, 1.15)	
5-6	5049 (41.3)	399 (7.9)	1(ref.)	1(ref.)	
7-8	1647 (13.5)	138 (8.4)	0.92 (0.73, 1.16)	0.96 (0.70, 1.33)	
>8	438 (3.6)	50 (11.4)	1.04 (0.64, 1.68)	1.02 (0.75, 1.39)	
Total	12,262 (100)				

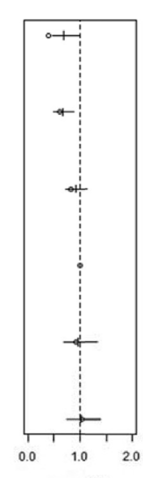

Fig. A1. Survival to hospital discharge by category of on-scene EMS personnel number who arrived within 10 min of 9-1-1 call and prior to death or transport. *Adjusted for age (years), sex, median income of census tract where cardiac arrest occurred, whether the arrest occurred in a public setting, whether the arrest was witnessed by bystanders, whether resuscitation was attempted by bystanders, initially detected cardiac rhythm (automated external defibrillator [AED] with no shock advised, asystole, pulseless electrical activity [PEA], ventricular fibrillation [VF], pulseless ventricular tachycardia [VT], cannot determine), and time (minutes) from 9-1-1 call receipt to first EMS vehicle arrival, and first arriving EMS agency. EMS agency level variables included for each cardiac arrest's first responding EMS agency were: population density served, annual EMS runs per Advanced Life Support (ALS) capable vehicle, paid ALS full-time equivalents (FTE) per 100k service population, and paid BLS FTE per 100k service population.

EMS personnel on-scene	No. of patients (%)	Unadjusted survival to discharge No. (%)	Unadjusted Odds Ratio for Survival (95%CI)	Adjusted Odds Ratio for Survival (95%CI)*
0	0 (0)	NA	NA	NA
1-2	535 (7.9)	15 (2.8)	0.57 (0.38, 0.84)	0.98 (0.59, 1.63)
3-4	755 (11.2)	40 (5.3)	0.98 (0.69, 1.39)	1.08 (0.66, 1.76)
5-6	2643 (39.2)	137 (5.2)	1(ref.)	1(ref.)
7-8	2248 (33.4)	176 (7.8)	1.28 (1.07, 1.53)	1.22 (0.92, 1.62)
>8	571 (8.5)	48 (8.4)	1.02 (0.70, 1.49)	0.78 (0.45, 1.35)
Total	6752 (100)			

Adjusted Odds Ratio for Survival (95%CI) Plotted

(○ = unadjusted OR)

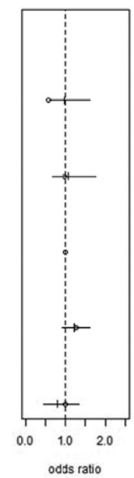

Fig. A2. Survival to hospital discharge by category of number of EMS personnel on-scene beyond 30 min after 9-1-1 call and prior to patient death or transport. *Adjusted for age (years), sex, median income of census tract where cardiac arrest occurred, whether the arrest occurred in a public setting, whether the arrest was witnessed by bystanders, whether resuscitation was attempted by bystanders, initially detected cardiac rhythm (automated external defibrillator [AED] with no shock advised, asystole, pulseless electrical activity [PEA], ventricular fibrillation [VF], pulseless ventricular tachycardia [VT], cannot determine), and time (minutes) from 9-1-1 call receipt to first EMS vehicle arrival, and first arriving EMS agency. EMS agency level variables included for each cardiac arrest's first responding EMS agency were population density served, annual EMS runs per Advanced Life Support (ALS) capable vehicle, paid ALS full-time equivalents (FTE) per 100k service population, and paid BLS FTE per 100k service population.

EMS personnel on-scene	No. of patients (%)	Unadjusted survival to discharge No. (%)	Unadjusted Odds Ratio for Survival (95%CI)	Adjusted Odds Ratio for Survival (95%CI)**
0	0 (0)	NA	NA	NA
1-2	1242 (10.2)	60 (4.8)	0.84 (0.63, 1.10)	0.97 (0.55, 1.42)
3-4	1514 (12.4)	78 (5.2)	0.83 (0.60, 1.14)	0.90 (0.62, 1.30)
5-6	5040 (41.2)	329 (6.5)	1(ref.)	1(ref.)
7-8	3497 (28.6)	306 (8.8)	1.26 (1.08, 1.47)	1.29 (1.04, 1.61)
>8	969 (7.9)	98 (10.1)	1.19 (0.92, 1.54)	1.09 (0.77, 1.55)
Total*	12,262 (100)			

Adjusted Odds Ratio for Survival (95%CI) Plotted

(○ = unadjusted OR)

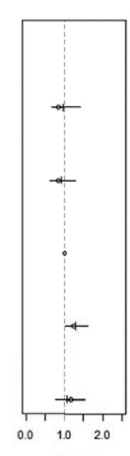

Fig. A3. Survival to hospital discharge by category of EMS personnel on-scene anytime after 9 1-1 call and prior to patient death or transport. *This secondary study population differs from the original study population on the basis of incomplete information used to calculate this alternate predictor. **Adjusted for age (years), sex, median income of census tract where cardiac arrest occurred, whether the arrest occurred in a public setting, whether the arrest was witnessed by bystanders, whether resuscitation was attempted by bystanders, initially detected cardiac rhythm (automated external defibrillator [AED] with no shock advised, asystole, pulseless electrical activity [PEA], ventricular fibrillation [VF], pulseless ventricular tachycardia [VT], cannot determine), and time (minutes) from 9-1-1 call receipt to first EMS vehicle arrival, and first arriving EMS agency. EMS agency level variables included for each cardiac arrest's first responding EMS agency were: population density served, annual EMS runs per Advanced Life Support (ALS) capable vehicle, paid ALS full-time equivalents (FTE) per 100k service population, and paid BLS FTE per 100k service population.

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