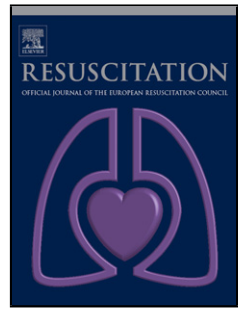
Accepted Manuscript



Title: Advanced vs. Basic Life Support in the Treatment of Out-of-Hospital Cardiopulmonary Arrest in the Resuscitation Outcomes Consortium

Authors: Michael Christopher Kurz, Robert H Schmicker, Brian Leroux, Graham Nichol, Tom P Aufderheide, Sheldon Cheskes, Brian Grunau, Jamie Jasti, Peter Kudenchuk, Gary M Vilke, Jason Buick, Lynn Wittwer, Ritu Sahni, Ronald Straight, Henry E. Wang, for the ROC Investigators

PII: S0300-9572(18)30192-8
DOI: https://doi.org/10.1016/j.resuscitation.2018.04.031
Reference: RESUS 7588

To appear in: *Resuscitation*

Received date: 5-2-2018
Revised date: 2-4-2018
Accepted date: 25-4-2018

Please cite this article as: Kurz Michael Christopher, Schmicker Robert H, Leroux Brian, Nichol Graham, Aufderheide Tom P, Cheskes Sheldon, Grunau Brian, Jasti Jamie, Kudenchuk Peter, Vilke Gary M, Buick Jason, Wittwer Lynn, Sahni Ritu, Straight Ronald, Wang Henry E.Advanced vs.Basic Life Support in the Treatment of Out-of-Hospital Cardiopulmonary Arrest in the Resuscitation Outcomes Consortium.*Resuscitation* https://doi.org/10.1016/j.resuscitation.2018.04.031

Advanced vs. Basic Life Support in the Treatment of Out-of-Hospital Cardiopulmonary Arrest in the Resuscitation Outcomes Consortium

Michael Christopher Kurz MD [1]

Robert H Schmicker MS[2]

Brian Leroux PhD[2]

Graham Nichol MD[3]

Tom P Aufderheide MD[4]

Sheldon Cheskes MD[5,6]

Brian Grunau MD[7]

Jamie Jasti MD[4]

Peter Kudenchuk MD[8]

Gary M Vilke MD[9]

Jason Buick MD[4]

Lynn Wittwer MD[10]

Ritu Sahni MD[11]

Ronald Straight MD[12]

Henry E. Wang MD[13]

for the ROC Investigators

1) Department of Emergency Medicine, University of Alabama School of Medicine, Birmingham, Alabama

2) Clinical Trial Center, Department of Biostatistics, University of Washington, Seattle, WA, United States

3) University of Washington-Harborview Center for Prehospital Emergency Care, University of Washington, Seattle, WA, US

4) Department of Emergency Medicine, Medical College of Wisconsin, Milwaukee, Wisconsin

5) Rescu, Keenan Research Centre, Li Ka Shing Knowledge Institute, St. Michael's Hospital, Toronto, Ontario, Canada

6) Division of Emergency Medicine, Department of Family Community Medicine, University of Toronto, Toronto, Ontario, Canada

7) Department of Emergency Medicine, University of British Columbia, Faculty of Medicine, Vancouver, British Columbia, Canada

8) Division of Cardiology, Department of Medicine, University of Washington, Seattle, WA, United States

9) Department of Emergency Medicine, University of California, San Diego, CA

10) Clark County Emergency Medical Services, Vancouver, WA

11) Department of Emergency Medicine, Oregon Health & Science University, Portland, OR

12) Providence Health Care Research Institute and British Columbia Emergency Health Services, British Columbia, Canada

13) Department of Emergency Medicine, University of Texas Health Science Center at Houston, Houston, Texas

Conflict of Interest Disclosure: none

Running Title: ALS vs. BLS Survival

Word Count (excluding abstract, tables, figures, references): 2706

Support: Please see declaration below.

Corresponding Author:

Michael C Kurz MD, MS, FACEP, FAHA
Associate Professor
University of Alabama at Birmingham
Department of Emergency Medicine
OHB 251
619 19th ST S
Birmingham, AL 35249-7013
Office: 205-934-3611
Fax: 205-996-5019
Cell: 804-836-4959
mckurz@uabmc.edu

Abstract:

Background: Prior observational studies suggest no additional benefit from advanced life support (ALS) when compared with providing basic life support (BLS) for patients with out-of-hospital cardiac arrest (OHCA). We compared the association of ALS care with OHCA outcomes using prospective clinical data from the Resuscitation Outcomes Consortium (ROC).

Methods: Included were consecutive adults OHCA treated by participating emergency medical services (EMS) agencies between June 1, 2011, and June 30, 2015. We defined BLS as receipt of cardiopulmonary resuscitation (CPR) and/or automated defibrillation and ALS as receipt of an advanced airway, manual defibrillation, or intravenous drug therapy. We compared outcomes among patients receiving: 1) BLS-only; 2) BLS+late ALS; 3) BLS+early ALS; and 4) ALS-first care. Using multivariable logistic regression, we evaluated the associations between level of care and return of spontaneous circulation (ROSC), survival to hospital discharge, and survival with good functional status, adjusting for age, sex, witnessed arrest, bystander CPR, shockable initial rhythm, public location, EMS response time, CPR quality, and ROC site.

Results: Among 35,065 patients with OHCA, characteristics were median age 68 years (IQR 56-80), male 63.9%, witnessed arrest 43.8%, bystander CPR 50.6%, and shockable initial rhythm 24.2%. Care delivered was: 4.0% BLS-only, 31.5% BLS+late ALS, 17.2% BLS+early ALS, and 47.3% ALS-first. ALS care with or without initial BLS care was independently associated with increased adjusted ROSC and survival to hospital discharge unless delivered greater than 6 minutes after BLS arrival (BLS+late ALS). Regardless of when it was delivered, ALS care was not associated with significantly greater functional outcome.

Conclusion: ALS care was associated with survival to hospital discharge when provided initially or within six minutes of BLS arrival. ALS care, with or without initial BLS care, was associated with increased ROSC, however it was not associated with functional outcome.

Keywords: cardiac arrest, advanced life support, basic life support, emergency medical services, cardiopulmonary resuscitation

Background:

Out-of-hospital cardiac arrest (OHCA) is a major public health problem affecting greater than 356,500 persons annually in the United States.[1] Although basic life support (BLS) interventions such as CPR and defibrillation form the foundation of OHCA resuscitation, efforts to improve OHCA outcomes led to the introduction of advanced level interventions in the out-of-hospital setting. The contemporary model of Emergency Medical Services (EMS) OHCA care in North America encompasses simultaneous response of providers capable of BLS care with those capable of advanced life support (ALS) interventions such as endotracheal intubation, manual defibrillation, and intravenous drug therapy.[2]

An understanding of the relative benefits of ALS and BLS OHCA care is extremely important, potentially guiding community EMS system design and resource investment. For example, the duration of advanced level paramedic training in the US is ten-fold higher than that required for basic-level emergency medical technicians.[3] Recent studies raise questions about the clinical value of ALS in OHCA care, suggesting that these interventions offer no additional survival benefit over basic measures.[4,5] However, these prior analyses contain some limitations, including the use of before-after study design or reliance upon hospital-based administrative data to infer the nature of care delivered by EMS.

The Resuscitation Outcomes Consortium (ROC) Epistry is one of the world's largest series of OHCA care and includes key details about clinical presentation and the type of care rendered. The objective of this study was to compare the effect of ALS versus BLS care upon adult OHCA survival in the ROC.

Methods:

Study Design:

This study was a retrospective analysis of data collected prospectively by the ROC.[6] Approval was obtained from each institutional review board or research ethics board at the respective institutions within the participating communities.

Study Setting and Data Source:

ROC is a North American multi-center research network focused on clinical intervention trials in out-of-hospital cardiac arrest and traumatic injury. ROC consists of 10 regional coordinating centers: Seattle/King County, WA; San Diego, CA; Milwaukee, WI; Pittsburgh, PA; Portland, OR; Dallas, TX; Birmingham, AL; Toronto, Ontario; Ottawa, Ontario; and British Columbia. A data coordinating center in Seattle provided centralized data collection and management. Approximately 150 EMS agencies are affiliated with ROC.

The ROC Epistry-Cardiac Arrest is a prospective, population-based registry characterizing OHCA episodes treated by EMS agencies in the network.[6] Responsible study personnel at each site determined the circumstances of each OHCA through review of dispatch logs, EMS patient care reports, defibrillator data files, and hospital and public death records. Data collection conformed to Utstein standards and included information regarding prehospital response, patient demographics, clinical information, prehospital interventions and complications, prehospital disposition, hospital information and outcomes.[7] ROC Epistry-Cardiac Arrest met the requirements for minimal risk at all US and Canadian sites.

Study Population:

We studied consecutive, adult, non-traumatic, OHCA cases receiving care by participating EMS agencies between June 1, 2011, and June 30, 2015. We defined OHCA as patients found pulseless and apneic in the out-of-hospital setting, receiving either attempt at external defibrillation by bystanders or EMS personnel or subsequent to EMS evaluation receives chest compressions.[6] Prisoners, visibly pregnant women, EMS-witnessed cardiac arrest, patients under the age of consent, persons with an obvious non-cardiac etiology of arrest, or those receiving no resuscitation attempt were excluded.

Outcome Measures:

The primary outcome was survival to hospital discharge. Secondary outcomes included prehospital return of spontaneous circulation (ROSC: defined as pulse present upon arrival at primary receiving emergency department [ED]), 24-hour survival, and favorable neurological survival defined as a modified Rankin score $\leq$ 3 at hospital discharge.

The key exposure was the level of EMS care delivered. We defined basic life support (BLS) care as the delivery of cardiopulmonary resuscitation (CPR) and/or automated defibrillation. We defined advanced life support (ALS) as the delivery of an advanced airway (endotracheal tube or supraglottic airway), manual defibrillation, or intravenous drug therapy. ALS calls were further characterized according to the arrival sequence of the ALS unit: A) BLS + late ALS (ALS arrival >6 minutes of BLS), b) BLS + early ALS (ALS arrival ≤6 minutes of BLS), and c) ALS-first, as many ROC EMS agencies utilize a tiered response including both BLS first response and ALS (Figure 1). We chose a six-minute threshold to represent three optimal BLS CPR cycles (2 min of CPR followed by pulse check and defibrillation as appropriate).[8]

Covariates used in the analysis included age, sex, witnessed arrest, bystander CPR, public location, interval between 911 call and EMS arrival, presenting electrocardiogram (ECG) rhythm, mean compression depth (mm), CPR rate (compressions/min), mean chest compression fraction (CCF), and geographic site. Presenting ECG rhythm was classified as shockable (including shock advised by automated external defibrillator, pulseless ventricular tachycardia or fibrillation), pulseless electrical activity (PEA), asystole, or no shock advised by automated external defibrillator.

CPR rate, depth, and chest compression fraction (CCF) along with pre- and post-shock pauses were determined by commercial chest compression detection technology used on all portable cardiac monitors (Zoll Medical Corporation, Chelmsford, MA; Physio-Control, Redmond, WA; Phillips, Andover, MA).[9]

Data Analysis:

We analyzed the data using multivariate logistic regression, modeling survival to hospital discharge as the dependent variable and prehospital care provided (BLS only, ALS first, or early/late combination) as the primary exposure. We adjusted these estimates for the confounding effects of age, sex, witnessed arrest event, provision of bystander CPR, presenting ECG rhythm, CPR depth, rate, fraction, and ROC site location.

We tested the robustness of the results in a series of sensitivity analyses. We examined the subset of patients with witnessed OHCA, initial shockable rhythm, and receiving bystander CPR. We repeated the primary analysis excluding patients with resuscitation terminated due to a valid Do Not Resuscitate order or physical signs of rigor or lividity. We repeated the analysis examining time of first EMS unit arrival as a continuous variable. We also repeated the analysis limited to care delivered prior to ROSC. We fit a model assessing dispatch assignment (BLS or ALS) rather than care delivered. We also fit a model with the categories a) BLS-only, b)BLS + Late ALS (ALS arrival >6 minutes of BLS arrival), c) BLS + Early ALS (ALS arrival within 2-6 minutes of BLS arrival), d) BLS + Immediate ALS (ALS arrival ≤2 min of BLS arrival), and e) ALS-first.

We conducted all analyses using S-Plus version 6.2.1 (TIBCO Software Inc. Palo Alto, California, USA), and Stata version 11 (StataCorp, College Station, Texas, USA).

Results

Of 55,612 OHCA treated during the four-year study period, we excluded 6,376 EMS witnessed OHCA, 3,345 of non-cardiac etiology, 1,299 pediatric OHCA, and 9,527 with incomplete data (3,743 with no CPR Start time; 2,365 no ALS intervention time; 257 missing agency service level, 3,698 missing covariate data). Of the remaining 35,065 subjects, 1,396 (4.0%) received BLS care only, 6,016 (17.2%) received BLS + Early ALS care, 11,054 (31.5%) received BLS + Late ALS, and 16,599 (47.3%) received ALS care first. (Table 1)

OHCA victims who were managed with BLS only were older and less likely to be male than those receiving ALS or a combination of prehospital therapy (Table 1). The most frequently delivered ALS interventions were Intravenous drug therapies, followed by intubation (Table 2). All measured parameters of CPR quality were higher for patients who received ALS-first, BLS+Early ALS, or BLS+Late ALS care with the exception of compression rate exceeding 120/minute. Mean CCF was identical between ALS-first and BLS + Early ALS cohorts. Mean CPR depth was highest among those patients receiving BLS + late ALS care. The maximum mean pre-shock pause was shortest among patients receiving ALS-first care due to the use of Automated External Defibrillators by BLS providers (Table 3).

Outcomes

In unadjusted analyses, ALS care, either alone or with BLS care, was associated with increased survival to hospital discharge both before (Table 4) and after adjustment for age, sex, witnessed arrest, bystander CPR, public location, response time, initial ECG rhythm, CPR rate, chest compression fraction, and ROC regional site (BLS-only reference; BLS + late ALS 2.48 [1.00-6.14].; BLS + early ALS 2.80 [1.12-6.97]; ALS-first OR 2.63 [95% CI: 1.06-6.54]). In adjusted analyses, ALS care, either alone or with BLS care, was associated with improvement in ROSC and survival to hospital discharge except when ALS care was provided late (> 6 minutes following arrival of BLS providers). Conversely, ALS care was not associated with functional neurological status. (Table 5).

Sensitivity Analyses

The relationships between the level of EMS care and outcome were consistent in sensitivity analyses that included analyses of EMS arrival time as a continuous variable, dispatch unit assignment, and with the addition of the BLS + Immediate ALS subgroup (Online Supplementary Appendices A-C). However, when cases where resuscitation was initiated and then appropriately terminated (i.e. due to the discovery of a DNR order, signs of rigor or lividity,) were removed from the analysis, associations between level of care level and ROSC were attenuated (BLS-only reference; BLS + late ALS 3.64 [2.00 – 6.63]; BLS + early ALS 4.31 [2.36 – 7.87]; ALS-first OR 3.56 [95% CI: 1.96-6.50]). Associations between care delivered and other outcomes, including survival to hospital discharge and functional status, were no longer evident (Appendix D). There were an insufficient number of cases to assess the effect of care delivered before ROSC or the subset of bystander witnessed arrests with a shockable rhythm and receiving bystander CPR.

Discussion

In an unadjusted analysis of a large prospective study of OHCA, we observed that ALS care was associated with increased survival to hospital discharge compared with BLS only care. In adjusted analyses, this observation was attenuated when the provision of ALS care occurred greater than six minutes after the arrival of BLS providers. Our results were consistent across a wide range of secondary outcomes and sensitivity analyses. Our data originated from the largest observational study of OHCA in North America with granular details of the pre-hospital clinical care rendered. These observations support the lifesaving role of ALS in prehospital care of patients with OHCA.

Our primary observations contrast with two prior studies of ALS OHCA care. In the Ontario Prehospital Life Support Study (OPALS), Stiell, et al. studied 5,638 OHCA, finding that ALS offered no significant improvement survival to hospital discharge over those receiving optimized BLS care.[4] However, the OPALS study used a before-after design and encompassed a smaller population in a single region. Furthermore, the paramedics who participated in OPALS were newly certified. EMS care and outcomes for OHCA have evolved in the 15 years since OPALS was completed.[1] Our analysis drew on contemporary patients with

OHCA from over 150 EMS agencies, 10 communities, and a population of approximately 18 million. When a sensitivity analysis removing cases where resuscitation was initiated and then appropriately terminated was undertaken our findings became consistent with the OPALS group despite differences in methodology.

Sanghavi et al. used Medicare claims data to suggest an association between receipt of ALS care and poorer outcomes among patients transported to the hospital after OHCA.[5] However, Sanghavi, et al. relied on Medicare claims data to identify cardiac arrests and to infer the level of care delivered. A claims-based approach entails inherent and important limitations including recall and reporting bias and documentation variations influenced by EMS billing practices.[10] Furthermore, the absence of fundamental clinical information characterizing the nature and outcomes of on-scene EMS care such as the characteristics of the patient, the circumstances of the cardiac arrest, and (most importantly) the specific types of interventions provided precluded any adjustment in that analysis.[11] For example, patients transported to the hospital after only CPR and defibrillation were likely to have experienced rapid resuscitation, without the opportunity to receive advanced level care; their higher survival likely reflected the rapidity of return of circulation, not the level of care.

An important observation in our sensitivity analysis was the identification of select cases with BLS initiation but early termination of care; the omission of this subgroup attenuated the observed associations between care level and

OHCA survival. Because of the uncertainty of the sequence of clinical care, we hesitate to formulate inferences based upon these observations. For example, we do not know why resuscitation was initially started or the circumstances by which advanced directive information was discovered by EMS personnel. In the setting of a clinical trial, these cases would be included in analysis per intention-to-treat principals. Further studies are needed to elucidate the details and influence of such cases. However, these observations underscore the critical importance of clinical data in characterizing the course of OHCA care. These clinical care subtleties could not be ascertained from claims data.[12]

The findings of the current study have important implications for EMS system care internationally, including the use of ALS measures in the continuum of OHCA care. The modern system of EMS care in North America evolved from efforts to improve the outcomes of patient suffering from OHCA or major trauma.[13] To parallel care delivered in the hospital, thought leaders proposed arming basic EMS providers with advanced level skills such as endotracheal intubation, defibrillation, intravenous line insertion, and the administration of vasoactive and antiarrhythmic medications. However, the implementation of ALS care is a significant investment for communities. For example, ALS providers receive more initial training than BLS providers (1200 vs 150 hours).[3,14] Communities must also choose whether to implement ALS across the entire system or choose a tiered response system, strategically dispatching advanced level units to higher acuity calls. Tiered systems may yield additional intangible benefits of allowing ALS providers to maintain a critical volume of high acuity experience, however at the cost of ALS response time. Interestingly, our results may indicate a combination of BLS + ALS care was associated with the best results, possibly as a result of these factors. Importantly, a tiered strategy requires a similarly mature system of 911 call triage and dispatch.

The benefits of ALS care may extend beyond the clinical effectiveness of individual care procedures. In delivering clinical care, ALS providers likely draw upon their greater foundation training, repertoire of interventions and clinical experience. Prior studies suggest positive associations between EMS personnel experience, procedural success, and patient outcomes.[15,16] In our analysis, the benefits of ALS care in OHCA appear to be temporally related (i.e. the effects of ALS care were maximized when provided early and outcomes were measured proximally). In the absence of other hospital level elements available to adjust our analyses, the benefits of ALS care may have been attenuated by evidence based post-resuscitation care, (i.e. targeted temperature management[20] or percutaneous coronary intervention[21]) and or other unmeasured hospital characteristics (OHCA volume, size, cardiac surgery facilities, etc.).[22]

Furthermore, EMS personnel provide care for a range of medical emergencies beyond OHCA, such as myocardial infarction, acute respiratory failure, and shock. The latter conditions require decision-making capabilities on par with (if not greater than) that needed for managing OHCA.[2] Our investigation is not equipped to evaluate the impact of ALS care in the management or outcome of other time-dependent disease states.

Limitations:

These data were derived from observation rather than random allocation to treatment assignment. While randomization is optimal for determining causality, the logistical, political, and ethical complexities of randomizing OHCA victims to different levels of care make such a trial unlikely.

Furthermore, while selection bias inherent to our study design cannot be eliminated, we believe it is mitigated by our population-based approach. We adjusted for common OHCA confounders, additional unmeasured or unmeasurable confounders may have been present. The low number of patients in the BLS-only group and the difference in baseline characteristics (while adjusted for), may have impacted BLS survival rates. In addition, other factors such as the number of EMS personnel present at scene[17] or their experience of each EMS provider have been demonstrated to influence OHCA outcomes.[18,19]

We did not account for in-hospital care, which may influence OHCA survival.[20,21] Finally, we examined the influence of ALS care on OHCA; we did not examine its effects on other disease states.

Conclusion

In this analysis of prospective data collected by the ROC in multiple large geographically separate sites, the provision of ALS care, when compared with BLS-only care, was associated with increased ROSC and with survival to hospital discharge except when ALS care was provided late in the resuscitation. ALS care was not associated with improved functional status. A better understanding of the precise mechanisms by which ALS care improves ROSC provides a promising strategy to improve outcomes for OHCA victims.

Financial Support

The ROC is supported by a series of cooperative agreements to nine regional clinical centers and one Data Coordinating Center (5U01 HL077863 University of Washington Data Coordinating Center, HL077866 Medical College of Wisconsin, HL077867 University of Washington, HL077871 University of Pittsburgh, HL077872 St. Michael's Hospital, HL077873 Oregon Health and Science University, HL077881 University of Alabama at Birmingham, HL077885 Ottawa Health Research Institute, HL077887 University of Texas SW Medical Center/Dallas, HL077908 University of California San Diego) from the National Heart, Lung and Blood Institute in partnership with the National Institute of Neurological Disorders and Stroke, U.S. Army Medical Research & Material Command, The Canadian Institutes of Health Research (CIHR) – Institute of Circulatory and Respiratory Health, Defense Research and Development Canada and the Heart, Stroke Foundation of Canada and the American Heart Association. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Heart, Lung and Blood Institute or the National Institutes of Health.

Dr. Wang received grant support from award UH2/UH3-HL125163 from the National Heart Lung and Blood Institute.

References:

1. Benjamin, EJ et al. "Heart Disease and Stroke Statistics – 2017 Update" *Circulation* 135 (2017) 35:e323-e341 DOI: 10.1161/CIR.0000000000000485
2. "National EMS Scope of Practice Model." NHTSA, http://www.ems.gov/education/EMSScope.pdf. Web. 16 July 2016.
3. "EMT-Paramedic - National Standard Curriculum" NHSTA, http://pdf-release.net/external/2520799/pdf-release-dot-net-New%20EMT-P%20Curriculum.pdf; Web. 16 July 2016.
4. Stiell, I. G., Wells, G. A., Field, et. al. Advanced cardiac life support in out-of-hospital cardiac arrest. *New England Journal of Medicine*, *351*(7), 647-656.
5. Sanghavi P, et al. "Outcomes after out-of-hospital cardiac arrest treated by basic vs advanced life support." *JAMA internal medicine* 175.2 (2015): 196-204.
6. Morrison, LJ, et al. "Rationale, development and implementation of the Resuscitation Outcomes Consortium Epistry—Cardiac Arrest." *Resuscitation* 78.2 (2008): 161-169.
7. Cummins RO, Chamberlain DA, Abramson NS, et. al. Recommended Guidelines for Uniform Reporting of Data from Out-of-Hospital Cardiac Arrest: The Utstein Style, Circulation 84 (2) August 1991, p. 960-75

8. Kleinman, ME, et al. "Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care." *Circulation* 132.18 suppl 2 (2015): S414-S435.
9. Nichol, G. et al. "Trial of continuous or interrupted chest compressions during CPR." *New England Journal of Medicine* 373.23 (2015): 2203-2214.
10. Coppler, P. J., Rittenberger, J. C., Wallace, D. J., et. al. Billing diagnoses do not accurately identify out-of-hospital cardiac arrest patients: An analysis of a regional healthcare system. *Resuscitation*, 2016 Jan:*98*, 9-14.
11. Wang HE and Kupas DF. "Outcomes after Out of Hospital Cardiac Arrest Treated by Basic vs Advanced Life support." JAMA: Internal Medicine. 2015 Aug;175(8):1421.
12. Drennan IR, Buick JE, Cheskes S. "Outcomes after Out of Hospital Cardiac Arrest Treated by Basic vs Advanced Life support." JAMA: Internal Medicine. 2015 Aug;175(8):1421-2.
13. Pozner, Charles N., et al. "International EMS systems: The United States: past, present, and future." *Resuscitation* 60.3 (2004): 239-244.

14. “EMT-Basic - National Standard Curriculum” NHSTA, www.nhtsa.gov/people/injury/ems/pub/emtbnsc.pdf Web. 16 July 2016.
15. Gold LS, Eisenberg MS. "The effect of paramedic experience on survival from cardiac arrest." *Prehospital Emergency Care* 13.3 (2009): 341-344.
16. Wang HE, et al. "Out-of-hospital endotracheal intubation experience and patient outcomes." *Annals of emergency medicine* 55.6 (2010): 527-537.
17. Warren SA, Prince DK, Huszti E, et. al. Volume versus outcome: More emergency medical services personnel on-scene and increased survival after out-of-hospital cardiac arrest. *Resuscitation*, *94*, 40-48.
18. Dyson K, BrayJ, Smith K, et. al. A systematic review of the effect of emergency medical service practitioners’ experience and exposure to out-of-hospital cardiac arrest on patient survival and procedural performance. *Resuscitation*, *85*(9), 1134-1141.
19. Soo LH, Gray D, Young T, et. al. Influence of ambulance crew’s length of experience on the outcome of out-of-hospital cardiac arrest. *European heart journal*, *20*(7), 535-540.

20. Nielsen N, et al. "Targeted temperature management at 33 C versus 36 C after cardiac arrest." *New England Journal of Medicine* 369.23 (2013): 2197-2206.
21. Larsen JM, Ravkilde J. (2012). Acute coronary angiography in patients resuscitated from out-of-hospital cardiac arrest—a systematic review and meta-analysis. *Resuscitation*, *83*(12), 1427-1433.
22. Kurz MC, Donnelly JP, Wang HE *Variations in Survival after Cardiac Arrest among Academic Medical Center-Affiliated Hospitals.* PLOS One, *2017.*

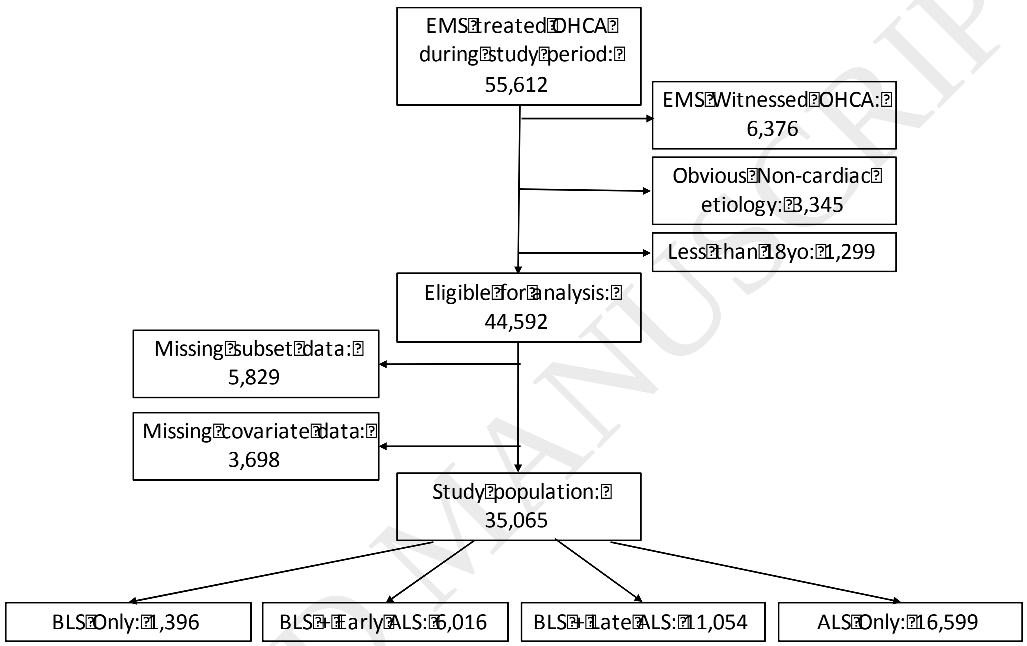
Tables and Figures:

Figure 1: Definition of Cohorts

BLS - Only	BLS interventions only
BLS + Late ALS	BLS first on scene + ≥1 ALS intervention ≥6 min after CPR start
BLS + Early ALS	BLS first on scene + ≥1 ALS intervention <6 min after CPR start
ALS - First	ALS first on scene + ≥1 ALS intervention ± BLS interventions

BLS = Basic Life Support; ALS = Advanced Life Support

Figure 2: Study Population



EMS = Emergency Medical Services; OHCA = Out-of-Hospital Cardiac Arrest; BLS = Basic Life Support; ALS = Advanced Life Support

Table 1: Characteristics of Study Population, Stratified by Treatment Level

	BLS Only	BLS + Late ALS (≥6min)	BLS + Early ALS (<6min)	ALS - First
n	1,396	11,054	6,016	16,599
Male, n (%)	777 (55.7%)	7,149 (64.7%)	3,962 (65.9%)	10,514 (63.3%)
Age				
Median (IQR)	76 (26)	68 (24)	66 (24)	67 (25)
<40 yrs, n (%)	96 (6.9%)	639 (5.8%)	422 (7.0%)	1078 (6.5%)
40-60 yrs, n (%)	263 (18.8%)	2,996 (27.1%)	1,802 (30.0%)	4,718 (28.4%)
>60 yrs, n (%)	1,037 (74.3%)	7,419 (67.1%)	3,792 (63.0%)	10,803 (65.1%)
Witness Status				
Bystander, n (%)	316 (22.6%)	5,103 (46.2%)	2,628 (43.7%)	7,316 (44.1%)
None, n (%)	1,080 (77.4%)	5,951 (53.8%)	3,388 (56.3%)	9,283 (55.9%)
Bystander CPR, n (%)	561 (40.2%)	5,308 (48.0%)	2,979 (49.5%)	8,880 (53.5%)
Initial rhythm				
VT/VF, n (%)	83 (5.9%)	2,811 (25.4%)	1,606 (26.7%)	3,979 (24.0%)
PEA, n (%)	179 (12.8%)	2,200 (19.9%)	1,109 (18.4%)	3,496 (21.1%)
Asystole, n (%)	872 (62.5%)	5,089 (46.0%)	2,930 (48.7%)	8,374 (50.4%)
No shock advised, n (%)	262 (18.8%)	954 (8.6%)	371 (6.2%)	750 (4.5%)
Episode location				
Public, n (%)	71 (5.1%)	1,719 (15.6%)	892 (14.8%)	2,380 (14.3%)
Private, n (%)	1,325 (94.9%)	9,335 (84.4%)	5,124 (85.2%)	14,219 (85.7%)
First agency arrival time				
>= 6 minutes, n (%)	732 (52.4%)	6,482 (58.6%)	3,802 (63.2%)	10,375 (62.5%)
< 6 minutes, n (%)	664 (47.6%)	4,572 (41.4%)	2,214 (36.8%)	6,224 (37.5%)
Mean arrival time (sd)	6.6 (3.5)	5.9 (2.6)	5.6 (2.4)	5.7 (2.6)
Site				
A, n (row %)	69 (1.6%)	1,414 (32.6%)	779 (18.0%)	2,075 (47.8%)
B, n (row %)	0 (0.0%)	2 (0.1%)	0 (0.0%)	2,465 (99.9%)
C, n (row %)	4 (0.6%)	120 (16.5%)	69 (9.5%)	534 (73.5%)
D, n (row %)	645 (7.7%)	3,779 (45.4%)	1,265 (15.2%)	2,637 (31.7%)
E, n (row %)	8 (0.1%)	635 (11.0%)	507 (8.8%)	4,602 (80.0%)
F, n (row %)	339 (7.9%)	2,566 (59.9%)	880 (20.5%)	500 (11.7%)
G, n (row %)	12 (0.5%)	632 (27.8%)	854 (37.6%)	775 (34.1%)
H, n (row %)	0 (0.0%)	10 (0.5%)	9 (0.5%)	1,867 (99.0%)
I, n (row %)	68 (4.7%)	213 (14.8%)	211 (14.7%)	948 (65.8%)
J, n (row %)	251 (7.0%)	1,683 (47.1%)	1,442 (40.4%)	196 (5.5%)

Table 2: Frequency of EMS Intervention, Stratified by Treatment Level

	BLS Only	BLS + Late ALS (≥6min)	BLS + Early ALS (<6min)	ALS-First
BLS unit intervention				
CPR	100%	100%	100%	N/A
AED applied	99.8%	99.7%	99.8%	N/A
ALS unit intervention				
Intubation	N/A	67.2%	71.2%	48.2%
Supraglottic Airway	N/A	27.8%	22.5%	38.3%
Defibrillation	7.6%**	39.4%	37.9%	33.8%
IV Drug Therapy	N/A	98.7%	98.7%	96.4%

** Defibrillation was delivered by the BLS unit via AED as there was no ALS provider present.

Table 3: CPR Process Measures, Stratified by Treatment Level

	BLS Only	BLS + Late ALS (≥6min)	BLS + Early ALS (<6min)	ALS - First
n	1,396	11,054	6,016	16,599
Available minutes, mean (sd)	4.3 (3.8)	9.1 (5.2)	9.6 (6.1)	7.9 (9.5)
CCF				
Mean (sd)	0.79 (0.12)	0.81 (0.12)	0.82 (0.12)	0.82 (0.13)
<=0.60, n (%)	80 (7.2%)	569 (5.6%)	294 (5.3%)	827 (6.0%)
0.61-0.80, n (%)	407 (36.5%)	3,514 (34.5%)	1,587 (28.6%)	3,815 (27.5%)
>0.80, n (%)	629 (56.4%)	6,108 (59.9%)	3,667 (66.1%)	9,227 (66.5%)
Compression Rate				
Mean (sd)	109.1 (11.7)	109.9 (10.4)	109.9 (10.5)	110.7 (12.3)
<100, n (%)	188 (18.0%)	1,382 (13.8%)	704 (13.0%)	1,834 (13.4%)
100-120, n (%)	687 (65.9%)	7,128 (71.3%)	3,915 (72.5%)	9,287 (67.7%)
>120, n (%)	167 (16.0%)	1,490 (14.9%)	782 (14.5%)	2,597 (18.9%)
Compression Depth				
Mean (sd)	43.0 (10.6)	48.8 (10.9)	48.4 (10.5)	47.4 (11.0)
<37, n (%)	152 (31.5%)	725 (13.7%)	378 (12.9%)	1,272 (16.2%)
37-51, n (%)	218 (45.2%)	2,401 (45.3%)	1,393 (47.6%)	3,888 (49.5%)
>51, n (%)	112 (23.2%)	2,178 (41.1%)	1,157 (39.5%)	2,699 (34.3%)
Max Pre-Shock Pause				
Mean (sd)	11.5 (8.1)	11.8 (11.0)	11.0 (11.8)	10.4 (30.2)
<10, n (%)	38 (48.7%)	1,332 (44.7%)	974 (53.1%)	2,075 (54.7%)
10-20, n (%)	28 (35.9%)	1,078 (36.1%)	560 (30.5%)	1,011 (26.7%)
>20, n (%)	12 (15.4%)	573 (19.2%)	302 (16.4%)	705 (18.6%)
Max Post-Shock Pause				
Mean (sd)	6.7 (4.9)	5.8 (9.4)	5.3 (7.5)	6.2 (27.2)
<10, n (%)	61 (81.3%)	2,667 (91.2%)	1,637 (92.1%)	3,345 (90.9%)
10-20, n (%)	10 (13.3%)	187 (6.4%)	96 (5.4%)	244 (6.6%)
>20, n (%)	4 (5.3%)	70 (2.4%)	45 (2.5%)	92 (2.5%)
Number of Shocks, mean (sd)	1.6 (1.0)	3.6 (3.4)	3.6 (3.2)	3.3 (2.8)

Table 4: Unadjusted Outcomes by Prehospital Treatment Level

	BLS Only	ALS Only	BLS + Late ALS (≥6min)	BLS + Early ALS (<6min)
n	1396	16599	11054	6016
Survival to Hospital Discharge	35 (2.5%)	1,494 (9.0%)	1,106 (10.0%)	719 (12.0%)
Prehospital ROSC	48 (3.4%)	3,878 (23.4%)	3,186 (28.8%)	1,995 (33.2%)
24-hour survival	51 (3.7%)	3,674 (22.1%)	2,622 (23.7%)	1,739 (28.9%)
MRS <=3	30 (2.1%)	758 (4.6%)	825 (7.5%)	502 (8.3%)

Table 5: Associations Between Level of Care and OHCA Outcomes

	OUTCOME		
Level of Care	ROSC on Emergency Department Arrival	Survival at Hospital Discharge	MRS <=3
BLS-Only	reference	reference	reference
BLS Plus Late ALS Care	9.13 (5.10, 16.4)	2.48 (1.00, 6.14)	3.70 (0.89,15.3)
BLS Plus Early ALS Care	10.8 (5.98, 19.3)	2.80 (1.12, 6.97)	3.65 (0.88,15.2)
ALS-Only	8.87 (4.94, 15.9)	2.63 (1.06, 6.54)	3.66 (0.88,15.2)

ROSC = Return of Spontaneous Circulation. MRS = Modified Rankin Scale. BLS = Basic Life Support. ALS = Advanced Life Support. Results expressed as Odds Ratios followed by (95% Confidence Intervals), adjusted for age, sex, witnessed arrest event, provision of bystander CPR, presenting ECG rhythm, CPR fraction, rate, depth, and ROC site location.