Supplementary Online Content

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eAppendix.

This supplementary material has been provided by the authors to give readers additional information about their work.

eAppendix

1 Hospital quality measures

Because the quality of hospitals to which ALS and BLS ambulances transport patients might differ systematically, we allow hospital quality to be part of the ambulance effect, while still controlling for the average quality of available hospital options. We constructed this measure of hospital quality as follows.

First, we selected all patients who had ALS ambulance service to each hospital in 2009 - 2011, with hospital-assigned diagnosis codes for acute myocardial infraction (AMI), congestive heart failure (CHF), or pneumonia (PN) from our Medicare claims, excluding cardiac arrest cases. Second, we obtained AMI, CHF, and PN 30-day mortality measures from Hospital Compare for 2009 - 2011, and averaged over the three years within each measure. Third, we linked each Medicare observation from the first step with the hospital mortality measures from the second step for the hospital to which the patient was taken. Fourth, we averaged the hospital mortality measures in the newly linked dataset by ZIP codes. This created ZIP-code level hospital mortality averages, weighted by the number of people visiting each hospital from the ZIP code.

In our analysis, we linked the ZIP code of each cardiac arrest patient with its corresponding ZIP code level hospital mortality rates. In cases where no ZIP code level hospital mortality rates were found, we linked with rates in ZIP codes that were nearby, based on sharing the same first four digits and numerically nearest fifth digit. We averaged in cases where mortality rates were found for two equidistant ZIP codes. Finally, for each observation, we computed an average of the ZIP code hospital mortality rates for AMI, CHF, and PN, weighted by the overall distribution of these cases in the Medicare sample. This is the final measure we used to control for the quality of available hospitals in a ZIP code.

2 Sensitivity analysis: Unmeasured severity in ALS transports

Unmeasured severity differences between patients might have led to differential ambulance dispatch and treatment, and also affected outcomes. Though this is unlikely in cardiac arrest cases, we used comorbidity scores to estimate this potential bias.

We regressed survival to 90 days on a binary indicator for ambulance type. Our logistic regression was specified similarly to our propensity score model in the main analysis. We incremented the average comorbidity score for ALS cases until the coefficient for ambulance type was not statistically significant at the 5% level.

The mean comorbidity score among BLS patients was 5.5 with a standard deviation of about 4, and among ALS patients was 4.8 with a standard deviation of also about 4. The observed difference in survival could be explained by an unobserved factor affecting ALS mortality that has an effect equivalent to an average comorbidity score that is 5 units higher, or 9.8, which is about 1.3 standard deviations above the observed mean ALS comorbidity score. It is unlikely that there was an unobserved difference in severity of this magnitude. Thus, our main findings are not sensitive to unobserved differences in severity. However, a limitation of this analysis was that comorbidity scores may not be good constructs for measuring severity in acute events.

3 Sensitivity analysis: Adjustment using logistic regression for outcomes

In our main analysis, we balanced the covariate distributions between Basic Life Support (BLS) and Advanced Life Support (ALS) by generating weights based on propensity scores. We developed our propensity score model systematically and used likelihood ratio tests to compare model specifications. As an additional alternative, we used logistic regression to estimate survival to 30 days and to 90 days. This allowed us to check the modeling dependency of our results.

We regressed the outcomes, survival to 30 days and to 90 days, on a binary indicator for ambulance type. Otherwise, our logistic regression used the same variables as our propensity score model in the main analysis. To estimate the difference in outcomes, we predicted the probabilities of survival for the population that was transported by BLS for both types of ambulances. Thus, we simulate the average effect of ALS for the BLS population as we did in the main analysis.

Survival to 30 days was 3.6 percentage points (95% CI: 1.1, 7.8) higher and to 90 days was 2.8 percentage points higher (95% CI: 0.7, 6.9) with BLS level of service (Appendix eTable 1). The direction or significance of our main findings did not change.

eTable 1. Survival outcomes by ambulance service level, adjusted by logistic regression model

	BLS (95% CI)	ALS (95% CI)	Difference (95% CI)
Survival to 30 days (%)	9.6 (3.2, 21.3)	6.1 (2.0, 13.9)	3.6 (1.1, 7.8)
Survival to 90 days (%)	8.1 (2.2, 19.9)	5.4 (1.4, 13.4)	2.8 (0.7, 6.9)

4 Sensitivity analysis: Death enroute to hospital

Ambulance diagnosis coding is generally of poor quality, and thus we did not use it in our main analysis. However, this may have excluded some beneficiaries who died prior to arrival at a hospital and thus do not have hospital claims. According to Medicare rules, if a patient dies after dispatch but prior to loading onto the truck, the ambulance service may only bill at the BLS level and indicate this situation with a HCPCS modifier code. Thus, it is not possible to know the service level in these cases. These cases are likely to often involve individuals who would not be considered revivable. If a patient was transported and the ambulance correctly coded cardiac arrest, we would expect the patient to have a death date on the same day as the ride, or at most, on the day after the ride. In this analysis, we check the sensitivity of our main findings to the inclusion of this group.

We included in our sample those beneficiaries who were transported by ambulance, were identified as being in cardiac arrest by the ambulance crew, do not have a hospital claim, and have a death date on the same day or the day after the ride. We identified 1,538 cases that met this criteria, of which 151 were provided with BLS service and 1,387 were provided with ALS service. It was not possible to exclude injury cases as codes for these diagnoses were generally not reported on ambulance claims. We applied the same propensity score model specification and weighting approach as in our main analysis, and estimated survival to 30 days and 90 days.

Survival to 30 days was 2.9 percentage points (95% CI: 1.5, 4.2) higher and to 90 days was 2.2 percentage points higher (95% CI: 0.9, 3.5) with BLS than with ALS (Appendix eTable 2). The direction or significance of our main findings did not change. However, this analysis was limited by the quality of ambulance diagnosis coding.

eTable 2. Survival outcomes by ambulance service level, with beneficiaries who died prior to hospital arrival

	BLS (95% CI)	ALS (95% CI)	Difference (95% CI)
Adjusted survival to 30 days (%)	8.8 (7.4, 10.1)	5.9 (5.5, 6.3)	2.9 (1.5, 4.2)
Adjusted survival to 90 days (%)	7.4 (6.1, 8.6)	5.2 (4.8, 5.5)	2.2 (0.9, 3.5)
Unadjusted survival to 90 days (%)	7.4 (6.1, 8.6)	5.6 (5.3, 5.8)	1.8 (0.6, 3.0)

5 Sensitivity analysis: Death in the field

We excluded patients with only an ambulance claim, and therefore individuals who died at the scene. If patients receiving BLS are more likely to die at the scene, our results may be confounded. However, for two key reasons, it is not possible to use the Medicare claims data to assess the sensitivity of our results to this exclusion. First, in cases where an individual is treated at the scene but pronounced dead before being loaded into the truck, both ALS and BLS providers are paid at the BLS level and therefore bill at this level. Second, these observations have only ambulance diagnosis coding, which is unlikely to be accurate in general, but even more so in cases where there was little time to observe the patient.

Therefore, we have used data sources other than the claims to estimate how deaths in the field may have affected our estimates. While these datasets likely differ in key ways from the Medicare sample, these approximate calculations provide reassurance.

In an analysis by the Resuscitation Outcomes Consortium (ROC)[30], approximately 63% of cardiac arrest cases where resuscitation was attempted by EMS were transported to a hospital. In eTable 3, we apply this figure to our Medicare sample to estimate the BLS/ALS distribution that would be required among cases that died in the field in order to eliminate our observed effect.

eTable 3. BLS/ALS distribution required among additional field deaths to remove observed effect using ROC[30] data

	Medicare sample size	*Medicare sample 90-day mortality*	Additional estimated deaths in field	Overall mortality rate
BLS	1,643 (5%)	*1,511*	1,934 (10%)	(1,511 + 1,934)/(1,643 + 1,934) = 96%
ALS	31,292 (95%)	*29,477*	17,409 (90%)	(29,477 + 17,409)/(31,292 + 17,409) = 96%
Total	32,935 (63%)	-	19,343 (37%)	-

To remove our observed effect, 10% of field deaths would have to have been treated by BLS, which is twice the overall percent of BLS in our sample. Further, the BLS mortality rate in the field (56%) would have to be 1.5 times the ALS mortality rate in the field (37%). This does not seem plausible.

We repeated the above analysis using data from the Cardiac Arrest Registry to Enhance Survival (CARES)[29], in which 22% of cases treated by EMS died in the field. In eTable 4, we show that to remove the observed difference between BLS and ALS, about 13% of field deaths would have to be treated by BLS. This is more than two times the overall percent of BLS in our sample. Also, the BLS mortality rate in the field (44%) would have to be twice the ALS mortality rate in the field (22%). Therefore, we do not believe accounting for deaths in the field would change the direction of our observed effect.

eTable 4. BLS/ALS distribution required among additional field deaths to remove observed effect using CARES[29] data

	Medicare sample size	*Medicare sample 90-day mortality*	Additional estimated deaths in field	Overall mortality rate
BLS	1,643 (5%)	*1,511*	1,208 (13%)	(1,511 + 1,208)/(1,643 + 1,208) = 95%
ALS	31,292 (95%)	*29,477*	8,081 (87%)	(29,477 + 8,081)/(31,292 +

				8,081) = 95%
Total	32,935 (78%)	-	9,289 (22%)	-

6 Sensitivity analysis: Nursing homes

Although we control for pickup location in the main analysis, there may be concern about residual confounding related with interactions between being in a nursing home and other covariates. For example, nursing home staff may selectively treat some patients with a defibrillator or CPR and therefore be able to request BLS service to the hospital. This would attribute survival to BLS instead of the nursing home staff. To study the sensitivity of our results to this potential source of confounding, we repeat our analysis for 30 day and 90 day survival using only observations that did not originate at a nursing home.

After removing nursing home pickups, our sample includes 1,205 BLS and 26,896 ALS cases. Survival to 30 days was 3.5 percentage points (95% CI: 1.7, 5.3) higher and to 90 days was 3.2 percentage points higher (95% CI: 1.5, 4.9) with BLS level of service (Appendix eTable 5). The direction or significance of our main findings did not change.

eTable 5. Survival outcomes by ambulance service level for non-nursing home pickups

	BLS (95% CI)	ALS (95% CI)	Difference (95% CI)
Survival to 30 days (%)	10.5 (8.7, 12.2)	7.0 (6.5, 7.5)	3.5 (1.7, 5.3)
Survival to 90 days (%)	9.4 (7.7, 11.0)	6.2 (5.7, 6.7)	3.2 (1.5, 4.9)

7 Sensitivity analysis: BLS requested ALS backup

In areas with two-tier response, it may be that BLS providers request ALS backup when BLS is unable to resuscitate a patient. In these cases, ALS would be spuriously associated with worse outcomes that otherwise should have been attributed to BLS.

Our sample includes only rides in which a transport occurred and a hospital bill was generated. Thus, in order for these cases to be included in our sample, the patient would have to survive until ALS arrives, be considered appropriate for transport, and be provided with service in the Emergency Department.

We estimate the number of BLS cases that would have to have been incorrectly attributed to ALS as described above in order to change the direction of our findings. In our sample, 1,511 of 1,643 BLS and 29,477 of 31,292 ALS patients did not survive to 90 days. For the calculation, we simply moved patients who died under ALS to the group of patients who died under BLS until the proportion of survivors was the same in both groups. We found this occurred when about 600 cases were removed from the sample of ALS patients who had died by 90 days after the arrest and added to the sample of BLS cases that had died by 90 days after the arrest. Thus, to change the direction of our findings, 600/(1,643+600) or 27% of BLS cases would have to have been in the situation where BLS could not resuscitate and called ALS for backup, ALS treated the patient and transported the patient to the hospital, and the Emergency Department provided service to the patient. This does not seem plausible.

8 Sensitivity analysis: Removal of respiratory failure observations

It is possible that outcomes after ALS and BLS are different for patients with cardiac arrest that originates from a cardiac etiology versus patients with a root respiratory cause. To study the sensitivity of our results to this potential source of confounding, we repeat our analysis for 30 day and 90 day survival for a sample that excludes patients with acute respiratory failure ICD-9CM diagnosis codes (518.4, 518.5x, 518.81, and 518.82).

After removing acute respiratory failure cases, our sample includes 1,373 BLS and 25,999 ALS cases. Survival to 30 days was 3.0 percentage points (95% CI: 1.7, 4.4) higher and to 90 days was 2.4 percentage points higher (95% CI: 1.2, 3.7) with BLS level of service (Appendix eTable 6). Though the overall mortality rates are higher in these cases, the direction or significance of our main findings did not change.

eTable 6. Survival outcomes by ambulance service level for observations with likely primary cardiac etiology

	BLS (95% CI)	ALS (95% CI)	Difference (95% CI)
Survival to 30 days (%)	6.7 (5.4, 8.0)	3.7 (3.3, 4.0)	3.0 (1.7, 4.4)
Survival to 90 days (%)	5.8 (4.5, 7.0)	3.3 (3.0, 3.6)	2.4 (1.2, 3.7)

9 Sensitivity analysis: Narrower definition of poor neurological performance

We inferred Cerebral Performance Categories (CPC) scale items 4 and 5 based on the presence of ICD-9CM diagnosis codes for anoxic brain injury (348.1), coma (700.01), persistent vegetative state (780.03), or brain dead (348.82). Since individuals with anoxic brain injury and coma can recover, defining poor neurological performance using only diagnosis codes for persistent vegetative state and brain dead may be more precise. Therefore, we repeat our analysis of poor neurological functioning following ALS and BLS using this narrower specification.

After restricting the definition to only persistent vegetative state and brain death, a higher percentage of ALS than BLS patients experienced poor neurological functioning, both overall and among only admitted patients, but the difference between ALS and BLS was not statistically significant (Appendix eTable 7).

eTable 7. Neurological performance outcomes by ambulance service level using narrower definition of poor neurological functioning

	BLS (95% CI)	ALS (95% CI)	Difference (95% CI)
Poor neurological performance, overall (%)	0.06 (-0.05, 0.2)	0.2 (0.1, 0.2)	0.1 (-0.02, 0.3)
Poor neurological performance, admitted patients (%)	0.2 (-0.2, 0.7)	0.7 (0.4, 1.0)	0.5 (-0.06, 1.0)

10 Propensity score regression parameters

Below, eTable 8 shows the regression parameters from the logistic regression model that was used to predict the probability of receiving ALS. This was used to generate propensity scores and hence balancing weights for the analysis.

eTable 8. Coefficients from logistic regression model for predicting the propensity to receive ALS (log-odds ratios are shown)

Variable	Coefficient	95% CI
Intercept	0.198	-0.921, 1.336
State fixed effects (not shown)	-	-

Female	-0.134	-0.240, -0.029
Linear age spline: 0 - 65 years	0.888	0.253, 1.498
Linear age spline: 65 - 75 years	0.973	0.419, 1.501
Linear age spline: 75 - 80 years	0.642	0.063, 1.195
Linear age spline: 80 - 85 years	0.850	0.278, 1.395
Linear age spline: 85 years and over	0.344	-0.383, 1.061
Race Reference: White	-	-
Race: Asian	-0.306	-0.665, 0.081
Race: Black	-0.167	-0.323, -0.009
Race: Hispanic	-0.224	-0.538, 0.110
Race: Other	-0.303	-0.634, 0.054
Pickup Reference: Residence	-	-
Pickup: Non-SNF Nursing Home[a]	-0.400	-0.648, -0.140
Pickup: SNF	-0.797	-0.928, -0.665
Pickup: Scene	0.203	0.050, 0.359
Chronic condition: Alzheimer's/Dementia[b]	-0.192	-0.312, -0.072
Chronic condition: Diabetes	-0.069	-0.176, 0.039
Chronic condition: Asthma	0.162	0.030, 0.298
Race/Income ZIP Mix[c] **Reference: Black, High Income**	-	-
Race/Income ZIP Mix: Black, Low Income	-0.051	-0.568, 0.446
Race/Income ZIP Mix: Integrated, High Income	0.198	-0.262, 0.622
Race/Income ZIP Mix: Integrated, Low Income	0.163	-0.303, 0.596
Race/Income ZIP Mix: White, High Income	0.516	0.047, 0.952
Race/Income ZIP Mix; White, Low Income	0.315	-0.188, 0.792
Metropolitan County[d]	0.166	-0.015, 0.345
Percent of Persons with 4 Plus Years of College in County	0.007	-0.001, 0.014
Percent General Practice Doctors in County	-0.011	-0.017, -0.006
Any Medical School-Affiliated Hospital in County	-0.079	-0.225, 0.065
Hospital Quality ZIP Measure[e]	0.218	0.161, 0.275

[a] Includes non-SNF residential, domiciliary, custodial, or nursing home facilities.

[b] Alzheimer's disease/dementia includes Alzheimer's, related diseases, and senile dementia.

[c] High if median household income > $40,000, low otherwise, and predominantly black if more than 80% black, predominantly white if more than 80% white, and otherwise integrated.

[d] Metropolitan areas have at least one urbanized area of 50,000 or more population, and micropolitan areas have at least one urban cluster of at least 10,000 but less than 50,000 population. Both types of area have adjacent territory that has a high degree of social and economic integration with the core as measured by commuting ties.

[e] Measure described in detail in Section 1 of Supplementary Appendix.