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Clinical paper

Demographic, social, economic and geographic factors associated with long-term outcomes in a cohort of cardiac arrest survivors☆

Patrick J. Coppler[a], Jonathan Elmer[b], Jon C. Rittenberger[b], Clifton W. Callaway[b], David J. Wallace[c,*]

[a] Department of Critical Care Medicine, University of Pittsburgh School of Medicine, 637 Scaife Hall, 3550 Terrace Street, Pittsburgh, PA, 15261, USA
[b] Department of Emergency Medicine, University of Pittsburgh School of Medicine, Suite 10028 Forbes Tower, Pittsburgh, PA, 15260, USA
[c] Department of Critical Care Medicine & Department of Emergency Medicine, University of Pittsburgh School of Medicine, 637 Scaife Hall, 3550 Terrace Street, Pittsburgh, PA, 15261, USA

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ABSTRACT

Background: Demographic, social, economic and geographic factors are associated with increased short-term mortality after cardiac arrest. We sought to determine if these factors are additionally associated with long-term outcome differences using a detailed clinical database linked to state-wide administrative data.

Methods: We included cardiac arrest patients surviving to hospital discharge from five hospitals in the United States from 2005 to 2013, with follow-up through 2015. We obtained information on sex, race, arrest location, initial rhythm, median ZIP code income, post-arrest illness severity, cardiac catheterization, internal cardioverter-defibrillator insertion, rural residence and drive time from residence to the nearest acute care hospital. We used Cox proportional hazard models identify predictors of mortality.

Results: We included 891 patients followed for 2081 patient-years. There were 340 deaths with median survival 6 years. In adjusted models we identified an interaction effect between median ZIP code income and cardiac catheterization. Among patients who had cardiac catheterization there was an attenuated benefit from cardiac catheterization at progressively lower neighborhood incomes (adjusted HR: 0.21 to 0.46 to 0.56). Residence more than 20 min from the nearest acute care hospital was associated with increased hazard of death (adjusted HR: 1.48; 95%CI: 1.35–1.62), after controlling for rural residence and residence in a Medically Underserved Area/Population. Female patients showed less benefit following ICD placement (male adjusted HR: 0.49; female adjusted HR: 0.66).

Conclusions: There are persistent long-term outcome differences in cardiac arrest survival based on sex, income, and geographic access acute care.

Introduction

Although overall survival after sudden cardiac arrest has improved over time [1–3], not all groups have benefited, with notable quality gaps associated with patient sex [4], race [5], socioeconomic status [6–10] and rural residence [11,12]. It is not clear to what extent these effects arise from health system elements, underlying biological differences, geographic access to healthcare or an intersection of multiple factors. Health system factors are an important potentially modifiable aspect of cardiac arrest care and can serve as quality improvement targets. There is recent evidence that in-patient cardiac arrest clinical guidelines [13]are applied variably across hospitals, and that women receive fewer guideline-recommended treatments in the prehospital setting [14]. Patients living in rural and lower income areas face other potential challenges, such as lower rates of bystander-initiated cardiopulmonary arrest [6,9], longer transit times to the hospital [12,15], less access to automated external defibrillators [16] and poorer access to specialist care [17]. Recognizing these continued disparities, the National Academy of Medicine emphasized sex, race, socioeconomic, and rural health disparities as priorities for cardiac arrest research [18–20].

Using a highly detailed clinical registry with long-term outcome data in cohort of cardiac arrest survivors, our study sought to determine if there are persistent long-term outcome differences based on sex, race, income status, or health care access. We hypothesized that male sex, black race, lower income status, residence in a rural area, residence in an area with a shortage of primary care providers, and residence at

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* Corresponding author.
E-mail address: wallaced@pitt.edu (D.J. Wallace).

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greater distance to the nearest hospital would be associated with shorter duration of survival after hospital discharge.

Methods

Patient cohort, outpatient procedures and outcomes

We included adult patients resuscitated from in-hospital cardiac arrest or out-of-hospital cardiac arrest treated at one of five hospitals in Pennsylvania between 2005 and 2013 [21]. We included both in-patient and out-of-hospital cardiac arrest events as it was our objective to describe and better understand the long-term outcomes for these patients as a whole. Although the precipitating etiologies are frequently different for in-patient and out-of-hospital cardiac arrest, the post-hospital needs for these patients are probably similar. In order to address both of these concerns (i.e., differing etiologies and yet similar long-term management strategy) we planned *a prior* to control for arrest location in our multivariable model.

We identified patients from a detailed clinical registry maintained at the University of Pittsburgh [21–24]. We obtained demographics (age, sex, race), arrest characteristics (location, presenting rhythm, and post-arrest illness severity modeled using Pittsburgh Cardiac Arrest Category) [24], hospital interventions (cardiac catheterization and implanted cardioverter-defibrillator (ICD) insertion), and functional status at hospital discharge (Cerebral Performance Category (CPC)) from this registry. We excluded patients who died before discharge, those who arrested secondary to trauma or neurologic catastrophe and sparsely represented demographic groups (defined as racial designations in fewer than 5% of the total cohort).

We linked registry records to data from the Pennsylvania Health Cost Containment Council (PHC4) using social security number, date of birth, name, and sex. PHC4 is an independent state agency that collects information on inpatient hospitalizations and ambulatory surgery procedures. We performed this linkage, in addition to index hospitalization data collection, to identify cardiac catheterizations or ICD insertions that took place within six months after index hospitalization in the outpatient setting, as in some clinical contexts it may be medically appropriate to delay these procedures to await physiological or myocardial recovery.

We used three measures to evaluate patient health care access: patient residence in a rural area (a measure of health care *availability*), patient residence in an area with barriers to care or a scarcity of primary care providers (a separate measure of health care *availability*), and estimated drive time from patient residence to the nearest acute care hospital (a measure of health care *accessibility*). Availability and accessibility are complementary measures of health care access, with availability representing the relationship between volume of services and volume of patients, and accessibility representing the relationship between the location of services and the location of patients. For our first measure of health care availability, we classified patients as living in a rural area if the geometric centroid of their home ZIP code was located in an area designated as rural by the United States Census Bureau [25]. We evaluated this exposure as rural health studies are a research priority outlined by the National Academy of Medicine. We additionally evaluated a second measure of availability using Medically Underserved Area or Population (MUA/P) designations. We obtained these locations from the Department of Health and Human Service's Health Resource & Services Administration (HRSA) [26]. HRSA develops criteria for geographic shortages of primary care providers, in addition to dental and mental health. These regions are not limited to urban or rural areas, and can span single or contiguous groups of counties. Medically Underserved Populations include groups who face economic, cultural or linguistic barriers to care. We designated a patient's home address as being an MUA/P if the geometric center of the ZIP code was contained within one of the HRSA MUA/P regions. We evaluated this second measure of availability, as these regions are potential targets for post-acute care investment. For our measure of accessibility, we used patient drive time to the nearest acute care hospital, rather than from arrest location or drive time to the actual treating hospital. We estimated the drive time to the closest short-term acute care hospital using the geometric center of each patient's home ZIP code and hospital street addresses reported in the 2013 Centers for Medicare and Medicaid Healthcare Cost Report Information System national database using ArcGIS Desktop 10.4 (Redlands, CA). We evaluated total drive time as a continuous variable using fractionated polynomial analysis with STATA command mfp to identify possible non-linear functional forms and to determine if there were natural time breakpoints associated with increased mortality.

We determined post-discharge survival by querying the National Death Index (NDI). The NDI is a comprehensive database of vital status obtained from state death records that has been used extensively to determine long-term mortality [27]. We linked registry records NDI data as previously described [21]. The follow-up period extended to December 31st 2014, providing two to nine years of follow-up.

Statistical analysis

We summarized patient demographics, arrest characteristics, hospital treatments, and long-term outcomes using descriptive statistics. We performed unadjusted Cox proportional hazard regression to test the associations between long-term outcome and race, sex, estimated median income (defined as household income less than $30,000, $30,000 to $60,000 and more than $60,000), extended drive time to the nearest hospital (defined as more than 20 min), arrest characteristics (location, presenting rhythm and post-arrest illness severity), invasive cardiac procedures (cardiac catheterization and ICD insertion), and functional status at hospital discharge. We created median income and Charlson Comorbidity thresholds using natural breakpoints from lowess plots with mortality.

We performed cross tabulations and evaluated correlations between our three measures of geographic access. We performed these steps as we expected they could represent at least partially overlapping exposures.

We evaluated interactions within demographic characteristics and between demographic characteristics and invasive procedures, to determine if there were nuanced relationships between health disparity risk factors and long-term outcome such that subgroups of patients benefited more that others. We then created a multivariable Cox model to evaluate the association between long-term survival and demographic factors and measures of health care access, controlling for all other covariates. We evaluated each geographic access measure separately in the multivariable model, and collectively. We included interactions that were significant below the alpha < 0.05 level in the final multivariable model. We performed a sensitivity analyses using additional drive times of 10, 15, 25 and 35 min, to evaluate if the relationship had a clear threshold. We performed standard regression diagnostics on all models, including checks for variable collinearity. We controlled for center clustering effects in all models.

We performed analyses using Stata version 13.1 (College Station, Texas) and ArcGIS Desktop 10.4 (Redlands, California).

Patients were not involved in any aspect of the study design or analysis. The University of Pittsburgh Institutional Review Board approved all aspects of this study under a waiver of informed consent.

Results

A total of 987 patients survived to hospital discharge. Twenty patients had missing race information and 9 were classified as "other", and were therefore excluded from analysis. Sixty-one patients did not reside in ZIP codes within Pennsylvania, making post-discharge record matching with PHC4 unreliable, and were also excluded. Six patients were treated at smaller hospitals that did not perform both cardiac