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Clinical paper

Long-term survival benefit from treatment at a specialty center after cardiac arrest☆

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ABSTRACT

Introduction: The Institute of Medicine and American Heart Association have called for tiered accreditation standards and regionalization of post-cardiac arrest care, but there is little data to support that regionalization has a durable effect on patient outcomes. We tested the effect of treatment at a high-volume center on long-term outcome after sudden cardiac arrest (SCA).
Methods: We included patients hospitalized at one of 7 medical centers in Southwestern Pennsylvania after SCA from 2005 to 2013. Centers were one regional referral center with an organized systems for post-SCA care, two moderate volume tertiary care centers and 4 low-volume centers. We abstracted clinical characteristics and outcomes at hospital discharge, and for survivors to discharge we queried the National Death Index for long-term survival data. We used Cox regression to determine the unadjusted associations of baseline predictors and survival, and built an adjusted model controlling for baseline predictors.
Results: Overall, 987 patients survived to discharge. During 2196 person-years of follow-up, median survival was 5.3 years and there were 396 deaths. In unadjusted analysis, treating center, age, arrest location, Charlson Comorbidity Index, initial rhythm, cardiac catheterization, defibrillator placement, discharge disposition, and neurological status at discharge were associated with long-term outcome. In adjusted analysis, treatment at the high-volume cardiac arrest center was associated with improved survival compared to treatment at other centers (hazards ratio 1.49, 95% confidence interval 1.19–1.86).
Conclusion: Treatment at a high-volume cardiac arrest center with organized systems for post-arrest care is associated with a substantial long-term survival benefit after hospital discharge.

Introduction

More than 500,000 Americans experience a sudden cardiac arrest (SCA) annually.[1] Despite advances in care, patient outcomes after SCA are poor, with only a 12% rate of favorable neurological recovery.[1] Among SCA patients who survive to hospital discharge, numerous factors are associated with long-term outcomes including baseline characteristics such as age, race, initial arrest rhythm, etiology and duration,[2–4] intermediate outcomes such as neurological status at hospital discharge,[5] and specific treatments such as use of targeted temperature management (TTM), coronary angiography and internal defibrillator implantation.[2,6–8] Although individual interventions are associated with improved survival, the overall effect of treatment at a high-volume center with organized systems of care for SCA is less clear.

In July of 2015 the Institute of Medicine (IOM) released its report "Strategies to Improve Cardiac Arrest Survival: a time to act," calling for tiered accreditation standards for post-arrest care centers.[9] Ten years earlier, amid debate in the resuscitation community about such standards,[10,11] we established a Post-Cardiac Arrest Service (PCAS), implemented hospital-wide care protocols for SCA care, and developed a regional referral network for post-arrest care.[12] Regionalization of SCA care was encouraged by analogy to the experience with coronary interventions, major trauma, surgery, and stroke, where center volume and organized

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systems of care are associated with improved outcomes.[13–18] More directly, we observed that in-hospital mortality after SCA varies widely by region, and although center volume has not consistently been associated with short-term outcome after SCA, adherence to evidence-based quality metrics is associated improved survival to discharge at the hospital level.[19–22] In this study, we examine whether the effect of treatment at a high-volume cardiac arrest center influences long-term outcomes after SCA.

Methods

Setting

The entirety of this work was approved by the University of Pittsburgh Institutional Review Board to be conducted with a waiver of informed consent.

We included adult patients treated at 7 hospitals within an integrated health delivery system in Southwestern Pennsylvania, with a catchment area of 2.5 million people. Hospitals included one high-volume, regional referral center with an organized PCAS (Center 1), two moderate volume tertiary care centers (Centers 2 and 3) and 4 low-volume centers (Centers 4–7) (Supplemental Table 1).

The PCAS at Center 1 (Supplemental Appendix) is consulted by the Emergency Department on consecutive out-of-hospital arrest patients with return of spontaneous circulation (ROSC), accepts SCA transfers from outlying facilities, and is consulted by intensive care providers on the majority of in-hospital SCA patients that achieve ROSC. The PCAS coordinates care through the entire post-arrest course including initial resuscitation and diagnostic workup, intensive care and inpatient care, neurological prognostication in comatose patients, detailed neurocognitive testing in patients who have awakened, secondary prevention and rehabilitation services. The PCAS also maintains an active quality assurance/improvement program that includes regular meetings, case review, feedback to emergency medical service providers and referring physicians, and 3- to 6-month telephone follow-up with discharged patients. Finally, the PCAS supports a research infrastructure with multiple ongoing clinical studies in this population. For patients transferred form one facility to another, we considered the final treating site to be the center for their index hospitalization.

Data sources

We identified patients from our prospective registry of SCA patients and by querying the electronic medical record for the diagnosis of SCA (International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9CM code 427.5) at all 7 centers. For patients identified by ICD-9CM code, we confirmed the diagnosis of SCA with a structured chart review, which we have confirmed to be essential for accurate case ascertainment.[23] We included patients resuscitated from in-hospital or out-of-hospital SCA who survived to hospital discharge, and excluded those with SCA secondary to surgical etiology such as trauma, or neurological catastrophe. We extracted name, sex, date of birth, race, marital status, state of last known residence, and social security number, and used these data to query the National Death Index (NDI) 2013 NDI Final File to obtain long-term survival data. We linked NDI query results to our SCA cohort using the standard NDI probabilistic scoring approach, and considered a score of >30 to represent a true match.[24]

Potential modifying factors

For eligible patients, we performed a structured chart review to collect age, gender, race, arrest location (in-hospital vs out-of-hospital), transfer status, presenting rhythm (ventricular tachycardia/fibrillation (VT/VF), pulseless electrical activity (PEA), asystole or unknown), pre-arrest Charlson Comorbidity Index, post-arrest illness severity (Pittsburgh Cardiac Arrest Category, a validated 4-level illness severity index that stratifies patients by severity of brain injury and cardiopulmonary failure (Supplemental Appendix)),[25] performance of coronary angiography, automated defibrillator implantation (AICD), Pittsburgh Cerebral Performance Category (CPC) at hospital discharge and discharge disposition (home, acute rehabilitation, long-term acute care (LTAC), skilled nursing facility (SNF), or hospice). Race was self-identified by the subject or surrogate, then recoded by the investigator into one of the 10 categories recognized by the NDI. We included race as a covariate because previous studies have associated race with long-term outcome after SCA.

Statistical analysis

We used descriptive statistics to summarize population characteristics, and report medians with interquartile ranges and numbers with corresponding percentages. We used Cox regression to determine the unadjusted associations of baseline predictors and survival, and built an adjusted model controlling for baseline predictors associated with survival at a level of $P < 0.1$. In unadjusted and adjusted models, there was no significant difference in the hazard of death across Centers 2–7 ($P = 0.36$ by Cox regression; $P = 0.48$ by log-rank test), so we report models where Center is treated as a binary variable. In adjusted models, we dichotomized initial rhythm, discharge CPC, and discharge disposition to avoid model over-fitting. We planned *a priori* to test for interactions between initial rhythm and cardiac catheterization, and between Pittsburgh Cardiac Arrest Category and Center. As a sensitivity analysis, we repeated Cox regression including all hospitalized patients (both survivors to discharge and non-survivors). We inspected scaled Shoenfeld residuals and log-log plots to check model assumptions. All analyses were performed using Stata Version 13 (StataCorp, College Station, TX), and we considered a P value <0.05 to be statistically significant for all analyses.

Results

Cohort characteristics and survival

Overall, we identified 3438 potentially eligible patients, of which 987 met inclusion and exclusion criteria (Fig. 1). Baseline population characteristics at Center 1 were similar to those at other centers (Table 1, Supplemental Table 2). Overall, median age was 63 (interquartile range 51–75) years and 40% of the population was female. During 2196 person-years of follow-up, median survival time was 5.3 years and there were 396 deaths. The remaining 591 patients surviving to December 31, 2013 were censored after a median of 2.5 (interquartile range 1.3–4.3) years after SCA. Unadjusted median survival was 6.6 years for patients treated at Center 1 and ranged from 0.8 to 4.5 years for Centers 2 through 7 (Fig. 2). The overall proportion of patients surviving to hospital discharge did not differ across centers (Supplemental Table 1, $P = 0.73$). However, post-discharge survival was significantly longer for patients treated at Center 1 ($P < 0.001$ for log-rank test), but did not differ across Centers 2 to 7 (log rank $P = 0.48$ after excluding Center 1). There was no change in long-term survival over time.

Unadjusted Cox regression

In unadjusted survival analysis, age, arrest location, Charlson Comorbidity Index, initial rhythm, cardiac catheterization,

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