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Clinical paper

Neighborhood characteristics, bystander automated external defibrillator use, and patient outcomes in public out-of-hospital cardiac arrest☆

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ABSTRACT

Background: Automated external defibrillators (AEDs) can be used by bystanders to provide rapid defibrillation for patients with out-of-hospital cardiac arrest (OHCA). Whether neighborhood characteristics are associated with AED use is unknown. Furthermore, the association between AED use and outcomes has not been well characterized for all (*i.e.* shockable and non-shockable) public OHCAs.

Methods: We included public, non-911-responder witnessed OHCAs registered in the Cardiac Arrest Registry to Enhance Survival (CARES) between 2013 and 2016. The primary patient outcome was survival to hospital discharge with a favorable functional outcome. We first assessed the association between neighborhood characteristics and bystander AED use using logistic regression and then assessed the association between bystander AED use and patient outcomes in a propensity score matched cohort.

Results: 25,182 OHCAs were included. Several neighborhood characteristics, including the proportion of people living alone, the proportion of white people, and the proportion with a high-school degree or higher, were associated with bystander AED use. 5132 OHCAs were included in the propensity score-matched cohort. Bystander AED use was associated with an increased risk of a favorable functional outcome (35% *vs.* 25%, risk difference: 9.7% [95% confidence interval: 7.2%, 12.2%], risk ratio: 1.38 [95% confidence interval: 1.27, 1.50]). This was driven by increased favorable functional outcomes with AED use in patients with shockable rhythms (58% *vs.* 39%) but not in patients with non-shockable rhythms (10% *vs.* 10%).

Conclusions: Specific neighborhood characteristics were associated with bystander AED use in OHCA. Bystander AED use was associated with an increase in favorable functional outcome.

Introduction

Outcomes from out-of-hospital cardiac arrest (OHCA) remains poor [1].To improve outcomes, guidelines focus on optimizing basic life support (*i.e.* cardiopulmonary resuscitation [CPR] and early defibrillation), advanced life support, and post-cardiac arrest care [2]. Multiple studies have shown that early bystander CPR is associated with improved outcomes [3–5]. Neighborhood characteristics (particularly racial composition and income) have been reported to be associated with rates of CPR training and the proportion of patients receiving bystander CPR [6,7]. In addition to bystander CPR, guidelines recommend the use of automated external defibrillators (AEDs) in OHCA [2]. Despite this, AEDs are relatively rarely used [4,8,9] even when they are available [10]. To our knowledge, no study has assessed whether there are neighborhood characteristics that are associated with bystander AED use. Identifying potential disparities is essential for

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targeted public health efforts to improve bystander AED use.

A recent meta-analysis of predominantly observational studies found an association between bystander AED use and improved outcomes after OHCA [11]. However, none of the included studies considered neighborhood characteristics in their analyses and there is limited contemporary data from the United States. The objective of this study was two-fold. First, we assessed the association between neighborhood characteristics and AED use by bystanders in OHCA. Second, we assessed the association between AED use and survival to hospital discharge with a favorable functional outcome while adjusting for patient, cardiac arrest, and neighborhood characteristics.

Methods

Data source

This was an analysis of data from the Cardiac Arrest Registry to Enhance Survival (CARES). CARES is a United States based prospective registry of OHCA with a catchment area of approximately 106 million people. CARES has collected data since 2005 and originally only included cardiac arrests of presumed cardiac etiology. In 2013, CARES changed their case definition to include all non-traumatic OHCA where resuscitation was attempted by a 911-responder including CPR and/or defibrillation. This also includes patients that received an AED shock by a bystander prior to the arrival of 911-responders. Additional details about the registry including participating sites, data definitions, data registration, and data validity have been provided in previous publications [12,13] and online [14,15].

CARES was approved and considered exempt from further review by the Emory University Institutional Review Board. The Committee on Clinical Investigations at Beth Israel Deaconess Medical Center, Boston, USA confirmed that this study is not considered human subjects research.

Patient population

We included OHCAs from January 1st, 2013 to December 31st, 2016. Given the substantial differences in cardiac arrest characteristics in infants (age ≤ 1 year) as compared to children and adults, we only included patients > 1 year old. We excluded cardiac arrests witnessed by 911-responders and cardiac arrests in healthcare facilities and nursing homes. AEDs are rarely used during cardiac arrests occurring in residential locations [16,17] and we therefore excluded all cardiac arrests occurring in non-public locations. We excluded cardiac arrests that could not be linked to a census tract. Lastly, we excluded cardiac arrests in census tracts with a very small total population (< 20) because no meaningful neighborhood characteristics could be calculated for these.

For the primary analysis, we excluded patients with missing data on any of the included variables except for race where an "unknown" category was created. The proportion of missing data was very low (see Fig. 1 and the Supplemental Material) for all variables except race. Missing data for race are a result of certain communities deciding not to provide these data rather than a result of incomplete data entry [13]. A comparison of patients meeting all inclusion criteria with and without missing data is provided in the Supplemental Material (eTable 1).

Geocoding and neighborhood characteristics

Geocoding was performed using the Centrus Desktop Geocoder version 6.0, as previously done with CARES data [6,18]. Neighborhood characteristics were captured and linked to geocoded census tracts using the U.S. Census Summary Files and the 2015 American Community Survey 5-year estimates [19].

The following neighborhood characteristics were included: median age, median household income, proportion of the population that are white, that are living alone, that have a high school degree or higher (25 years or older), and that are unemployed (16 years or older). All neighborhood characteristics were categorized according to approximate quartiles. In *post hoc* analyses, we also utilized a neighborhood variable characterizing the level of urbanized areas within a census tract. An urbanized area is defined as a densely developed territory that contains 50,000 or more people [20]. This variable was obtained from the 2010 Census Summary Files.

Bystander automated external defibrillator use

The use of an AED was defined as the application of AED pads to the patient with a minimum of one cardiac rhythm analysis performed, regardless of whether a defibrillation was delivered. We only considered AED use by lay persons (*i.e.* bystanders) which could include family members, non-family members, and non-dispatched medical providers. AED use by 911-responders (*i.e.* emergency medical services or first responders such as police or firefighters) was not considered bystander AED use.

Patient outcomes

The primary patient outcome was survival to hospital discharge with a favorable functional outcome. A cerebral performance category (CPC) score of 1 (mild or no neurological/functional deficit) or 2 (moderate cerebral disability but sufficient cerebral function for independent activities of daily life) was considered a favorable functional outcome [21]. The CPC score was determined by data abstractors reviewing the medical record. Secondary outcomes were return of spontaneous circulation (ROSC) and survival to hospital discharge. ROSC was defined as no further need for chest compressions sustained for at least 20 min.

Covariates

Inclusion of patient and cardiac arrest characteristics (Table 1) were based on clinical reasoning, availability in CARES, and prior literature [3,4,22–27]. For additional details, see the Supplemental Material.

Statistical analysis – objective #1

To assess the association between neighborhood characteristics and AED use, we used logistic regression with generalized estimating equations (GEE) to account for clustering of patients within neighborhoods [28]. First, we considered the unadjusted association between individual neighborhood characteristics and AED use. Second, we adjusted for patient and cardiac arrest characteristics (Table 1) except for initiation of CPR since bystander CPR is closely related to AED use ("Model 1"). Third, we added all neighborhood characteristics (Table 2) to the same model ("Model 2"). As a sensitivity analysis, we conducted the same analyses while restricting the population to those that received bystander CPR. In *post hoc* sensitivity analyses, we restricted the cohort to neighborhoods with 100% urbanized areas.

Statistical analysis – objective #2

To assess the association between AED use and survival to hospital discharge with a favorable functional outcome, we first created a matched cohort based on propensity scores. The propensity score was estimated using logistic regression with GEE. AED use was the dependent variable and we included all patient, cardiac arrest (including bystander CPR), and neighborhood characteristics as independent variables (see Tables 1 and 2). In order to optimize balance within subgroups according to the first monitored rhythm, we included interaction terms between all included variables and the first monitored rhythm [29]. We next performed 1:1 matching on the propensity score using a nearest neighbor-matching algorithm with a maximum caliper