AN EXAMINATION OF OUT OF HOSPITAL CARDIAC ARREST AND VIOLENT CRIME IN NEW ORLEANS, LOUISIANA

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Abstract

Out of hospital cardiac arrest remains one of the most common causes of death in the United States. Researchers continue to study a wide variety of modifiable risk factors at the individual level and research survival with the goal of creating interventions at multiple levels to reduce mortality and morbidity. These traditional variables, however, account for only a portion of the survival, and research on neighborhood level factors has recently shown promise for explaining differences in outcomes, including short term survival. In this dissertation we seek to evaluate out of hospital cardiac arrest (OHCA) data from New Orleans, Louisiana, over the five-year period from 2012 to 2017 (n=1,602 cases) and to examine selected literature and neighborhood level variables to determine the associations with OHCA. Traditionally studied predictors of cardiac arrest, such as age, sex, race, and health status, account for less than 75 percent of the variability in survival and substantial differences in survival among communities remains unexplained. Seeking to better explain the factors influencing survival, the central hypothesis is that certain neighborhoods, delineated by census tracts in New Orleans (n=172), have previously unidentified characteristics, namely violent crime, which contribute to increased incidence of cardiac arrest. First, we examine the level of association between violence in neighborhoods and incidence of cardiac arrest. Then, we examine the role of bystander CPR and what correlations with neighborhood violent crime rates may exist. Finally, we examine ambulance response times in neighborhoods with high rates of violent crime.

We find that those neighborhoods with higher rates of violent crime are more likely to have higher rates of cardiac arrest, to a statistically significant level. We also identify opportunities for public health interventions based upon analysis of rates of both witnessed cardiac arrests and bystander CPR provision, as well as ambulance response times to cardiac arrests in neighborhoods with high rates of violent crime.
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Chapter 1: Background and Significance

While data show that the rate of deaths due to cardiovascular disease has declined in the United States, heart disease and its related conditions still account for approximately one out of every three deaths in the country (Mozaffarian et al., 2016). Cardiovascular disease (CVD), also called heart disease, is a class of diseases affecting the circulatory system. CVD includes coronary artery disease, stroke, heart failure, hypertension, and other types of diseases impacting the heart or blood vessels. In a technical report for the American Heart Association (AHA), Khavjou, Phelps, and Leib. (2016) estimate that in 2015, over 40 percent of the US population had at least one CVD condition. The direct dollar costs of CVD are higher than other chronic diseases, including diabetes. Indirect costs, including the loss of productivity from morbidity and premature mortality, is expected to reach $368 billion by 2035, increasing over $100 billion from the current estimated costs (Khavjou, et al., 2016). Medical expenditures in the United States are among the highest in the world and the medical costs for CVD account for the largest portion, almost 20 percent, of the nation’s total personal health spending (Roehrig, Miller, Lake, & Bryant, 2009).

The majority of risk factors for CVD are highly modifiable and risk can be decreased through lifestyle choices. A lack of physical activity, unhealthy diet and tobacco use are the most common risk factors. These risk factors can lead to diabetes, hypertension and hyperlipidemia, all of which increase the risk of acute CVD such as heart attack and stroke. In a stroke or heart attack, blood flow to the brain or heart, respectively, is interrupted, causing the flow of oxygenated blood to cease to these vital organs. Most often, the cause of these interruptions from a heart attack is from a buildup of plaque in the arteries, called atherosclerosis. As plaque, made of fatty deposits, builds up in arteries, it occludes the blood vessels and prevents adequate
circulation. Blood cells may deposit around the deposits in vessels, forming a clot, and further occluding vessels. In more severe instances, the clot or fatty deposits can dislodge from arterial walls, moving throughout the circulatory system and potentially ending up in the brain, blocking the supply of oxygenated blood and causing a stroke.

One of the deadliest outcomes from CVD is sudden cardiac arrest (SCA). Different from a heart attack, SCA occurs when problems in the heart’s electrical system cause an irregular heartbeat. In a heart attack, blood flow may be hampered or reduced. With SCA, a person’s heart suddenly stops beating or is unable to beat effectively. SCA may occur as a result of a heart attack, but the loss of perfusion from SCA means that blood is not flowing, and vital organs are without oxygen and nutrients. Within minutes, organs begin to shut down, and death is a likely outcome. For every minute that passes in a sudden cardiac arrest, a person’s odds of survival decrease by 7 to 10 percent (Larsen, Eisenberg, Cummins, & Hallstrom, 1993). As the leading cause of death in the United States, over 300,000 people each year experience a sudden cardiac arrest in public or at home, labelled OHCA. Odds of surviving an OHCA remain low, with only an average of one in ten returning home alive or without substantial impairment (McNally, 2011).

Improving the odds of survival from OHCA is possible. Decreasing likelihood of serious morbidity and mortality from OHCA depends on a chain of survival: early access to care, early advanced cardiac life support, early cardiopulmonary resuscitation, early defibrillation and early post-resuscitative care (Cummins, Ornato, Thies, & Pepe, 1991; Graham, McCoy, & Schultz, 2015). Improvements in any one of these areas have been linked to increased chances of survival, with the greatest chances of survival in those receiving early CPR (Sasson, Rogers, Dahl, & Kellermann, 2010; Swor et al., 1995). The foundational notion is simple: the act of CPR,
mechanically pumping the heart through external compressions, continues circulation and perfusion of vital organs. This simple act provides valuable time, saving tissue from deoxygenation and death, and can improve the survival rate by 10 percent (Sasson, C., Rogers, M.A., et al., 2010). Medical attention has turned to increasing the incidence of so called “bystander CPR” in the last decade, where a bystander on the scene of the emergency quickly initiates CPR. Researchers have concluded that those suffering a witnessed OHCA with initiation of bystander CPR are more likely to survive (McNally, 2011; Ritter et al., 1985; Spaite et al., 1990).

![Figure 1: Chain of Survival](Source: Resuscitation Academy, 2014)

**Table 1: Chain of Survival**
*Summarized from Cummins et al. (1991) and Graham, McCoy & Schultz (2015)*

<table>
<thead>
<tr>
<th>Link</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Access</td>
<td>Recognizing the event, activating the emergency medical system by calling 911</td>
</tr>
<tr>
<td>Early CPR</td>
<td>Initiating CPR immediately after the event to return perfusion</td>
</tr>
<tr>
<td>Early Defibrillation</td>
<td>Reestablishing normal, spontaneous electrical rhythm in the heart</td>
</tr>
<tr>
<td>Early Advanced Cardiac Life Support (ACLS)</td>
<td>Delivery of intravenous drugs and advanced airway management to support reestablishing a normal, spontaneous electrical rhythm</td>
</tr>
<tr>
<td>Early Post Resuscitative Care</td>
<td>Advanced treatments, including cardiac catheterization, to reduce the shock from an OHCA on the body</td>
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As for many chronic diseases, CVD disproportionately affect minority populations. The risk factors for CVD, including hypertension, diabetes, obesity, and hypercholesterolemia, are markedly higher in minority populations than among whites and, these risk factors account for nearly 40 percent of the disparity in life expectancy between African-Americans and whites (Khavjou et al., 2016). CVD itself accounts for 25 percent of annual deaths among non-whites in the United States and mortality from CVD at all ages tends to be highest in African Americans (Mozaffarian et al., 2016). Data suggest that not only do these disparities exist in the disease burden, but also in the protective factors, such as provision of bystander CPR, which can dramatically improve outcomes. The Cardiac Arrest Registry to Enhance Survival (CARES), developed in 2004 by the Centers for Disease Control and Prevention in collaboration with Emory University School of Medicine, captures cardiac arrest data from 13 statewide programs and 23 communities representing over 800 emergency medical service agencies and 1,300 hospitals. The goal of CARES is to provide data to help communities increase survival rates. Data show that across communities such as Atlanta, Georgia, census tracts with more African-American residents, lower household incomes, and lower education levels, saw lower rates of bystander CPR (McNally, 2011). Race is not the only factor impacting outcomes. There are higher rates of heart disease and higher rates of resulting negative outcomes, including OHCA, in communities with lower socioeconomic status (Becker et al., 1993; Clarke, Schellenbaum, & Rea, 2005; Reinier et al., 2006). Communities of lower socioeconomic status can have as much as twice the incidence of OHCA as their wealthier counterparts, as the higher rates of risk factors present in less wealthy communities greatly increase poor outcomes (Uray et al., 2015).

The fact that strong relationships exist between socioeconomic status and health outcomes along with residential clustering by socioeconomic status has lead researchers to
explore how the built and social environment may impact OHCA. Beyond location, other “placed based” determinants of health outcomes – being more distal - can be difficult to measure, but the simple relationship between proximal health outcomes, like those which lead to OHCA, and place, are more easily explored. Researchers find that after controlling for multiple other variables, including education and income, living in a poor neighborhood is associated with an increased incidence of CVD (Roux et al., 2001). The characteristics of a neighborhood in which someone suffers an OHCA, for example, can even directly influence the provision of bystander CPR. As indicated, one of the most important factors in survival from OHCA is early provision of CPR. An OHCA occurring in a predominately African-American neighborhood is less likely to receive lifesaving bystander CPR compared with those in white neighborhoods (Moon et al., 2014; Sasson et al., 2012; Sasson et al., 2010). In short, these disparities lead to higher rates of morbidity and mortality for those living in these neighborhoods.

Within Louisiana, from the state to local level, data show how disproportionate the burden of cardiovascular diseases and its deadly outcomes such as heart attack and cardiac arrest can be. Each year over 25 percent of deaths in Louisiana are attributable to diseases of the heart. Heart disease and its deadly outcomes are responsible for more deaths annually in Louisiana than accidents, cerebrovascular, and respiratory disease deaths combined. In New Orleans alone, each year there are over 600 deaths from heart disease and approximately 500 OHCA (Louisiana Department of Health and Hospitals, 2010). Such disparate outcomes demonstrate the need to further quantify and qualify those community and neighborhood level variables which contribute to OHCA outcomes. Further, the functions of neighborhood and community level variables underscore the growing thought that place matters in health, not only in the long term, but also in the short-term outcomes for such critical events.
Identification of at risk neighborhoods and classification of confounders, such as socioeconomic status, race, and bystander CPR training, have produced valuable information about neighborhoods which can direct public health education and outreach efforts (Becker et al., 1993; Clarke et al., 2005; Nichol et al., 2008). The neighborhood environment can influence health-related behaviors such as smoking, physical activity, dietary choices, and those others leading to chronic disease and negative health outcomes (Roux et al., 2001). Research has also demonstrated the strong relationship between neighborhood level variables and survival from cardiac arrest. The work, however, focuses on identifying areas with chronically high incidence of cardiac arrest due to the most common risk factors and often assesses long term survival to discharge from the hospital. Unknown risk factors are mediating effects of chronic disease and such variables as noise, blight, quality of public spaces, and violence are likely all having an impact on not only long-term outcomes but the incidence of OHCA itself. The fact remains that even after controlling for income, education and other confounders, place still matters in the outcome and health of individuals (Roux et al., 2001).

Evaluating Cardiac Arrest Survival

Regarding cardiac arrest survival, there is a considerable literature on the survivability, causes, and treatments. The basic tenants of the Chain of Survival, including ventilation even chest compression, have been researched at least the mid-1700s (Chamberlain, 2004; Webb & Bacon, 2017). Putting the pieces of the puzzle together, however, has only been accomplished with the last few decades. As a result, a large research body accompanies the study of the cause and treatment of cardiac arrest in hospitals but comparatively, focused evidence-based research on interrupting and treating OHCA only took hold in the last thirty years (Chamberlain, 2004).
The origins of this research started hundreds of years ago, following the development of modern medicine and the growth of understanding of human physiology. As early as the late 1700s, researchers were experimenting with the use of electrical impulses to restore pulse in hens, frogs, and other small animals. At the same time, medical essays describe the use of assisted ventilations, what we understand to be mouth to mouth resuscitation, in victims of smoke inhalation, drowning, and other afflictions. During the period of innovation and machine automation, experiments continued with techniques of electrical stimulation of muscle tissue, the use of bellows for artificial ventilation, and other impressively modern techniques by early standards (Chamberlain, 2004).

The advent of more sensitive instruments in the 1800s and early 1900s lead to Willem Einthoven coining the term “electrocardiogram” and demonstrating the phenomena of electrical impulses that drive the human heart. Successful experiments in mammals had also demonstrated cardiac massage and chest compression, and in some countries, such techniques became the norm for surgeons and doctors. By 1906, doctors at the Bristol Royal Hospital not only demonstrated successful use of heart massage to restore pulse, but also the use of electricity to restore normal heart rhythms in patients who had suffered cardiac arrest (Green, 1906). These techniques, however, did not enter mainstream medical practice, and such procedures remained the exception rather than norm. For decades, minor discoveries continued, but there was minimal interest treating cardiac arrest or advancing resuscitation (Webb & Bacon, 2017).

It was not until the 1940s and 1950s until technology had advanced to a point where Dr. Claude Beck was able to successfully defibrillate a human heart during cardiac surgery and when Dr. Paul Zoll pioneered the use of closed-chest defibrillation. Studies, however, centered on in-hospital cardiac arrest populations, and the reversal of cardiac arrest in the operating theatre
While the world was returning to a state of peace following World War II, lessons learned from the battlefield were being implemented in contemporary medical practice. One of the biggest advancements, impacting not only health and medicine, but specifically cardiac arrest, was the fundamental change in prehospital emergency medical care (Institute of Medicine [IOM], 2007).

While advancements in engineering and physics allowed for implantable pacemakers, routine electrocardiograms, and external defibrillation, prehospital emergency medicine was taking hold. Before the 1950s, ambulances brought no more than basic first aid or a quick ride to a hospital. For over a hundred years, wagons, carts, and cars were designed to transport a casualty on a battlefield back to doctors and hospitals. Following World War II, civil authorities took lessons from the war theatre and began to deploy lifesaving equipment and personnel in ambulances. In the United Kingdom, the tragic Harrow and Wealdstone Rail Crash of 1952 killed 112 and injured 340, forcing authorities to rethink the ambulance and how to provide emergency care outside of the hospital (Chamberlain, 2004; IOM, 2007). Commercial manufacturers of special ambulance vehicles and the continued growth of the automobile and interstate system in the United States meant the rapid expansion of automobile culture. By 1966, the National Academy of Sciences noted in its landmark report “Accidental Death and Disability: The Neglected Disease of Modern Society” that prehospital care was inadequate and unacceptable, setting the stage for major change in emergency services (National Research Council (US). Committee on Trauma & National Research Council (US). Committee on Shock, 1966).

A large body of work continued to be generated through the modern era of medicine, and by the 1970s, researchers noted that over 300 prehospital emergency medical providers had some
degree of advanced emergency care in communities across the country (Eisenberg, Bergner, & Hearne, 1980). Like their peers studying cardiac arrest in hospitals, those examining OHCA focused on the systems and care, but did not document much success in outcomes for patients. Not surprisingly, as risk factors for CVD and thus cardiac arrest began to rise in the population, so did research into the associations of risk factors and outcomes. As Americans saw the rise in effects from smoking, obesity, and sedentary lifestyles, researchers continued to study how these new issues impacted health in the community.

Eisenberg and colleagues, reviewing a decade of literature from the 1970s, found widely disparate methods and processes among agencies treating life threatening emergencies and OHCA. The lack of uniformity led to confusing levels of analysis and difficulty in drawing conclusions from impacts of programs and interventions (Eisenberg et al., 1980). The Eisenberg team cited Polnitsky, who only three years earlier, called for a uniform, simplified reporting format and standardized research methods. These were the first two times researchers recognized the potential for the analysis of systems level data, including initial cardiac arrest rhythm, bystander CPR, and time to definitive care. Researchers grew continually frustrated by different styles of reporting, which lead to inconsistent terminology, vast differences in survival rates, and no able to discern the causes in different outcomes. The goal of a single, coordinated system to compare outcomes and create evidence-based interventions to meaningfully impact cardiac arrest in the prehospital environment would not come to fruition until the 1990s.

Recognizing the importance of uniformity in cardiac arrest and resuscitation research, representatives from the United States, Canada, Europe and Australia met in 1990 to discuss the lack of standardization in research and reporting. The task force, called the Utstein Consensus Conference after the original meeting place, Utstein Abby in Norway, offered new
recommendations to set a baseline for uniform reporting of OHCA. Supported by a glossary of terms, template for reporting, and recommended outcome measures, the so called “Utstein Style” offered the first comprehensive way to understand OHCA and compare outcomes and interventions. Standardization of nomenclature allowed consistent use of terminology, an effective way to evaluate new technologies, and promised a clearer epidemiological picture of cardiac arrest in all communities (Cummins et al., 1991).

The Utstein Style, or template, starts by identifying the population served. From there, the protocol encourages uniformity in the reporting of cardiac arrests through standardized definitions on all categories. The glossary of terms defines measures for what constitutes an attempted resuscitation, an arrest by cardiac etiology, and so on. Along with the reporting protocol seen in Figure 2, the Utstein task force recommended that key time components be recorded for critical components of each cardiac arrest event. As one of the most critical elements in the Chain of Survival is reducing the amount of time an individual in cardiac arrest is without perfusion through rapid delivery of interventions, these event times provide essential information on some of the most key determinants of survival. Figure 3 demonstrates the times collected in an OHCA under the Utstein template. Together, these times and events provide a wealth of information that, when collected according to the standardized methods established by the task force, allow researchers, clinicians, and emergency medical providers to better understand cardiac arrest and provide better treatment to improve outcomes (Cummins et al., 1991).
Figure 2: Recommended Utstein Style Template

The Utstein Style, in creating guidelines that can be used to compare multi-site outcomes, is the basis for the Cardiac Arrest Registry to Enhance Survival (CARES). Created in 2004 as a partnership between Emory University School of Medicine and the Centers for Disease Control and Prevention, the goal of CARES was to create a registry for OHCA which would allow communities to increase survival rates. Currently, CARES collects individual level patient data in over 36 states, tracking measures from EMS intervention to hospital outcomes. The data provides coordinated longitudinal tracking to provide improvement in survival rates. Participating communities can compare performance to aggregated data at local, regional, and national levels, allowing prehospital care providers to target at the neighborhood or community level for factors impacting their residents’ health (McNally, Kellerman, Park, & Click, 2007).
Place Based and Neighborhood Level Factors of Cardiac Arrest

The influence of place on health has been increasingly viewed as an important factor in addressing health inequality. Extensive research has shown the strong influence of environment in dictating health outcomes (Nichol et al., 2008; Ronaldson et al., 2015; Starks, Schmicker, Peterson, & al, 2017; Theall, Brett, Shirtcliff, Dunn, & Drury, 2013; Theall, Shirtcliff, Dismukes, Wallace, & Drury, 2017). Over a decade ago the World Health Organization charged the Commission on Social Determinants of Health with examining the health of poor people and the social gradient of health across populations. Findings suggest that mortality and morbidity in lower socioeconomic individuals across the globe is made worse because various factors in the “conditions in which people are born, grow, live, work and age” (Marmot, Friel, Bell, Houweling, & Taylor, 2008). For example, staying healthy through physical activity requires access to infrastructure. Without parks, safe bicycle routes, or space to exercise, residents are less likely to engage in healthy behavior. The study of these living and working conditions continues to show how the environment is a key part of public health. From 2005 to 2009, research on social determinants of health and environmental influences doubled, and specific assessments of neighborhood conditions and health showed how important they were to health outcomes. The study of how neighborhood affects cardiac arrest and heart health has followed suit.

While the growth of the Utstein Style allowed for better data management and more comprehensive data tracking over the past two decades, it also provided researchers the opportunity to examine OHCA outside of the usual variables of sex, gender, race, comorbidities and other factors. Yen and Syme (1999) describe the history and outline a future for the combining of epidemiology and sociology, so that physical and social environments are also considered for their role in influencings individual-level health outcomes. While research had
previously concentrated on identifying physical factors, Yen and Syme argue that identifying the specific elements of the social environment which contribute to individual and community health can play a critical role in developing interventions, evaluating effectiveness, and expanding the theories associated with disease patterns in our communities. They specifically point out that these environmental factors must be considered to better understand disease etiology and create change in communities. In fact, Rea and colleagues (2010) found that the traditional etiological variables in the Utstein template accounted for an average of only 72 percent of the predicted survival, and only a moderate amount of the variability between sites. Rea and colleagues analyzed data from 7 unique and geographically diverse areas in the United States, accounting for over 10,600 cardiac arrests during a 16-month period. Their findings show variables in the Utstein template predict much of survivability (between 68 to 78 percent) following OHCA, however, in some communities, substantial differences in outcomes may not be completely explained by the variables tracked in the Utstein template. Researchers noted that the results supported the notion that the understanding of the complex interactions surrounding cardiac arrest is far from complete; novel predictors at both the individual and systems level such as chronic disease, EMS system design, and more contribute to the variability in outcomes (Rea et al., 2010).

In the mid-1990s, researchers applying the Utstein template to OHCAs concluded that socioeconomic factors, and perhaps even neighborhood factors, were contributing to the outcomes of cardiac arrest (Lombardi, Gallagher & Gennis, 1994). Although they did not have reliable data to test their hypothesis, researchers speculated that “additional sociodemographic features…such as minority status and poverty…might result in higher cardiac arrest mortality” (Lombardi et al., 1994). Studies across multiple cities and regions have, for some time, been able
to clearly demonstrate disparities in racial, ethnic, and socioeconomic factors influencing survival from cardiac arrest (Nichol et al., 2008; Reinier et al., 2006; Sasson et al., 2011). However, many ignore the variations in survival and potential effects at the more granular neighborhood level. Utilizing CARES data, Sasson and colleagues have explored the variables impacting survival from cardiac arrest and how they differ by neighborhood. In some instances, variables of the Utstein template were shown to have a direct impact on survivability, such as bystander CPR. They found bystander CPR rates were almost two times greater in highest income neighborhoods, and that through examining the surveillance data for cardiac arrest, officials could identify areas ready for targeted public health intervention (Sasson et al., 2011; Sasson et al., 2012; Sasson, C., Keirns, C.C., et al., 2010). Sasson and colleagues’ work, originally focused on Fulton County (Atlanta), Georgia, has been translated to Franklin County (Columbus) Ohio, Houston and Austin, Texas, and communities in Arizona (Moon et al., 2014; Raun, Jefferson, Persse, & Ensor, 2013; Root et al., 2013; Semple et al., 2013).

Researchers consistently show disparities in survivability due to multiple factors for those with lower socioeconomic status and of non-white race or ethnicity. Most recently, researchers considering a multisite analysis of over 22,000 cardiac arrests found that bystander CPR and survival from OHCA was significantly lower in neighborhoods with higher percentages of African American residents (Starks et al., 2017). While the study examined the association between neighborhood demographic and short-term survival, it did not examine potential confounders that could play a role in the association between race and survival outcomes. Additionally, Starks and colleagues (2017) note that out of the sites assessed, they found “most of the black neighborhoods clustered in 4 sites,” thus limiting their ability to provide strong associations between neighborhood composition and outcomes from cardiac arrest. With this
challenge in mind, they argue that future research should concentrate on neighborhoods with higher percentages of minority residents and in areas where neighborhood variation is much more homogenous, thus limiting the effects of clustering of minority neighborhoods and skewing results of potential associations (Starks et al., 2017).

Buick and colleagues, however, previously considered these limitations and proposed a methodology to evaluate several neighborhood level factors, including race, and their influence on outcomes of OHCA. Like Rea and colleagues (2010), Buick noted that the traditional variables, including those found in the Utstein template, account for only a portion of the explained survival and that neighborhood level information is critical for understanding clinical outcomes relevant to OHCA (Buick et al., 2015). Their proposed methodology, however, has yet to be tested in research and remains theoretical in application. Our research uses this and other theoretical foundations to move forward the examination of neighborhood level variables and their impact on OHCA.

Exposure to Stress, Violence, and Relationship to Cardiac Arrest

The environmental factors associated with CVD and the deadly outcome of cardiac arrest, including smoking, diet, and exercise, have well established links as major risk factors. However, it is evident that heart disease and cardiac arrest are the result of complex interactions at multiple levels of the social ecological framework. As previously noted, risk factors for both CVD and for cardiac arrest account for a major portion of risk, but there are still underlying associations that are not completely understood. The exploration of risk factors has been limited to those environmental in nature which stem from determinants that are easily measured through quantitative means, such as smoking, obesity, exercise, and the like. However, the remaining
portions of risk, which may offer valuable information on disease process, risk, and intervention, are relatively understudied.

In 1986 Dr. James Henry, a longtime proponent of socio-biologic and environmental approaches to understanding disease, summarized a nascent body of research linking external psychological stressors to biological responses, and applied the understanding to a concept of how stress can lead to CVD. Henry’s summary includes a discussion on protective factors, such as partner intimacy, marriage, and social support—all early notions of indicators we now know to be associated with positive health outcomes. More importantly, Henry also provides a visual summary of how what researchers termed “threats” induce fear and create a physiological response and induction of a “flight” behavior, including moderate increases in blood pressure, heart rate, and cortisol. Henry’s summary, while describing a short term outcome in a typical action-reaction scenario, points out that over time there is likely a dose-response relation, and while concentrated on personality traits or characteristics which may make someone more vulnerable to CVD, offer the foundational notion of environment contributing to CVD and its outcomes (Henry, 1986).

More studies have advanced on this work to establish a detailed link between factors such as violence, neighborhood disorder, and individual level health outcomes. In 2013, Theall et al. provided some of the first evidence linking neighborhood level variables of poverty and disorder to changes at the individual, biological level. Disorder, marked by a selection of blighted buildings, abandoned vehicles, and other markers, was associated with a change in telomeres, a novel biomarker. “Telomeres are specialized nucleoprotein complexes located at the termini of chromosomes that prevent genomic instability…telomere length…has been associated with multiple negative health outcomes across the lifespan, including CVD, dementia, diabetes, and
cognitive decline” (Theall et al., 2013). Telomere length has been looked at to provide an indicator of overall physiological status, as they have diverse effects on many different organs and may be integral to the ability of an individual to adapt to, and thus respond well in, changing environments. Researchers found that in children under 15 across 87 census tracts in New Orleans, those with shorter telomeres were often found in neighborhoods with higher levels of disorder and poverty, thus demonstrating an association between stress and negative biological change.

In fact, such adverse childhood experiences (ACEs) like growing up in a neighborhood characterized by social disorder, exposure to household dysfunction and interpersonal violence, when experienced in a severe and chronic way, are thought to form a complex interaction that contributes to greater risk of CVD, and thus a greater likelihood of sudden cardiac arrest (Su, Jimenez, Roberts, & Loucks, 2015). In addition to the individual level biological changes noted earlier, researchers over the past decade have demonstrated that ACEs are associated with high risk behaviors and lifestyle choices which contribute to CVD and cardiac arrest, including smoking, obesity, physical inactivity, sleep apnea, and others (Gilbert et al., 2015). Specific ACEs, including exposure to interpersonal violence, childhood maltreatment, and emotional abuse have each been individually linked to both the behavioral and biological pathways contributing to CVD. And while the individual contributions of ACEs to smoking, obesity, physical inactivity, sleep apnea, and CVD biomarkers such as high blood pressure and atherosclerosis, are helping to highlight the implications of environment on individual health, the cumulative biological risk from these factors remains a web of complex interactions that continues to develop (Slopen, Non, Williams, Roberts, & Albert, 2014).
Emergency Medical Services in New Orleans

New Orleans Emergency Medical Services, the primary provider of prehospital emergency care for the City of New Orleans, is a third service emergency medical service (EMS) provider, with a unique history and approach to providing medical care. First started as the Charity Hospital Ambulance in the early 1900s, EMS in New Orleans has gone through multiple system changes. Since Hurricane Katrina in 2005, the system has become one of the nation’s foremost providers of prehospital care, handling over 50,000 calls for service each year (City of New Orleans, 2015).

In 1947 EMS for the City of New Orleans was turned over to the New Orleans Police Department. Over the next two decades, as cities adopted more advanced prehospital care provision, New Orleans followed suit. By the early 1970s, following the national trend to increase the availability and professional standards of emergency medical technicians, New Orleans was training paramedics capable of providing advanced medical care in the field. In 2005, Hurricane Katrina changed emergency medical services in New Orleans, destroying the EMS headquarters and almost every ambulance in the fleet. Since that time, New Orleans EMS has rebuilt into a nationally recognized service and implementing evidence-based practices in the delivery of prehospital emergency care (City of New Orleans, 2015).

The deployment of ambulances throughout New Orleans is done through a method known as System Status Management. System Status Management (SSM) is a dynamic approach to determining ambulance placement throughout a response area based upon demand and available resources (Stout, 1983). Widely accepted since the 1980s when management statistics such as unit hour utilization (UHU) were first introduced, it wasn’t until the 1990s when commercially available global positioning systems allowed for the easy identification of
clustered calls, ambulance locations, and other location-based information provided adequate tools for widespread implementation (Dean, 2004). The goal is to reduce ambulance response times in environments with high call volume and UHU, ensuring that ambulances are near to the most likely locations of calls. In New Orleans, core posting locations differ by day and night, and are respectively identified in Figures 4 and 5. Posting locations are selected based upon current call loads and available ambulances. The posting locations have a priority order and are selected considering call volume, traffic, and demand. The posting locations are filled based upon the number of ambulances available and not currently on a call for service. This means that resources are constantly being shifted throughout the city based on demand and real time call and resource availability. SSM has seem limited research to validate results in acute calls, such as OHCA, but has been shown to result in favorable response intervals as it relates to those tracked on the Utstein Template (Fairbanks, 2003).
New Orleans EMS Nighttime Ambulance Posting Locations

Figure 4: Daytime Posting Locations for New Orleans EMS

New Orleans EMS Daytime Ambulance Posting Locations

Figure 5: Nighttime Posting Locations for New Orleans EMS
In 2010, EMS began studying the “bundling” of cardiac arrest interventions, studying the use of certain advanced life support interventions, that when delivered together, increased short term survival from OHCA (Saussy, Elder, Flores, & Miller, 2010). To further study the outcomes from these interventions, New Orleans EMS joined the CARES program, standardizing the collection and reporting for data on OHCA by using the Utstein template. Since 2012, New Orleans EMS has collected standardized data according to the Utstein template. In addition to the standard variables collected by CARES following the Utstein template, New Orleans EMS collects additional data on advanced medical interventions delivered by first responders. As such, it represents the most comprehensive data for New Orleans on the topic that is available. For this study, we will use the data from 2012 to 2017.
Chapter 2: Hypothesis and Aims

Our long-term program goal is to reduce deaths from cardiac arrest in Orleans Parish. Cardiovascular disease is a leading killer of individuals in Orleans Parish, and over 400 individuals die each year from an OHCA (Louisiana Department of Health and Hospitals, 2010). There are promising interventions to drastically increase survival, but first we must carefully enumerate the problem (Graham et al., 2015). Our work is innovative because it capitalizes on current and new literature exploring the importance of place-based impacts on individual health, and because it takes advantage of newly available data sources in New Orleans. Our work also provides additional links to show that neighborhood level variables impact health. By carefully exploring a range of psychosocial variables at the neighborhood level – specifically violent crime rates in neighborhoods – we begin to show how those variables are associated with OHCA. The central hypothesis is that violent crime, as a measure of neighborhood disorder outlined in the theoretical model below, contributes to increased rates of OHCA. This hypothesis is based upon a strong body of research demonstrating, among other things, that neighborhoods with lower socioeconomic status have higher rates of death from cardiac arrest, and that individuals in neighborhoods with high numbers of minority residents show disproportionately lower survival rates from cardiac arrest. The theoretical basis of the hypothesis stems from neighborhood disorder’s impact on psychophysiological distress and health. Neighborhood disorder, which we hypothesize to be in the form of violent crime, contributes to both psychological and physiological stress, mediating health outcomes (Hill, Ross, & Angel, 2005). Stress can contribute to the onset of cardiac arrest, so it is a logical extension that this psychological and physiological stress could increase the likelihood of cardiac arrest in neighborhoods with high rates of violent crime (Rozanski, Blumenthal, & Kaplan, 1999). Figure 6 shows the pathway by
which Hill, Ross and Angel (2005) propose neighborhood disorder impacts distress and health. The model serves as the basis for examination of violent crimes and cardiac arrest and is further refined, as shown in Figure 7, to provide the basis for our research.

Figure 6: Theoretical Model

*Items in blue represent the theoretical foundations of Hill, Ross and Angel (2005), adaptations and logical extension from our studies is outlined in red*

Our study model, as shown in Figure 7, is based on the tenants of Hill, Ross, and Angel (2005), and establishes neighborhood violence as the specific form of neighborhood disorder. Our model seeks to determine the degree to which neighborhood violence as the neighborhood disorder directly operates to impact health via this pathway of psychological and physiological stress responses. We theorize that greater levels of neighborhood violence will lead to lower amounts of bystander CPR, lower levels of witnessed OHCA, and higher response time intervals from EMS. Because of fearful anxiety individuals in neighborhoods with higher rates of violent crime will be less likely to provide bystander CPR and fewer OHCAAs will be witnessed, as individuals are afraid to offer help in an emergency. We also theorize that this fearful anxiety will be present external to the neighborhood and impact the response time from emergency
medical services, delayed in neighborhoods with higher rates of violent crimes, as responders are more cautious with response. Our study does not measure fearful anxiety, but rather concentrates on violent crime, OHCA, bystander CPR, witnessed cardiac arrest, and EMS response to these incidents.

Figure 7: Study Theoretical Model

The rationale for the proposed research is that by adding to the growing body of literature on neighborhood and place-based impacts on health outcomes, we can expand the scope and activity of interventions to target the underlying health problems. An additional benefit is that these neighborhood characteristics, if amendable to intervention, are likely to impact a broad range of diseases and social conditions. Three specific aims will help to accomplish this:

**SA1:** Determine the level of association between neighborhood violent crime rates and the incidence of OHCA.

**SA2:** Examine how neighborhood violent crime rates influence the provision of bystander CPR in New Orleans.

**SA3:** Determine whether response time from New Orleans Emergency Medical Services in responding to OHCA varies by neighborhood due to violent crime rate.
Chapter 3: Methodology  

The overall purpose of this study is to evaluate existing data to determine whether the incidence of violent crime has an impact on OHCA in neighborhoods of New Orleans. Through examining emergency services calls to 911, OHCA calls, and census tract level data from the American Community Survey, we aim to determine if environmental factors contribute to those risk factors which increase the likelihood of cardiac arrest, with the hope of providing evidence for further research and targeted interventions.

Secondary data analysis was conducted on three data sets: data from New Orleans Emergency Medical Services (EMS) CARES database, calls for service to the New Orleans Police Department (NOPD), and the Centers for Disease Control American Community Survey (CDC ACS). Figure 8 provides an overview of the study design and the general steps taken to research OHCA and violent crime in New Orleans’ neighborhoods, starting with a literature analysis, then spatial analysis, and preliminary and secondary data analyses. Data from 2012-2017 was obtained for both the New Orleans EMS CARES database and the NOPD calls for service from public records requests. The CDC ACS data for 2016 was obtained from the CDC public data sets available online. Both the New Orleans EMS CARES data and the NOPD calls for service provided individual level, de-identified data for cases. Spatial analysis was used to geocode individual cases in both these datasets, thereby linking cases to their census tracts, allowing for analysis of tract level information. Census tracts represent relatively homogenous subdivisions, with respect to population characteristics, economic status, and living conditions.
Specific Aim 1: Determine the level of association between neighborhood violent crime rates and the incidence of OHCA.

Data from New Orleans Emergency Medical Services CARES Database for 2012-2017 was utilized for OHCA data. The database contains de-identified data for all OHCAs during the time period (n=3,160) with 78 variables relating to each individual cardiac arrest. We included all OHCAs for which individuals were 18 years of age or older and of presumed cardiac etiology (n=2,268). Addresses were geocoded using ArcGIS 10.5 (ESRI, Redlands, CA). Addresses were geocoded to the street level, meaning that each address was matched to a latitude and longitude. Ninety-eight percent (98%) of addresses were able to be geocoded. From this set, we excluded cardiac arrests which occurred at nursing homes, assisted living facilities, hospitals, medical centers, commercial places or in public to provide only those cardiac arrests which occurred at a home or place of residence (n=1,602). Each case was matched to its census tract through linking to geographic data through the incident address.

Data for violent crime rate was obtained from the City of New Orleans Calls for Service records, available as open public records. Calls to the New Orleans Police Department for 2012-2017 (n=505,012) include 16 variables for each call record. Variables of interest include call type, call location in both de-identified address (to the 100 block) and latitude and longitude coordinates. Calls with a valid address and latitude and longitude which were indicative of a
violent crime (n=18,012) were selected for analysis. Violent crime was determined by using the Federal Bureau of Investigation’s Uniform Crime Reporting (UCR) Program definitions. The UCR Program provides a standardized method of tracking violent crime across the United States. The UCR Violent Crime types include murder, manslaughter, forcible rape, robbery, aggravated assault, burglary, larceny-theft, and motor vehicle theft (U.S. Department of Justice, Federal Bureau of Investigation, 2018). The corresponding call for service types selected from the Calls for Service records to measure violent crime include aggravated arson, aggravated assault, aggravated domestic assault, aggravated battery, stabbing, shooting, aggravated burglary, armed robbery, auto theft, carjacking, theft and discharging a firearm. Each case was matched to its census tract through linking to geographic data through the incident address and latitude and longitude provided in the records. Ninety-nine point five percent (99.5%) were included in analysis (n=17,924). The remainder were excluded after combining with census tract level data as explained below.
Census tract level information was obtained from the 2016 American Community Survey. The City of New Orleans has 177 census tracts; however, five tracts were removed from analysis. Figure 9 shows the census tracts not meeting the case definition in relation to the City of New Orleans. One tract contains no habitable land and comprises much of the area of Lake Pontchartrain. Additional census tracts were excluded as they either contained no population and thus no data in the 2016 ACS or were solely industrial/commercial census tracts with no residential OHCAs and thus did not include cardiac arrests that met case definitions. Census tract variables to include age, gender, race, education and poverty were included in analysis.

Census Tracts Not Meeting Case Definition

![Census Tracts Not Meeting Case Definition](image)

*Figure 9: Census Tracts Not Meeting Case Definition*
Sum totals across census tracts (n=172) for the period 2012-2017 for both cardiac arrests and violent crime calls for service were calculated, and incidence rates calculated. Rates were calculated by dividing the total number of events in each census tract by the 2016 ACS population estimates for each respective census tract and then multiplying by 10,000 to provide a rate per 10,000 persons. These calculations were done in Microsoft Excel.

For this aim, we examined two main variables of interest: incidence of cardiac arrest and violent crime calls for service by tract. First, bivariate analysis was conducted to determine any relationship between violent crime rate and rate of OHCA. Then, logistic regression was performed to determine the impact of census tract level variables on OHCA. Following, tracts were categorized, creating two new categorical variables for each census tract according to

![Census Tracts by Rate of Out of Hospital Cardiac Arrest in Residences](image.jpg)

*Figure 10: Census Tracts by Rate of OHCA in Residence*
incidence of cardiac arrest and violent crime rate. The dichotomous categorical variable for cardiac arrest (low/high) was created based upon the calculated citywide median cardiac arrest rate of 42.95 per 10,000. Low cardiac arrest rate was defined as less than or equal to the median rate of 42.95 per 10,000. High cardiac arrest rate was greater than the median rate. Figure 10 visually represents this dichotomization, showing the census tracts in New Orleans considered in both the “low” and “high” OHCA categories. The median rate was selected to prevent bias from outliers. This type of categorization is typical among studies seeking to determine social determinant impacts on OHCA and represents a first step in analysis of new data (Sasson et al., 2012; Sasson et al., 2013; Semple et al., 2013; Starks et al., 2017). The trichotomous categorical variable for violent crime (low/medium/high) was created based upon the calculated violent crime rate. High violent crime rate was determined by being equal to or above the third quartile, 372.1419, medium violent crime rate was determined by being greater than 42.9555 and less than 372.1419 and low violent crime rate was determined by being less than or equal to 42.9555. All values represent violent crimes per 10,000 residents. Categorical variables were used to develop a simple classification system that could be easily applied across all census tracts, and to visually demonstrate in GIS format, as show in Figure 10, clustering of census tracts where cardiac arrest was higher than the citywide median, or, as seen in Figure 11, the clustering of census tracts with high, medium, and low violent crime rates. Such visual representation provides actionable information to first responders and acts as foundational level analysis for further research. As this research is initial in nature, the goal is to provide insight into the presence of association and provide building blocks for future research. The use of the quantitative values behind these categorical variables, while important and meaningful, does not itself provide meaningful and actionable information to translate research into operation. While
the categorization of the variables does not utilize the full extent of variable information, until the relationship is fully examined, categorization allows us to eliminate any concern of nonlinear effects and concentrate on the core question in the model at hand: identify associations with out of hospital cardiac arrest and violent crime through the theorized pathways of the model previously shown in Figure 7.

Figure 11: Census Tracts by Violent Crime Rate Category
These two census tract variables- violent crime category and out of hospital cardiac arrest category- were combined and the outcome was the dichotomous variable (yes/no), which indicated census tracts with both a high incidence of cardiac arrest and a high violent crime rate. Almost forty percent (n=63) of census tracts were categorized as having high violent crime rate and high OHCA.

The Kruskal-Wallis test for continuous variables was used to test if OHCA rate was different for the different census tract groups of violent crime rate category (low/medium/high), as the data for OHCA rate did not meet normality assumptions necessary for one-way ANOVA. Next, binomial logistic regression was used to determine the probability that the study covariates, including age, sex, race, income, and education had on the computed dichotomous categorical variable of high violent crime and high cardiac arrest (y/n). A p value of <0.05 was considered statistically significant. All analyses were performed using SPSS version 25 (IBM Corp., Armonk, NY) software.

Specific Aim 2: Examine how violent crime rates influence the provision of bystander CPR in New Orleans.

Again, only those cardiac arrests which occurred at a home or place of residence (n=1,602) were selected to determine how violent crime influences bystander CPR in New Orleans. Analysis was conducted at the individual level using the CARES data and at the census tract level with aggregated data.

For this aim, we examined two main variables of interest: bystander CPR and violent crime rate (as determined by calls for service) by tract. Bystander CPR was determined by examining the categorical variable which tracked the initiation of CPR for each OHCA. All categories of lay person provided CPR (Lay Person, Lay Person Family Member, Lay Person
Medical Provider) were collapsed to create the categorical variable of “Bystander CPR” (Y/N) for each individual level OHCA. Sum totals of cardiac arrests in which there were bystander CPR were calculated across census tracts and aggregated to provide the total number of cases across all census tracts in which bystander CPR was provided (n=397).

Similarly, two other variables of interest were created in the same way. The categorical variable “Arrest Witnessed” (Y/N) was created from an individual level categorical variable tracking whether each OHCA was witnessed by a bystander (Unwitnessed Arrest/Witnessed Arrest). Sum totals of cardiac arrests in which there was a witness was calculated across census tracts and aggregated to provide the total number of cases across all census tracts in which there was a witnessed cardiac arrest (n=599). The categorical variable “ROSC” (Y/N) was created from an individual level categorical variable tracking whether each OHCA had a return of spontaneous circulation (ROSC). At the individual level the categories indicating ROSC (Yes, pulse at end of EMS care / Yes, no pulse at end of EMS care / No) were collapsed to create the dichotomous categorical variable (Y/N). Then, sum totals of cardiac arrests in which there was a ROSC were calculated across census tracts and aggregated to provide the total number of cases across all census tracts in which there was a ROSC (n=497).

Before conducting census tract level analysis, the dichotomous categorical variables that were created for witnessed arrest, ROSC, and bystander CPR were analyzed using Chi-Square test for association. Then, for census tract level analysis, the variables “Arrest Witnessed_sum,” “ROSC_sum,” and “Bystander CPR_sum” were created from the aggregate sums for each of the 172 census tracts. To calculate a percentage of the OHCAs in which there was a witnessed arrest, ROSC, and bystander CPR the respective sums were divided by the previously calculated number of cardiac arrests in each census tract.
Specific Aim 3: Determine whether response time from New Orleans Emergency Medical Services in responding to OHCA varies by neighborhood due to violent crime rate.

New Orleans EMS utilizes a dynamic unit posting method, system status management, to adjust posting locations in the city to account for call volume and resource availability. When resources (ambulances) are low, postings are adjusted to the core of the city where population is concentrated. To assess how this deployment strategy may impact the response of advanced life support assets to the patient—and thus the arrival of Advanced Cardiac Life Support, one of the most critical components of the chain of survival from OHCA—we examine variables of interest from the CARES data related to response time. Three specific time variables were analyzed: “Call Receipt,” “Ambulance On Scene,” and “EMS at Patient Side.” Three measures of time interval, in seconds, were calculated for each of the individual OHCA case definitions: time from call receipt to ambulance on scene (so called response time), time from ambulance on scene to patient side, and finally the overall interval from call receipt to EMS arrival at patient side. The three time intervals were selected based on their importance in the Utstein Template and established importance in identifying intervals in the Chain of Survival which can increase the likelihood of survival from OHCA. A total of 1,200 individual cases were selected for analysis. Exclusions were made due to missing or incomplete data in any of the three time variables selected.

Tests of normality by using the Shapiro-Wilk test were completed on the three newly calculated individual level variables, due to the sample size (n=1,200). Individual level data were aggregated by the median values for each of the time intervals for each census tract and then combined with census tract level data. Median time values were found to be available for 98 percent of the census tracts (n=169). Analysis at the census tract level was conducted to assess
the relationship between the median time from call receipt to EMS arrival at patient side and census tract violent crime rate.

Census tract violent crime rate was normalized by transforming the value with a logarithmic function. Median time from call receipt to EMS arrival at patient side likewise required transformation to be normalized, as there was excess positive skew. Transforming the median time variable required a two-step inverse normalization process for following fractional ranking and then use of the IBM SPSS version 25 IDF (inverse distribution function). The resulting transformed continuous variables were analyzed in bivariate analysis using Pearson’s correlation tests. Finally, a partial regression model was run to predict time from call receipt to EMS arrival at patient side in census tracts from both rate of crime and OHCA.
Chapter 4: Results

Specific Aim 1: Determine the level of association between neighborhood violent crime rates and the incidence of OHCA.

Sum totals across census tracts (n=172) for the period 2012-2017 for both cardiac arrests and violent crime rate, as determined through calls for service to the New Orleans Police Department, were calculated and incidence rates calculated. Rates were calculated by dividing the total number of events in each census tract by the 2016 ACS population estimates for each census tract and then multiplying by 10,000 to provide a rate per 10,000 persons. These calculations were conducted using Microsoft Excel. Table 2 shows the results of calculating rates for violent crime and OHCA across 172 census tracts in New Orleans. Categorization of census tract according to violent crime rate and OHCA rate into a categorized variable resulted in the distribution shown in Table 3 for violent crime rate category and OHCA category. Low violent crime rate was determined to be equal to or lesser than the 25th percentile rate (231.37 per 10,000); medium violent crime rate was determined to be greater than the 25th percentile rate but lesser than or equal to than the median (231.37 to 372.14 per 10,000); high crime rate was greater than the median (372.141 or greater per 10,000). Low OHCA was equal to or lesser than the median (42.96 per 10,000); high OHCA was greater than the median (42.961 or greater per 10,000).

Table 2: Violent Crime Rate and OHCA Rates in New Orleans Census Tracts

<table>
<thead>
<tr>
<th>n=172</th>
<th>Calculated Violent Crime Rate</th>
<th>Calculated OHCA Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>697.88</td>
<td>60.0722</td>
</tr>
<tr>
<td>Median</td>
<td>372.14</td>
<td>42.96</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>1890.98</td>
<td>154.34</td>
</tr>
<tr>
<td>Percentiles</td>
<td>25</td>
<td>231.37</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>372.14</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>722.81</td>
</tr>
</tbody>
</table>
Examining census tract level variables across these categories, as shown in Table 5, yields interesting initial information. For example, in high violent crime rate census tracts for both low and high OHCA, there tend to be higher populations of African-Americans than compared to the low crime rate census tracts. Additionally, the median age in high violent crime rate census tracts is lower than the overall median age and lower than the median age of census tracts with low crime rates in both low and high OHCA groups. Both percentage of population 100 percent below the Federal Poverty Level (FPL) and percentage of the population with a bachelor’s degree show changes when moving from the low to medium to high violent crime rate census tracts in both the low and high OHCA category census tracts. The percentage of the population 100 percent below the FPL increases from low to medium to high and is greater in the high violent crime rate and high OHCA rate census tracts. Conversely, the percentage of population with a bachelor’s degree or higher decreases when moving from low to medium to high violent crime rate census tracts across both the low and high OHCA groups, with the high OHCA rate census tract group having almost half the percentage of the population with a bachelor’s degree or higher than in all violent crime rate categories than the lower OHCA rate census tracts.

A multiple regression was run to predict OHCA from census tract crime rate, median age, percent of male population in a census tract, percent of African-American population in a census tract, median census tract income, percent of population below 100 percent of the FPL, and
percent of population in census tract with a bachelor’s degree or higher. There was linearity as assessed by partial regression plots and a plot of studentized residuals against the predicted values. There was independence of residuals as assessed by a Durbin-Watson Statistic of 1.774. There was no evidence of multicollinearity, as assessed by tolerance values greater than 0.1. The multiple regression model statistically significantly predicted OHCA rate, $F(7,16) = 18.345$, $p<.05$. Of the variables in the equation, only median age added statistically significantly to the prediction. Regression coefficients and standard errors, found in Table 4, show that only median age contributed significantly to the prediction.

<table>
<thead>
<tr>
<th>Variable</th>
<th>$B$</th>
<th>SE$_B$</th>
<th>$\beta$</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-7.626</td>
<td>26.536</td>
<td>.774</td>
<td></td>
</tr>
<tr>
<td>Median Crime Rate</td>
<td>.005</td>
<td>.003</td>
<td>.109</td>
<td>.128</td>
</tr>
<tr>
<td>% Bachelor’s Degree or Higher</td>
<td>-.327</td>
<td>.193</td>
<td>-.276</td>
<td>.093</td>
</tr>
<tr>
<td>% below 100% FPL</td>
<td>.210</td>
<td>.196</td>
<td>.122</td>
<td>.285</td>
</tr>
<tr>
<td>Median Income</td>
<td>.000</td>
<td>.000</td>
<td>-.171</td>
<td>.252</td>
</tr>
<tr>
<td>% population African American</td>
<td>.122</td>
<td>.114</td>
<td>.147</td>
<td>.287</td>
</tr>
<tr>
<td>% population male</td>
<td>.301</td>
<td>.340</td>
<td>.059</td>
<td>.378</td>
</tr>
<tr>
<td>Median Age</td>
<td>1.229</td>
<td>.335</td>
<td>.261</td>
<td>.000</td>
</tr>
</tbody>
</table>

A Kruskal-Wallis test was conducted to test the null hypothesis that the distribution of OHCA rate was the same across census tract categories of violent crime rate: “low” (n=43), “medium” (n=43), and “high” (n=86). The test result was a rejection of the null hypothesis. Distributions of OHCA rate were similar for all groups, as assessed by visual inspection of a boxplot. Median OHCA rates were statistically significantly different between groups, $\chi^2 (2) = 59.332$, $p < .001$. As the Kruskal-Wallis test showed statistical significance, indicating that the distribution of median OHCA rates is different from other groups, a post hoc test was run. Pairwise comparisons were performed using Dunn’s test procedure with a Bonferroni correction for multiple comparisons. Adjusted p-values are presented. This post hoc analysis revealed
statistically significant differences in median OHCA rates between the low (Mdn = 23.71) and medium (Mdn = 36.00) (p = .014), low and high (Mdn = 56.80) (p = .000), and the medium and high (p = .000) crime rate category groups.

With the previous tests demonstrating differences in median OHCA rates between crime rate categories, further investigation by means of bivariate Pearson Correlation was conducted to measure the strength of the relationship between the continuous variables of violent crime rate and rate of OHCA. Violent crime rate and OHCA rate were determined to have a statistically significant linear relationship (p < .001). The relationship was a positive one, with greater violent crime rates being associated with higher rates of cardiac arrest, and there was found to be a strong association (r = .949).
<table>
<thead>
<tr>
<th></th>
<th>Overall (n= 172)</th>
<th>Low Cardiac Arrest Rate (n=86)</th>
<th>High Cardiac Arrest Rate (n=86)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low (n=38)</td>
<td>Medium (n=25)</td>
</tr>
<tr>
<td>Age, median (IQR)</td>
<td>36.4 (6.4)</td>
<td>37.3 (5.6)</td>
<td>36.9 (8.3)</td>
</tr>
<tr>
<td>Population composition, median (IQR)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent white</td>
<td>24.7 (59.8)</td>
<td>80.75 (54.1)</td>
<td>29.5 (56.8)</td>
</tr>
<tr>
<td>Percent black</td>
<td>68.8 (61.9)</td>
<td>11.3 (43.7)</td>
<td>50.6 (61.9)</td>
</tr>
<tr>
<td>Median income (IQR)</td>
<td>$21,869 (17,138)</td>
<td>$37,232.50 ($16,404)</td>
<td>$26,641 ($14,524)</td>
</tr>
<tr>
<td>Percent below poverty level, median (IQR)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent bachelor’s degree or higher, median (IQR)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHCA rate, median (IQR)</td>
<td>42.96 (33.92)</td>
<td>21.16 (17.86)</td>
<td>29.31 (15.82)</td>
</tr>
</tbody>
</table>
Figure 12 shows using GIS the dichotomous variable (yes/no), which indicated census tracts with both a high incidence of cardiac arrest and a high violent crime rate (n=63). This combination of high OHCA/high violent crime rate was utilized as the dependent variable in a logistic regression model to determine the tract level factors associated with high violent crime and high OHCA. As a result, logistic regression was performed to ascertain the effects of age, gender, race, income, poverty, and education on the combination of high violent crime rate and high OHCA census tracts versus all others. The factors used in the model were census tract level

Census Tracts with High Crime Rate and High Out of Hospital Cardiac Arrest Rate

Figure 12: Census Tracts with High Crime Rate and High OHCA Rate
measures obtained from the ACS 2016 and included median age, percent of population that was male, percent of population that was African American, median income, percent of population below 100 percent of the Federal Poverty Level, and percent of population with a bachelor’s degree or higher. Table 6 shows the results of the analysis by each variable in the model analyzing tract level factors associated with census tracts that have both high rates of OHCA and high rates of violent crime. The logistic regression model was statistically significant, $\chi^2 (6) = 61.624$, $p < .005$. The model explained 41.7 percent (Nagelkerke $R^2$) of the variance in census tracts with high cardiac arrest and high crime, and correctly classified 76.5 percent of high violent crime/high OHCA census tracts. Of the six predictor variables only two were statistically significant: median age, and percent male. Increasing median age in a census tract was associated with a slightly higher likelihood of high OHCA/high violent crime combination. Additionally, census tracts with higher rates of male population had about a 1.10 times greater likelihood of being a census tract with high OHCA/high violent crime classification. Other variables, including sex, race, income, poverty, and education showed little effect on high violent crime rate and high OHCA. Interestingly, although not statistically significant at the .05 level, the percentage of population with a bachelor’s degree or higher was associated with a decrease in the likelihood of being a high OHCA/high violent crime census tract.

Table 6: Tract level factors associated with areas that have high rates of OHCA and high violent crime rates

<table>
<thead>
<tr>
<th>Tract level factors associated with areas that have high rates of OHCA and high rates of violent crime (n=172)</th>
<th>B</th>
<th>SE</th>
<th>Wald</th>
<th>OR</th>
<th>(95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median Age</td>
<td>.078</td>
<td>.040</td>
<td>3.869</td>
<td>1.08</td>
<td>(1.00-1.17)</td>
<td>0.049</td>
</tr>
<tr>
<td>Population composition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent Male</td>
<td>.094</td>
<td>.040</td>
<td>5.627</td>
<td>1.10</td>
<td>(1.02-1.19)</td>
<td>0.018</td>
</tr>
<tr>
<td>Percent African American</td>
<td>.000</td>
<td>.013</td>
<td>.001</td>
<td>1.00</td>
<td>(.98-1.03)</td>
<td>0.973</td>
</tr>
<tr>
<td>Median Income</td>
<td>.000</td>
<td>.000</td>
<td>.632</td>
<td>1.00</td>
<td>-</td>
<td>0.427</td>
</tr>
<tr>
<td>Percent 100% below FPL</td>
<td>.037</td>
<td>.021</td>
<td>2.948</td>
<td>1.04</td>
<td>(.99-1.08)</td>
<td>0.086</td>
</tr>
<tr>
<td>Percent with bachelor's degree or higher</td>
<td>-.038</td>
<td>.023</td>
<td>2.800</td>
<td>0.962</td>
<td>(.92-1.01)</td>
<td>0.094</td>
</tr>
</tbody>
</table>
Specific Aim 2: Examine how neighborhood violent crime rates influence bystander CPR in New Orleans.

Analyzing each cardiac arrest at the individual case level which occurred in a residence (n=1,602), a Chi Squared analysis showed that there was no statistically significant association between bystander CPR and return of spontaneous circulation ($\chi^2 (1) = .164, p=.685$). As shown in Table 7, the results suggest that the rate of bystander CPR is similar in instances where there was a return of spontaneous circulation and where there was no return of spontaneous circulation.

Table 7: Results of Chi-square Test and Descriptive Statistics for Bystander CPR by Return of Spontaneous Circulation

<table>
<thead>
<tr>
<th>Bystander CPR</th>
<th>Return of Spontaneous Circulation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>827 (69%)</td>
<td>377 (31%)</td>
</tr>
<tr>
<td>Yes</td>
<td>277 (70%)</td>
<td>120 (30%)</td>
</tr>
</tbody>
</table>

*Note.* Numbers in parentheses indicate row percentages.

Further, no statistically significant association was found between whether an OHCA was witnessed and bystander CPR was performed ($\chi^2 (1) = .817, p=.366$), with the results of the test shown in Table 8.

Table 8: Results of Chi-square Test and Descriptive Statistics for Witnessed Out of Hospital Cardiac Arrests and Bystander CPR

<table>
<thead>
<tr>
<th>Bystander CPR</th>
<th>Witnessed OHCA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td>No</td>
<td>762 (76%)</td>
</tr>
<tr>
<td>Yes</td>
<td>241 (24%)</td>
</tr>
</tbody>
</table>

*Note.* Numbers in parentheses indicate column percentages.

The test of association results indicate that bystander CPR does not appear to be statistically associated with whether an out of hospital cardiac arrest was witnessed; the results show no statistically significant difference in bystander CPR rates between witnessed and
unwitnessed out of hospital cardiac arrests. The results suggest that the rate of bystander CPR is similar for witnessed and unwitnessed arrests.

However, there was a weak to moderate association (Phi and Cramer’s V = .198) between whether an arrest was witnessed and a return of spontaneous circulation ($\chi^2 (1) = 62.908$, $p=.000$).

Table 9: Results of Chi-square Test and Descriptive Statistics for Witnessed Out of Hospital Cardiac Arrests and Return of Spontaneous Circulation

<table>
<thead>
<tr>
<th>Witnessed Arrest</th>
<th>Return of Spontaneous Circulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td>No</td>
<td>762 (69%)</td>
</tr>
<tr>
<td>Yes</td>
<td>342 (31%)</td>
</tr>
</tbody>
</table>

*Note. Numbers in parentheses indicate column percentages.*

Chi-squared results show a statistically significant difference in return of spontaneous circulation between unwitnessed and witnessed out of hospital cardiac arrests. Reasonable enough, return of spontaneous circulation is more likely in instance of a witnessed out of hospital cardiac arrest than in an unwitnessed instance, as shown in Table 9 and Figure 13.

![Figure 13: Category of Bystander CPR by Witnessed Arrest Category](image-url)
At the census tract level, the continuous variables for rate of witnessed arrests and bystander CPR were individually assessed for any statistical relationship with violent crime rate. A Pearson’s product-moment correlation was run assessing the relationship. Preliminary analysis indicate that the rate of bystander CPR provision and violent crime rate were found to have no statistically significant linear relationship (p = .124). Likewise, the rate of witnessed arrest was found to have no statistically significant linear relationship with violent crime rate (p = .646).

Table 10 shows the results of these tests across the 172 census tracts examined.

Table 10: Relationship between Rate of Witnessed OHCA and Bystander CPR with Violent Crime Rate

<table>
<thead>
<tr>
<th>Violent Crime Rate</th>
<th>Rate of Witnessed OHCA</th>
<th>Rate of Bystander CPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Correlation</td>
<td>.035</td>
<td>-.118</td>
</tr>
<tr>
<td>Significance (2-tailed)</td>
<td>.646</td>
<td>.124</td>
</tr>
<tr>
<td>N</td>
<td>172</td>
<td>172</td>
</tr>
</tbody>
</table>

Specific Aim 3: Determine whether response time from New Orleans Emergency Medical Services in responding to OHCA varies by neighborhood due to violent crime rate.

The two variables from the CARES data set, time from call receipt to ambulance on scene and ambulance on scene to EMS at patient side, were examined using descriptive statistics. The time interval variable that was created measuring the time from call receipt to EMS at patient side is simply the sum of the two time intervals. Table 11 shows descriptive statistics for the two variables from the CARES data set as well as the time interval variable that was created.

Table 11: Time Intervals for All Cardiac Arrests in All Census Tracts, in seconds (n=1,200)

<table>
<thead>
<tr>
<th></th>
<th>Call Received to Ambulance On Scene</th>
<th>Ambulance on Scene to EMS at Patient Side</th>
<th>Call Received to EMS at Patient Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>505.83</td>
<td>121.68</td>
<td>627.51</td>
</tr>
<tr>
<td>Median</td>
<td>480.00</td>
<td>120.00</td>
<td>600.00</td>
</tr>
</tbody>
</table>
Normality tests for the three created variables of time interval at the individual level: Call Receipt to EMS Arrival; EMS to Patient Side; Call Receipt to EMS at Patient Side demonstrated highly significant non-normality, as shown in Table 12. As a result, median was chosen as the measure of central tendency to provide more normalized results.

Table 12: Normality Tests for Three Computed Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Shapiro-Wilk Significance</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Call Receipt to Ambulance on Scene</td>
<td>p = .000</td>
<td>.722</td>
<td>.568</td>
</tr>
<tr>
<td>Ambulance on Scene to Patient Side</td>
<td>p = .000</td>
<td>6.806</td>
<td>97.338</td>
</tr>
<tr>
<td>Call Received to EMS at Patient Side</td>
<td>p = .000</td>
<td>1.281</td>
<td>5.759</td>
</tr>
</tbody>
</table>

Median time values in all three variables were calculated by census tract to provide tract level data. Median time values were available in 98 percent of the census tracts (n=169). Both the newly calculated median times and the crime rate were assessed for normality as shown in Table 13.

Table 13: Normality Tests for Calculated Median Times and Crime Rate

<table>
<thead>
<tr>
<th>Variable</th>
<th>Shapiro-Wilk Significance</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median Time: Call Received to EMS at Patient Side</td>
<td>p = .000</td>
<td>1.817</td>
<td>6.316</td>
</tr>
<tr>
<td>Census Tract Crime Rate</td>
<td>p = .000</td>
<td>4.028</td>
<td>21.399</td>
</tr>
</tbody>
</table>

Both variables were transformed and reassessed for normality as shown in Table 14 and Figure 14.

Table 14: Normality Tests for Transformed Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Shapiro-Wilk Significance</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median Time: Call Received to EMS at Patient Side</td>
<td>p = 1.000</td>
<td>.000</td>
<td>-.250</td>
</tr>
<tr>
<td>Transformed Census Tract Crime Rate</td>
<td>p = .495</td>
<td>.145</td>
<td>.227</td>
</tr>
</tbody>
</table>
A Pearson Correlation was run to determine the relationship between the two transformed continuous variables, median time from call receipt to EMS at patient side and census tract violent crime rate. Table 15 shows the results of this test and the negative correlation between the two variables. There was a negative correlation between time from receipt of call to EMS at patient side and violent crime rate, which was statistically significant (r = -.310, n = 168, p = .000).

### Table 15: Relationship between Violent Crime Rate and Created Time Interval Variable for Call Received to EMS at Patient Side

<table>
<thead>
<tr>
<th>Violent Crime Rate</th>
<th>Time Interval Variable: Call Received to EMS at Patient Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Correlation</td>
<td>-.310</td>
</tr>
<tr>
<td>Significance (1-tailed)</td>
<td>.000</td>
</tr>
<tr>
<td>N</td>
<td>168</td>
</tr>
</tbody>
</table>

A partial correlation was run to determine the relationship between a census tract’s median time from call receipt to EMS arrival at a patient’s side, utilizing the transformed variable, and the census tract violent crime rate and census tract OHCA rate while controlling for
a census tract’s rate of witnessed OHCA. Results from the partial correlation are shown in Table 16. There was a moderate, negative partial correlation between a census tract’s median time from call receipt to EMS arrival at a patient’s side (615.26 ±178.22 seconds) and census tract crime rate (2.60±.36), while controlling for census tract rate of witnessed OHCA (37.74±20.47 percent), which was statistically significant $r(165) = -.305$, $N = 168$, $p = .000$. There was a moderate, negative partial correlation between a census tract’s median time from call receipt to EMS arrival at a patient’s side and census tract OHCA rate (1.60±.30), which was not statistically significant $r(165) = -.145$, $N = 168$, $p = .061$. However, zero-order correlations showed that there was a statistically significant, moderate, negative correlation between census tract median time from call receipt to EMS arrival at patient side and census tract crime rate ($r(166) = -.310$, $N=168$, $p = .000$) and a somewhat significant, moderate, negative correlation between census tract median time from call receipt to EMS arrival at patient side and census tract OHCA rate ($r(166) = -.149$, $N = 168$, $p = .054$), indicating that a census tract’s rate of witnessed OHCA had very little influence in controlling for the relationship between median time from call receipt to EMS arrival at a patient’s side and either violent crime rate or rate of OHCA.

Table 16: Summary of Partial Regression Analyses for Variables Predicting Census Tract Median Time from Call Receipt to EMS Arrival at Patient Side ($n = 168$)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Correlation</th>
<th>Sig. (p)</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Zero Order Correlation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Violent Crime Rate</td>
<td>-.310</td>
<td>.000</td>
<td>166</td>
</tr>
<tr>
<td>OHCA Rate</td>
<td>-.149</td>
<td>.054</td>
<td>166</td>
</tr>
<tr>
<td><strong>Controlling for Witnessed Arrest Rate</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Violent Crime Rate</td>
<td>-.305</td>
<td>.000</td>
<td>165</td>
</tr>
<tr>
<td>OHCA Rate</td>
<td>-.145</td>
<td>.061</td>
<td>165</td>
</tr>
</tbody>
</table>
Chapter 5: Discussion

The study utilizes geospatial data to evaluate differences by geography in OHCA that occurs in homes and at places of residence and the environment in which they occur. By harnessing the power of location, we were able to identify census tracts with high rates of cardiac arrest and high rates of violent crime as well as identify that census tracts characterized by a higher percentage of population with greater than a high school education were associated with lower crime and cardiac arrest rates. The study carries forward the work of Fosbol et al. (2014) as well as others that demonstrate that identifying high-incidence areas of OHCA is possible and can support targeted interventions to decrease risk. Our study builds on this work, which previously identified characteristics such as age, race, and income as indicators of high risk areas, to include preliminary evidence that violent crime rate may be another indicator of high-incidence OHCA areas. There are several published methods available to consider OHCA and geographical variation. The adopted strategy builds on the analysis methods by Starks et al. (2017), to develop additional considerations in exploring OHCA and its social determinants.

The study does so by making use of data that, while in existence, has not been widely utilized beyond local government, and even then, only for management purposes. As computerized prehospital records and healthcare records grows, so does the availability of these datasets. Utilizing almost a decade worth of OHCA data for the first time in a research application demonstrates the potential uses of this data, and that we must continue to push the use of local level, relevant data to provide critical direction to policy makers and operational managers. The study demonstrates how important the use of this data is and shows that the outcomes, real and targeted intervention into health outcomes, is possible with this data. Research must continue to figure out how to apply these datasets as they grow and as we
continue to explore them together. Guiding philosophies, including the theoretical basis of this study, are frameworks for interesting and deep dives into the social context of health and our cities. Without the data and research to hang on the theoretical framework, they are like an empty page. Research much continue to iterate using these frameworks, and develop new and novel ways to explore, explain and measure the complex interactions between people, their environment, and their health.

The study also provides additional support that environmental and neighborhood effects may contribute to more health outcomes than previously considered. The theoretical model, positing that neighborhood disruption, in our case violent crime, has pathways to impact individual level health and health outcomes, provides the basic context for exploring the data. We have selected a narrow pathway for analysis in examining violent crime, but there is much more that contributes to neighborhood disorder and should be assessed in an ongoing and holistic framework. Blight, especially post Katrina in New Orleans, remains a large issue in low income neighborhoods. Sidewalks, streets, and buildings remain in disrepair as the population is still only 86 percent of its pre-2005 levels (Evans, Zimmerman, Woolf, & Haley, 2012). These issues of persistent exposure to neighborhood disorder are as important as the exposure to violent crime and likely contribute to overall health status in additional ways that while unmeasured here, are just as important in the pathway of how place impacts health.

The argument that neighborhood disorder and disruption impacting health outcomes has an almost broken windows theory basis to it. First proposed in the early 1980s, Wilson and Kelling considered that levels of blight and social disruption, the most vivid example being broken windows in an abandoned building, contribute to high levels of crime and a trajectory to more violent crimes due to the lack of social order (Wilson, 1982). The thought that disorder
causes crime, and that the crime causes more disorder which feeds the cycle, while simplistic in nature, illustrates the concept of how disorder impacts health in our theoretical foundation. As violence, blight, and social disruption cause greater levels of stress, the result is poor health status. The cycle continues as a tapestry of interactions in neighborhoods with higher crime, also having less access to healthy food alternatives, high alcohol outlet density, lower SES, lower educational achievement, higher rates of smoking, diabetes, heart disease and other factors, all blend to create a complex and yet coordinated impact on health status of individuals living there. Our task here is examining one single thread of that tapestry, focused on the narrow outcome of OHCA as a newly explored indicator in New Orleans, and how violent crime in neighborhoods plays into that. However, further research should continue to explore the degree to which other currently unmeasured neighborhood level variables factor into OHCA as a major health status indicator.

Specific Aim 1

Initial geospatial analysis showed definitive clustering of high rates of cardiac arrest in residences across census tracts throughout New Orleans. When census tracts with both high rates of crime and high rates of OHCA in residences were selected, neighborhood clusters were easily seen across the Central City, Treme, Hollygrove, Lower 9th Ward, St. Claude/Florida, Behrman, and sections of Little Woods in New Orleans East. Bivariate statistical analysis showed that census tracts with higher rates of crime was associated with higher rates of cardiac arrest. These results seem to support current theories of neighborhood disorder and violence which relate environmental stressors to physiological distress and health outcomes (Hill et al., 2005). Initial regression models identifying factors associated with OHCA rate showed that only median age was statistically significantly associated with the outcome, and crime played little into the
modeling. However, further analysis demonstrated a definite association between high crime rate and high OHCA as evident by the results of further regression analysis. The logistical regression models showed that commonly identified variables such as income and poverty, showed little effect on high violent crime rate and high OHCA. The findings, while surprising, may not be novel. Previous studies exploring neighborhood violence and impacts on health outcomes have also shown that other neighborhood measures, such as poverty, showed weaker and less statistically significant associations with health outcomes (Do et al., 2011). Moreover, race was not found to be statistically significantly associated with health outcome. Previous research has continued to show that African Americans are at a higher risk for OHCA and less likely to survive (Becker et al., 1993; Starks et al., 2017; Wilde, Robbins, & Pressley, 2012). Starks et al. (2017) was limited in that the clustering of predominately African American neighborhoods was limited to a few specific study sites, thus producing a lack of heterogeneity across the analysis. Census tracts in New Orleans, especially since 2005, have seen a great deal of mixing. While census tracts in the city vary by percentage of white and non-white residents, the majority have a heterogeneous mixture of demographics, especially race. Certain areas though, remain predominately one race, and targeted research on risk is necessary to tease out the exact impacts. The result of the majority of census tracts being such a melting pot may mask this association with race and the underlying relationships with OHCA, thus contributing to the lack of association seen here with race that many other researchers consistently identify.

So while poverty and other measures of disorder may be contributing to health outcomes, the impact of these neighborhood level factors may not be as acute, as the exposure is more diffuse than something as acute as neighborhood violence, where the outcomes are uncertain, life threatening, and have been shown to cause a direct physiological response in individuals (Theall
et al., 2017). Census tracts with higher levels of individuals who had a bachelor’s degree or greater were associated with likelihood of not being in the high crime/high OHCA category, though surprisingly, the finding here was not statistically significant. Likewise, in the multiple regression model, only median age was found to contribute is any statistical significance to OHCA rate. For almost forty years, researchers have demonstrated the positive association between education and health, where lower levels of education are associated with high rates of chronic disease and shorter life expectancy (Ross & Wu, 1995). The fact that census tracts with higher rates of individuals having a bachelor’s degree or greater presents an interesting opportunity for intervention- wherein initiatives to improve educational attainment across the community may have a positive impact on not only socio-economic status but also health through providing additional job opportunities, psycho-social support, and support better health behaviors. Such cross-cutting impact addresses the complex web of interactions in both neighborhood and individual level variables which contribute to health status outcomes.

Consistent with research, census tracts with higher median age and higher percentages of male population were associated with a greater likelihood to be in the high OHCA/high violent crime category. Among the most basic risk factors for OHCA are age and sex- where older individuals and males are more likely to suffer an OHCA (Mozaffarian et al., 2016). Though not revolutionary in conclusion, the result does provide actionable information for public health intervention, signaling that the basic tenants of public health education, communication of risk factors, and interventions for at risk populations are still necessary to impact morbidity and mortality.

**Specific Aim 2**

The individual level analysis in Specific Aim 2 showing no association between bystander CPR and short term survival (return of spontaneous circulation) seemed counter to the
Chain of Survival concept in which early CPR contributes to more positive outcomes (Katz, 2011; Sasson et al., 2010). Research has shown, however, that ineffective bystander CPR may not contribute to positive outcomes, and that variables such as initial rhythm of cardiac arrest and interval of time from cardiac arrest to CPR dramatically impact outcomes (Gallagher, Lombardi, & Gennis, 1995). It may be the case that bystander CPR is being ineffectively provided or that there is a delay in the initiation of bystander CPR which contributes to this finding. Further, the neighborhood characteristics, including lack high turnover in residences, lack of social cohesion, or individual level factors such as fear of harm or injury also may moderate provision of bystander CPR. Additional research is needed to determine to what degree, if any, these factors may be limiting the positive effects otherwise seen by researchers in other situations.

The weak to moderate association found between a witnessed OHCA and positive short-term outcomes, as measured in this case by return of spontaneous circulation, does point to the fact that shortening the intervals of the Chain of Survival, in this case early access to emergency care by notifying 911, leads to positive outcomes. In the witnessed arrests, defined as when a bystander actually witnesses the onset of OHCA, versus when it is unwitnessed, the thought is that decreasing the initial intervals of time between onset and action is due to early activation of mechanisms in the Chain of Survival. Other studies have shown that long term survival from OHCA almost doubles when the arrest is witnessed, supporting our results that in witnessed arrests there are generally more positive outcomes (Sasson et al., 2010). Less than half of the cardiac arrests occurring in residences over the time frame were witnessed, whereas previous research analyzed in Sasson, Rogers, et al.’s 2010 meta-analysis showed just the opposite, with most OHCA events being witnessed. This fact may account for the weak to moderate association found in our study. Further analysis is needed to examine why in New Orleans OHCA in
residences are less likely to be witnessed. Whatever the case, the results, taken together with the previous individual level analysis on bystander CPR and ROSC, indicate that public health interventions focused on recognizing the signs and symptoms of cardiac arrest as well as the prompt delivery of bystander CPR may provide significant increases in survival across New Orleans.

At the census tract level, the lack of an association between both witnessed cardiac arrests and bystander CPR to neighborhoods with high violent crime rates seems to indicate that neighborhood violence has no impact on whether bystander CPR will be provided. Previous studies have examined individual level barriers to learning and performing CPR in high risk neighborhoods and hypothesized that one of the barriers was the unsafe neighborhood and resulting risk to personal health (Sasson et al., 2013). Our results seem to indicate that these hypothesized barriers are not related to neighborhood level violent crime rate and require further analysis to determine the exact association. One can imagine the broad range of properties that are included in this outcome- everything from neighborhood social cohesion to the mixture of single family versus multi-family dwellings in the neighborhood. The datasets used, while robust in outcomes and event, are designed to carefully measure variables associated with either violent crime or OHCA.

**Specific Aim 3**

Along the Chain of Survival, reducing the interval from the occurrence of a cardiac arrest the arrival of emergency medical services provides the opportunity to greatly increase survival. In emergency medical systems with at least two first responders trained in advanced cardiac life support at out of hospital arrests, survival rates of greater than 20 percent are possible, twice the national average (American Heart Association, 2000). To determine if violent crime rate in New Orleans impacted ambulance response time, analysis on median time from call receipt to EMS
arrival at patient side was used. Analysis showed that in neighborhoods with higher rates of violent crime there was a statistically significant faster response time, meaning that the time from receipt of call to the time of arrival of EMS at patient side was less in census tracts with higher violent crime rates, even when controlling for the rate of witnessed cardiac arrests. New Orleans Emergency Medical Services is a high-volume ambulance service, responding to approximately 65,000 calls for service a year with a unit hour utilization of .65 (City of New Orleans, 2018). With such a busy service, it can be surmised that paramedics and emergency medical technicians are highly familiar with high rates of violent crime, regularly responding to calls for service in these areas. Further, some of the census tracts with the highest rates of cardiac arrest were located in the areas surrounding the city’s major hospitals- meaning that more often than not, ambulances or emergency medical resources would be closer by, more familiar with the neighborhood, and thus more readily accessible. Additionally, EMS has a diversion protocol whereby units enroute to a less serious call for service can be rerouted to a more serious incident, such as OHCA. These dynamic variables associated with ambulance status, location, and movement create complex scenarios in the analysis. The scale of the city, one in which you can easily traverse the span from lake to river (almost north to south) and the majority of the distance from Uptown to Downtown to the East (east and west) in fifteen to twenty minutes, is also an important characteristic. Other urban environments present much denser and separated neighborhood geographies, with interstate systems in a ring configuration and roadways leading into and out of their core on spurs, as in Houston, Dallas, Atlanta, Memphis, New York, Cleveland, and others. New Orleans, on the other hand, has the major interstate systems and expressway systems bisecting its geography, moving through east to west with major roadways running almost north to south, river to lake and then minor streets branching off. This unique
geography most assuredly plays into the response time components of EMS. To investigate further, additional research would be necessary to compare total call volume and types of calls for service across census tracts as well as exploring roadway and drive time maps with GIS modeling. These data were not available for this study, and as such we are unable to determine the root cause for this association.

Interestingly, that when controlling for rate of witnessed cardiac arrest, test statistics showed only a minor difference in change from the zero order correlation, meaning that the impact of witnessed arrest rate had very little influence on the relationship between median time from receipt of call to EMS at patient side and violent crime rate. Perhaps this can also be explained when the lack of a significant relationship is identified by the test statistics between the census track median time from call receipt to EMS at patient side and OHCA rate. Cardiac arrest, in and of itself, is likely under-recognized in the community and especially in higher risk areas. Targeted interventions, including public awareness campaigns on the signs and symptoms of cardiac arrest in high risk census tracts, should be explored to counter this trend and ultimately improve outcomes.

Whatever the case, the strong, significant association found in the regression model between time from call receipt to EMS arrival at patient side and high violent crime rate census tracts (p = .000), indicates that there are additional underlying factors which should be explored to better understand this association. The association has strong implications in training of emergency medical technicians and paramedics, unit placement, and response strategy for emergency medical services in New Orleans.
Chapter 6: Limitations

There are several limitations which may influence the results presented. First, a reporting bias may be present in the CARES data obtained from New Orleans Emergency Medical Services. The data, especially in the early years, was obtained from recall, wherein paramedics and emergency medical technicians would complete call record sheets following each OHCA. Recording times, particularly, are highly subject to recall bias of the emergency medical services personnel, as they were not all automated, with some based on the ability of emergency medical personnel to manually record times during a cardiac arrest- at times a frenzied and chaotic event. Data were then manually entered into the database, presenting the opportunity for transcription errors. In later years of the CARES data collection, the process was automated, taking times directly from Computer Aided Dispatch (CAD) and directly linked to the Electronic Patient Care Report (ePCR), thus decreasing the likelihood of errors.

Likewise, the 911 Calls for Service Data has some foundational limitations. The data, taken directly from Computer Aided Dispatch, reflects the information provided by a caller directly to a call taker or dispatcher. Such critical information as the location of call and type of incident is based on the information provided to the dispatcher, meaning that it is subject to error. This means that the creation of violent crime rate was based on a reported type of incident, and not based on a verified or substantiated incident after police investigation. The result is that certain call types may be over reported or underreported. Despite this limitation, we feel that it is critical that the perceived crime, especially in the cases violent crime, is valuable in this study. The basic questions in this study seek to examine the neighborhood environment’s impact on health outcomes, and those individual level perceptions, especially about violent crime, directly reflect the real or perceived environment in a neighborhood.
Utilizing census tract as the proxy for neighborhood comparison in New Orleans, while convenient for the dataset, also presents some issues in applying valid interpretation. The 172 census tracts split up New Orleans’ generally accepted 73 “official” city neighborhoods, which can also be categorized into 17 “wards,” 5 council districts, 8 police districts, and the list goes on (Swenson, 2015). Since Hurricane Katrina, there has been a marked change in the demographics of neighborhoods and dramatic shift in the characteristics of many neighborhoods (Evans et al., 2012). In essence, the social, economic and behavioral indicators of any area in the city have changed dramatically and may provide limitations on the interpretation of the long term effects of violent crime on health outcomes. The results, however, are robust and show repeated statistical significance in some cases, leading to show that the limitations may be minor.

In and of itself, the time variables selected for specific aims to measure response time may hold limitations. As identified, a key measure of the chain of survival is the time to get a first responder to a patient’s side, stopping the clock with the delivery of life saving interventions, including automated external defibrillators and basic and advanced cardiac life support. Within the New Orleans system, many acute emergencies engage the New Orleans Fire Department (NOFD) as a critical link in the chain of survival. While not trained and equipped to deliver advanced cardiac life support, the NOFD does respond to OHCA in New Orleans and delivers resuscitative care. Data for NOFD response times is included, to a limited extent, in the CARES data. NOFD does not respond to all OHCA as well. In the event that there is a large fire or other incident, NOFD units may stop responding to medical calls. Due to the inconsistency in the recording of these times (it is not automated, as is the case with EMS data) and the additional degree of variability within the response parameters, it was decided to not utilize the NOFD times as the marker for response to patient side. Though since the chain of survival identifies
access to ACLS as the critical link, selecting the EMS response time still answers the important
question of ambulance response and corresponds to the critical time intervals in the Utstein
template.

When conducting analysis, several categorical variables were created from continuous
variables and these transformed variables utilized in much of the analysis. Creating these discrete
categories does lessen the ability of variables to paint a full and complete picture during analysis,
however, in the instance of new data, often categorical values can provide insight into
complicated relationships between variables of interest and outcomes. In the instance of OHCA
and the growing body of work surrounding social and environmental influences on health
outcomes, the relationships are not neatly linear and are often still not understood. In these
instances, the categorical variables can provide valuable initial insight into the relationships,
establishing associations from which we can grow the theoretical underpinnings of complex
modeling and further analysis. So, creation of these discrete variables, does, in the end, limit the
results of interpretation, but it does provide a more meaningful outcome and result for
operational implementation by emergency medical services through utilizing easy to understand
categories and actionable information for communities.

Additionally, the lack of clear understanding on the causal relationships between complex
neighborhood environmental factors and health outcomes creates a situation in which it is
difficult to establish that the hypothesized pathways are simply not a reflection of other factors,
yet to be understood. What is clear, however, is that individual level health outcomes are
impacted by neighborhood level factors, and that the pathways, mediators, and causal factors
come together in a complex set of interactions which requires additional structured analysis.
Chapter 7: Conclusion and Recommendations

While we concluded that violent crime rate and OHCA rate has an association at the census tract level, further work is needed to examine the nature of the relationship and demonstrate that such an association is true across other communities. While we were unable to provide insight into other impacts of violent crime on factors associated with OHCA survival, including bystander CPR, valuable preliminary evidence for public health interventions and emergency medical services in New Orleans was created. Further, the research continues to demonstrate the need for the applied development of theories concerning health and health disparities and the use of available data. The study represents the first use of the OHCA data in New Orleans outside of use for management statistics. The implications for OHCA in New Orleans, specifically in certain neighborhood level areas, is weighty. Continued use of the data and development of models to understand health outcomes in a transparent, understandable and implementable way is a critical task for public health research. Public health researchers argue that improving overall survival rates through targeted interventions by up to 10 percent is a possibility (Sasson et al., 2010), and results such as those from this study provide the foundational evidence to direct these efforts, which have never been attempted in New Orleans.

Examining the theoretical models and links between health status, specific disease outcomes and environment is necessary to push forward our theories in order to elucidate in a more fine-grained fashion how social factors directly or indirectly contribute to population mortality and morbidity. Through data such as the OHCA dataset and the violent crime data identified here, researchers can move forward understanding how persistent issues such as income inequality, education gaps, discrimination and racism, play out in a medicalized end of
life scenario, and begin to populate connections between these factors in a tangible and more manipulable way for our health system and our communities.

Grounded in the work of social determinants of health, future research has an opportunity to explore the environmental impact on health inequities in New Orleans as it specifically relates to out of hospital cardiac arrest. Given improvements in ambulance services, emergency room services and access to care, linkages to social, cultural and economic determinants can sometimes be under examined in describing events leading to death from cardiac arrest. However, in over a decade since Hurricane Katrina, extensive research continues to examine the social determinants of health and crime in New Orleans, presenting an opportunity to examine specific health outcomes through an ever-growing body of comprehensive and context-sensitive literature specific to the area (Evans et al., 2012). The CARES data specific to New Orleans remains a relatively untapped resource, requiring additional investigation to elicit key fundamentals only briefly discussed in our work, including many of the pathways linking social and economic determinants with outcomes. This will likely mean exploring the action of these pathways in specific neighborhoods and areas within neighborhoods with higher risk for OHCA, areas with lower survival rates, hospital outcomes to determine long term health outcomes.
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