The Cost of Gun Shot Wounds to the Head: An unevenly distributed burden

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Abbreviations

GSW – Gun shot wounds to the head

GSWH – Gun shot wounds to the head

ICU – Intensive care unit

MDC – Miami-Dade County

ME – Medical Examiner

SES – Socioeconomic status

TBI – Traumatic brain injury

Introduction:

Despite the significant clinical consequences and socioeconomic costs of gun-shot wounds to the head (GSWH), studies examining pre-hospital risk factors, geo-spatial patterns, and economic cost are lacking.

Methods:

A retrospective analysis was performed for GSWH patients (single or multiple injuries) presenting to the level one Ryder Trauma Center (hospital patients) as well as the Miami Dade County Medical Examiner (ME) Department, from October 2013 to October 2015. Additionally, ME data was queried from the previous decade (2008-2017) to analyze longitudinal trends.

Results:

402 consecutive cases met inclusion criteria: 297 (74%) presented to the ME and 105 (26%) presented to the hospital. GSWH in our cohort had a case fatality rate of 89%, predominantly afflicting males, Caucasians, and victims of suicide, with a mean age of 41.9 ± 20.6 years. Hospital patients were more likely to be Black males from low socioeconomic (SES) regions involved in assault. Older, Caucasian males were overrepresented in patients attempting and completing suicide, thus comprised a higher percentage of ME cases. Geo-spatial analysis of hospital patient injury zip-codes illustrates GSWH are significantly clustered in low-income urban centers with greater poverty rates. In Miami-Dade County, the economic burden of GSWH, as measured by total healthcare costs and lifetime productivity losses, was estimated to be $11,867,415 and $246,179,498 respectively.

Conclusion:

In the first analysis of GSWH with the inclusion of both hospital and ME data in a representative urban setting, our findings demonstrate pre-hospital risk factors and the unequal distribution of the significant economic costs of GSWH.

Introduction

As of 2020, United States firearm-related fatality rates in civilian settings accounted for 13.7 fatalities per 100,000 citizens, largely due to suicides (7.4 fatalities) and homicides (5.9 fatalities) [1,2]. Accounting for 17.3% of all injury deaths in the U.S, gun violence has thus reached epidemic proportions [1-3]. Of firearm-related injuries, gunshot wounds to the head (GSWH) portend a particularly poor prognosis and account for approximately 50% of injuries [1,4-6]. Despite an over 50% improvement in neurotrauma mortality in the last 150 years, mean mortality has remained stable since 1990 at approximately 35% [7]. Similarly, among the GSWH literature, mortality rates range from 54.6-91% without improvement [5,6,8]. Despite the high prevalence and mortality of civilian GSWH, the epidemiology in contemporary, urban, U.S. populations has not been well-documented. The increasing public health burden of gun violence is becoming more apparent and attempts to combat these preventable injuries necessitate an assessment of the populations at-risk.

The economic burden of gun violence has been demonstrated to be substantial in the United States, with estimates of the initial hospitalization costs of firearm related injury to be $735 million per year [9]. Accounting for socioeconomic and medical domains, the cost to provide care for both nonfatal and fatal gun violence victims in 2010 was approximated at $174 billion, a number which was nearly 3 times the budget allocated for the US Department of Homeland Security and close to 2 times that of the US Department of Education [10-13]. The established economic burden of gun violence, coupled with the particularly devastating potential of GSWH, illustrates the need to further elucidate the societal cost of GSWH with the hopes to better direct preventative resources.

To better characterize at-risk populations, researchers have worked to investigate relationships between race, ethnicity, and SES with regards to gun violence. Specifically, correlations with social determinants of health have been examined at the level of patient outcomes, disposition, and follow up/rehabilitation. Chiu et al examined mortality rate, length of hospital stay, and surgical rate after GSWH and found no significant correlations among racial/ethnic groups [14]. Crutcher et al found similar results, reporting no

differences in GSWH survival outcomes based on race [15]. However, with regards to discharge disposition, Caucasian GSWH patients have been found to be more likely enrolled in immediate care and rehabilitation than Black patients [14]. This disparity is supported by previous studies examining TBI patients, demonstrating that compared to Caucasians, Hispanic and Black patients were less likely to be discharged to a rehab center and receive intensive rehab services [16,17]. Additionally, with respect to follow-up rates, Chun Fat et al. discovered that Black trauma patients had fewer post discharge injury-related outpatient visits [18]. Overall, these findings illustrate the presence of health disparities at several levels of care. However, with respect to the sub-population of GWSH patients, whose injuries carry substantial morbidity and mortality, little research has been done to examine the correlation of these aforementioned factors with pre-hospital risk of gun violence involvement.

In the first in-depth epidemiologic study of GSWH in Miami-Dade County (MDC), we investigated the public health burden of GSWH by examining patient-specific variables, social determinants of health, geo-spatial trends, and economic impact via a cost analysis. Previous studies of GSWH focused solely on patients presenting to the hospital, in addition to a variable inclusion of patients with multiple GSW. To quantify the full spectrum of GSWH, this study includes patients presenting to the hospital and to the ME department, in addition to the inclusion of both single and multiple GSW, thus encompassing the often-unrepresented patients who suffer polytrauma or whose injuries are fatal at the scene. We hoped to provide an accurate calculation of the case fatality rate as well as an understanding of where and when these injuries occur.

Methods

Study population:

A retrospective analysis was performed on all GSWH patients presenting to the level one Ryder Trauma Center (hospital) as well as the MDC Medical Examiner (ME) Department, from October 2013 to October 2015. All patients with calvarial GSWH were included - both isolated and multiple GSWs.

Patients were excluded if they had non-penetrating/perforating brain injuries, such as superficial and tangential GSWH. 402 consecutive cases met inclusion criteria, of which 297 (74%) presented to the ME and 105 (26%) presented to the hospital (Figure 1). This study was approved by the University of Miami Institutional Review Board as part of the TRACK TBI Miami Registry. Data were collected from patient histories, witness accounts, investigative documents, EMT and fire rescue logs, hospital charts, and post-mortem findings.

Statistical analysis:

The relationship between SES and injury/residence locations of injury was examined using linear regression analysis. The ten zip codes with the most GSWH were included. Neighborhood poverty status was obtained by examining the percentage living below the poverty line from the 2010 Census with a poverty threshold of $10,830 in annual income per one person families [19]. Heat maps were subsequently created with the Open Heat Map online resource [20]. Average cost of a GSWH admission was calculated utilizing our average hospital and ICU length of stay and reported costs of average inpatient stays in Florida [21]. Lost income per year was estimated utilizing the median incomes of the top ten zip codes in each cohort. Total income lost over a lifetime was determined by the total lost years of life in both cohorts based on an average life expectancy of 78 years [22]. In order to account for the changing value of money i.e. inflation, future years' incomes were discounted by three percent per the typical rate of multiyear cost calculations [23]. Cohort differences were assessed for significance using analysis of variance or independent samples Mann-Whitney U tests for continuous variables, and Pearson's chi-squared test or Fisher's exact test for categorical variables. Statistical significance was assessed at $\alpha = 0.05$. All analyses were performed using the IBM Statistical Package for the Social Sciences (SPSS, version 23; IBM Corporation, Chicago, IL).

Results

The rates of fatal gun violence (GSW-induced homicides and suicides) were examined in MDC over ten years from 2008 to 2017. The longitudinal trends were established based on the annual incidence of each injury etiology (homicide and suicide) stratified by those caused by GSWs (Figure 2). The total number of victims of homicide or suicide presenting to the ME remained relatively stable over this time period with an average of 59.9% and range 54.7% – 64.2%. Injury etiology as a percent of total gun violence demonstrates homicides as responsible for 66% on average (range 62% - 69%), while suicides were responsible for 34% on average (range 30.6 – 38%). Homicides peaked in 2013 and have since declined, while the suicide rate peaked in 2015.

In order to more closely assess GSWH epidemiology, an in-depth analysis of victims presenting to the ME department and a large level one trauma center were performed. Over the two-year study period (2013-2015), 200 GSWH occurred per year on average. An annual incidence of .0074% (7.4 cases / 100,000 population) was calculated based on Miami-Dade County 2015 population of 2,693,117. The case morbidity rate (cases per population) over the two-year period was 14.9 per 100,000 persons (1.5%) with a crude mortality rate (deaths per population) of 13.3 per 100,000 persons (1.3%). The case fatality rate of injured patients (deaths per cases) was 89%, illustrating the high mortality of GSWH (Figure 3). Most patients (297, 74%) were found dead on the scene and presented directly to the ME department. In cases where the patient was brought to the hospital (105, 26%), mortality was 58% (61). Mortality decreased to 42% for those surviving to obtain CT, and to 31.3% of those surviving to leave the trauma bay. Specifically, 39% (41) of hospital patients died in the trauma bay, and 19% (20) died before discharge. Therefore, 42% (44) of hospital patients, or 11% of our total GSWH cohort, survived to discharge.

Demographic characteristics of the overall cohort were examined. Overall, GSWH victims were predominantly male (86.3%), with an average age of 41.9 (std dev=20.6), Caucasian (50.7%), victims of homicide or suicide (47% each), and by single GSW (68.4%) (Table 1). The cohort was assessed for differences in race/ethnicity, gender, etiology, and mortality by injury etiology (suicide vs. assault).

Younger, Black patients were more likely to be victims of assault, while older age was significantly associated with suicide (47.8%; $p<0.0001$). There was no significant association between age and homicide. Males were significantly more likely to be victims than females ($p<0.0001$), and both by suicide (89.6%) and assault (82.1%; $p=0.0402$). Injury etiology was significantly associated with mortality, with suicide (98.4%) having a higher fatality rate than assault (81.7%, $p<0.0001$). Cases with single GSW's (68.4%) were more common than those with multiple GSW's (31.6%) at both locations ($p=0.0049$). Temporal analysis showed that GSWH occurred more frequently during the night (64.3%), especially 6 PM - 6 AM (41.1%), and on Sunday (28%) (Figure 4).

Patient populations presenting to the two locations (hospital vs. ME department) were analyzed to assess for differences in demographics or injury characteristics. Patients presenting to the hospital were younger than those presenting to the ME department (31.4 years vs. 45.6, $p<0.0001$) (Figure 5). Hospital patients were more commonly Black (63.8%), victims of assault (68.6%), and with single GSWs (14.9%). ME cases displayed a bimodal age distribution (peaks at 20 and 50 years old) but were more commonly Caucasian (58.2%), victims of suicide (60%), with single GSWs (53.5%). All these demographic differences were statistically significant between the two groups ($p<0.0001$).

Subgroup analysis of patients presenting directly to the ME included GSWH with 100% mortality and included initial investigation data. The average age of this group was 46 ± 20 years with homicide victims younger than suicide victims (31.3 years vs. 55.1 years, $p<0.0001$). Victims were more commonly male in both injury etiologies (78.1% homicide vs. 88.3% suicide, $p=0.0268$). Comparison of race showed Blacks were more likely to be victims of homicide (64.8%), while Caucasians were more likely to be suicide victims (59.1%) ($p<0.0001$). Suicide victims were more likely to have single GSW than homicide victims (96%, 37.1%, $p<0.0001$). Homicide-suicides, in which the perpetrator commits homicide followed by suicide, was equally prevalent among both genders. However, female homicide victims knew their assailant more frequently than male victims ($p<0.0001$).

Risk factors such as substance abuse and mental illness were examined in this ME subgroup. Alcohol was the most commonly abused drug in victims of both injury etiologies (19 – 24%) (Figure 6). However, opiates (9%, 1%, p=0.0065) and benzodiazepines (21%, 2%, p<0.0001) were more common in victims of suicide, while victims of homicide were more commonly positive for "street drugs" like cocaine (17%, 5%, p=0.0011), amphetamines (8%, 2%, p=0.0237) and cannabinoids (5%, 2%, p=0.0360). Finally, in a comparison of the mental illness incidence, depression (38.0%), bipolar disorder (5.9%), and schizophrenia (1.8%) were prevalent at higher rates in suicide victims than the overall US population (depression 6.7%, bipolar 2.6%, schizophrenia 1.2%) (Figure 7) [1]. Additionally, depression was identified more commonly in suicide victims than homicide (38.0%, 2.9%, p<0.0001).

Given that injury etiology varied by presenting location, injury clusters were examined to determine if the distribution was random. Both residence and injury location were analyzed in association with SES (Figure 8). In the hospital cohort, the number of injuries in a given zip code was positively and significantly correlated with the percent of the population living below the poverty line as defined by the Miami zip codes poverty percentage in the 2010 Census (p=0.0306, R2=0.4621)[19]. Zip code of residence was also significantly correlated (p=0.0014, R2=0.7395). Both injury and residence locations with higher poverty were found to be associated with higher levels of GSWH in the hospital cohort. However, in the ME cohort, the number of injuries in each zip code was not significantly correlated with the percent of the population living below the poverty line (p=0.8050, R2=0.008076). Additionally, when stratifying by injury etiology, homicide was found to be significantly associated with residence (p=0.0101, r2=0.5392) and injury (p=0.0050, r2=0.6027) locations (Table 2). This was not found to be true with the suicide cohort regarding residence (p=0.3595, r2=0.0939) or injury (p=0.5768, r2=0.0406) locations.

Lastly, the costs associated with GSWH were calculated to assess healthcare spending and productivity losses as measures of economic burden. Examining our cohort, GSWH victims experienced an average hospital length of stay of 21.52 days and ICU length of stay of 12.42 days. With the average daily costs of $2,087 and $5,484 for hospital and ICU care respectively, the average cost of each GSWH admission is

$113,023 [21,23]. Thus, the cost of the 105 GSWH admissions within our cohort is estimated to be $11,867,415. Next, the average annual income was estimated by using the average of the most represented zip codes of residence in each patient cohort. The average annual income for hospital patients was thus estimated to be $24,000 and the average annual income for ME victims was estimated to be $34,000. We then calculated that 368/402 patients in our cohort were unable to go back to work as they were either deceased (n=297) or severely impaired (n=71) based on GCS (GCS 3-9). Thus, the lost income per year, without the calculation of accruing inflation, of our entire cohort is calculated to be $11,820,000 (hospital=71 patients x $24,000/year; ME=297 patients x $34,000/year). Knowing the average life expectancy of 78 years and the average age of each subgroup (hospital=31.4, ME=45.6), the potential years lost were calculated (hospital=46.6, ME=32.4)[24]. Subsequently, the potential years lost in each subgroup (ME = 46.6, hospital=32.4) were multiplied by lost income per year adjusted by a 3% inflation rate resulting in an estimated lifetime income loss of $43,921,310 and $202,258,188 among hospital and ME patients respectively. Thus, the estimated lifetime income loss of our entire cohort (ME and hospital) is $246,179,498 (Table 3).

Discussion

Overall, GSWH victims in our study were predominantly male, Caucasian, in their fifth decade of life, and victims of suicide. Hospital patients were more likely to be Black males from low SES regions involved in assault. However, in our ME cohort, Caucasians were also frequently involved in gun violence. Specifically, older, Caucasian males were most likely to be victims of suicide and significantly more likely to perish, thus comprising a higher percentage of ME cases. Rolle et al. and Crutcher et al. in studies of 205 and 111 urban GSWH victims, respectively, found that functional and mortality outcomes were not correlated with race[15,25]. However, both investigations discovered an association with race and injury etiology, noting that assault victims were more likely to be Black males while suicide victims were more likely to be Caucasian males[15,25]. Additionally, Rolle et al. discovered a correlation with race and income level with respect to injury etiology, noting that assault victims were more likely to be Black men

of lower income classes[25]. With the broader inclusion of patients presenting to both the hospital and ME, our findings present a more accurate estimation of the true GSWH incidence and thus strengthen these initial observations.

To further elucidate the interplay of race, SES, and GSWH, we investigated the presence of violence hot-spots in MDC. Among hospital patients, our geo-spatial analysis of injury zip codes demonstrated that the number of GSWH occurring in each zip code as well as victims' zip code of residence were significantly correlated with percent of population living below the poverty line. These zip codes were found to be clustered in low-income urban centers, namely Liberty City, Hialeah, and Opa-locka. While cases presenting to the ME shared some common zip code origins with hospital injuries such as Liberty City, more were clustered in cities such as North Miami Beach, Miami Gardens, and Alameda, which are documented to have a lower percentage living below the poverty line. Demonstrating overlap with our own spatial analysis of MDC, a previous study of GSW identified injury hotspots which correlated with low-income black communities of Opa-Locka, Liberty City, and Overtown and carried morbidity rates 5-10 times higher than the national average[26]. These findings demonstrate clear urban-rural disparities in large metropolitan areas, further substantiating the focal, persistent tracts of gun violence in modern MDC, and likely other major urban centers.

GSWH spatial patterning has been previously examined at the levels of scene injury type (residential, street, highway, public building etc.) and broad U.S regions (Midwest, Northeast, North, South, etc.). Among both pediatric and adult patients, Denge et al. discovered most GSWH injuries occurred at residential settings in the Southern region of the U.S [6,27]. In contrast, our study represents the first community level geo-spatial analysis which has identified a link between discrete geographical areas, poverty rates, and GSWH incidence. In totality, these multi-level geographical findings highlight distinct starting points for societal intervention and may help guide the targeted deployment of public health efforts.

We found that individuals with mental health conditions are at a significantly higher risk for GSWH. These findings supplement previous studies demonstrating how psychiatric conditions, including depression, bipolar disorder, and schizophrenia, are more common in homicide and suicide victims[28,29]. With respect to substance use, alcohol was the most commonly abused drug in victims of both suicide and assault in the ME cohort. Additionally, 72% of our ME cohort were found to be positive for illicit substances at the time of injury. These findings are supported by a study of Philadelphia adolescents which discovered increased odds of becoming a victim of firearm homicide with alcohol and illicit drug use[30]. Of note, the presence of this association among illicit drug users was found not only at the level of the individual, but also at family and neighborhood societal levels[30]. These findings further support the indirect impact of substance use on firearm violence[31]. Specifically, via its negative effects on employment, income status, educational ascent, and interactions with delinquent peer groups, each of which is known to directly increase the risk of firearm homicide[31-33].

Lastly, our economic analysis is the first to elucidate the cost burden of civilian GSWH for a single county, both in terms of healthcare-associated costs as well as lost income. In 1994, Cook et al. estimated the national cost of GSWs to be $17,000 for acute-care and follow-up treatment, amounting to $2.3 billion in lifetime costs, with US taxpayers responsible for nearly half of that cost[34]. In a study of self-inflicted injuries, GSWH were found to have a significantly greater financial burden with a mean treatment cost of $117,338 [35]. This is similar to the calculated mean, independent of injury etiology, in our study of $113,023 which amounted to a total cohort admission cost of $11,867,415. Patients often cannot afford the expensive hospitalization costs, which then fall on the taxpayers via taxpayer-funded Medicaid and Medicare [36]. Additionally, despite survival of their injuries, patients may not recover adequately to be gainfully employed. This thereby imposes yet another economic burden on society. Notably, the calculated total income lost over the lifetime of our cohort amounted to $246,179,498, a number which clearly illustrates the severe economic burden of GSWH and serves as a call to action to curtail its incidence.

There are several limitations of our study. First, our study design was retrospective which confers inherent bias. Second, the presence of other trauma centers may compete with Ryder for patients. Patients who survive initial trauma may be preferentially brought to closer hospitals for treatment. If the zip codes in those regions have higher or lower numbers of GSWH or are of higher or lower SES than those near Ryder, this data set could be biased. On the other hand, the ME cohort has the potential to capture patients from all zip codes surrounding these hospitals. Third, our cost-analysis is limited given the use of averages in calculations for hospital costs and patient incomes, lack of inclusion of disability and unemployment costs, our static assumption that patients remain in the same GCS state, and the high likelihood of recidivism costs with these survivors. Future work could account for these limitations more thoroughly by investigating the effects of Quality Adjusted Life Years as a secondary outcome incorporating actual health-related quality of life data.

The data in this study elucidates the geographic and economic burden of GSWH in Miami. Using this information may allow for translational interventions aimed at reducing the incidence of GSWH. While there are various interventions that focus on treatment following injury, we believe the best approach centers on injury prevention. In fact, dozens of cities including Chicago, New Orleans, Oakland, and Baltimore, have implemented the National Network for Safe Communities' Group Violence Intervention for over two decades with successful violence reductions of 40-70% [37-39]. Such programs take the form of violence interrupter models (VIM), which focus on education to mitigate the spread of gun violence by using strategies associated with disease control. By investing in our communities, which possess the unique power to unify members from the inside-out, we can aim to reduce gun violence.

Conclusions

The high mortality (89%), particularly initial mortality (74%), of GSWH warrants the use of primary prevention programs to more effectively combat its public health burden in MDC. Injury and violence prevention programs must target hot spots of violence with the greatest poverty percentage to reap the maximal effects. Further, our cost-analysis illustrates the utility of public health intervention, which if

successful, could alleviate its substantial economic burden estimated to be $246,179,498 over the lifetime of our cohort. The results of our study are important for both MDC and the rest of the U.S, as the inclusion of both hospital and ME patients provides insight into the true incidence of GSWH, and subsequently, the generalizable epidemiologic associations there within. Overall, our findings provide direct support for the targeting of public interventions, specifically among at-risk populations and SES regions in MDC that would benefit most.

Figures & Tables

Table 1. Demographic characteristics of patients at presentation.

GSWH victims were predominantly male (86.3%), with an average age of 41.9 (std dev=20.6), Caucasian (50.7%), victims of both homicide and suicide (47% each), and by single GSW (68.4%). Younger, Black patients were more likely to be victims of assault, while older age was significantly associated with suicide (47.8%; $p<0.0001$).

Table 2. Associations between injury etiology and location.

Stratifying by injury etiology (homicide vs. suicide) yields significant associations between the homicide cohort and both residence ($p=0.0101$, $r^2=0.5392$) and injury ($p=0.0050$, $r^2=0.6027$) locations. This was not found to be true with the suicide cohort with regard to residence ($p=0.3595$, $r^2=0.0939$) or injury ($p=0.5768$, $r^2=0.0406$) locations.

Table 3. Socioeconomic costs of GSWH. Total income lost in overall cohort determined to be $246,179,498. Calculations are based on averages of published hospital expenses and socioeconomic census data with an adjusted income discount of 3% per year [21-23]. (K = $1,000, ME = Medical Examiner)

Figure 1. Patient cohort flowchart stratified by location of presentation. The majority of patients present directly to the ME (74%). Of those presenting to Ryder Trauma Center (26%), mortality status at discharge is shown.
(ME = Medical Examiner)

Figure 2. GSW-related homicides & suicides. From 2008-2018 GSW-induced homicides and suicides in MDC remained within a narrow range, with a recent decline in homicides. (MDC=Miami-Dade County, GSW = gunshot wound)

Figure 3. GSWH outcomes. The majority of victims died at the scene. Overall mortality was 89%. 74% died at the scene with 26% surviving to the hospital. Of those reaching the hospital alive, mortality was 58%. Of those patients that survived to leave the trauma bay, in-hospital mortality was 31.3%.

Figure 4. Temporal analysis of GSWH. GSWH tend to be more common during the night (64.3%), especially 6 PM - 6 AM (41.1%), and Sunday (28%).

Figure 5. Differences in patient populations stratified by presenting location.

A) Hospital patients were significantly younger than those at the ME, which possessed more of a bimodal age distribution. **B)** Caucasian patients were more likely to be victims of suicide (86.5%) while Black patients were more likely to be victims of assault (72.9%; $p<0.0001$).

Figure 6. Comparison of toxicology profiles between homicide and suicide victims.

Of those presenting to the ME, victims of homicide were more commonly positive for street drugs (cocaine $p=0.0011$, amphetamines $p=0.0237$, cannabinoids $p=0.0360$). Opiates ($p=0.0065$) and benzodiazepines ($p<0.0001$) were more common in victims of suicide.

Figure 7. Rates of diagnosed mental illness.

Comparison of the mental illness prevalence reveals higher rates in GSWH victims than the overall US population [1]. Depression is significantly more common in suicide than homicide victims (38.0%, 2.9%, $p<0.0001$).

Figure 8. Geographic association of injury location and socioeconomic status.

A,B. In the hospital cohort, the number of injuries in a given zip code was significantly correlated with the % of the population living below the poverty line. Zip of residence was also significantly correlated ($p=0.0014$, R square=0.7395). **C,D.** In the ME cohort, the number of injuries in a given zip code was not significantly correlated with the % of the population living below the poverty line. (Heat maps and regression analysis include only the top ten zip codes. Poverty percentages based on 2010 Census and threshold of $10,830 in annual income per one person families[19].)

Statements & Declarations

Declarations:

The authors have no relevant financial or non-financial interests to disclose. There are no conflicts of interest.

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Conflicts of Interest:

The following authors have no financial disclosures or personal conflicts of interest: NS, DM, VA, SS, EL, JJ, RB, AR.

Consent for publication

All patient data included in this retrospective study has been deidentified. All use of patient data in this study has been approved by the University of Miami IRB.

Data Availability:

All data represented in this study is available on reasonable request via contact of the corresponding author.

Authorship Contribution:

All authors contributed to the study conception and design. Material, preparation, data collection, and analysis were performed by Nathan Schoen, David Matichak, Dr. Valeria Armstrong, and Dr. Shaina Sedighim. The first draft of the manuscript was written by Nathan Schoen; David Matichak, Dr. Armstrong, Dr. Sedighim, Dr. Lew, and Dr. Jagid edited and contributed to the second draft of the manuscript. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Ethics Approval:

This is a retrospective study. All retrospective human participant data has been deidentified and approved under the IRB, no ethical approval was deemed necessary.

Running Title: Cranial Gun Shot Wounds: A Geo-Spatial and Public Health Burden Analysis

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Table 1. Demographic characteristics of patients at presentation.

	Total, n (%)	Ryder Trauma, n (%)	Medical Examiner, n (%)	p-value
Age (mean ± SD)	41.9 ± 20.6	31.4 ± 17	45.6 ± 20.5	p<.0001
Gender				
Male	347 (86.3)	96 (91.4)	251 (84.5)	
Female	54 (13.4)	9 (8.6)	45 (15.2)	
Race/Ethnicity				p<.0001
African American	165 (41.0)	67 (63.8)	98 (33.0)	
Caucasian	204 (50.7)	31 (29.5)	173 (58.2)	
Hispanic	84 (20.9)	22 (21.0)	62 (20.9)	
Other	7 (1.7)	4 (3.8)	3 (1.0)	
Injury Etiology				p<.0001
Suicide	192 (47.8)	14 (13.3)	178 (60.0)	
Homicide/Assault	191 (47.5)	72 (68.6)	119 (40.1)	
Accident	9 (2.2)	9 (8.6)	0 (0.0)	
# GSW				p=.0049
Single	275 (68.4)	60 (14.9)	215 (53.5)	
Multiple	127 (31.6)	45 (11.2)	82 (20.4)	

*GSWH victims were predominantly male (86.3%), with an average age of 41.9 (std dev=20.6), Caucasian (50.7%), victims of both homicide and suicide (47% each), and by single GSW (68.4%). Younger, Black patients were more likely to be victims of assault, while older age was significantly associated with suicide (47.8%; p<0.0001).

Table 2. Associations between injury etiology and location.

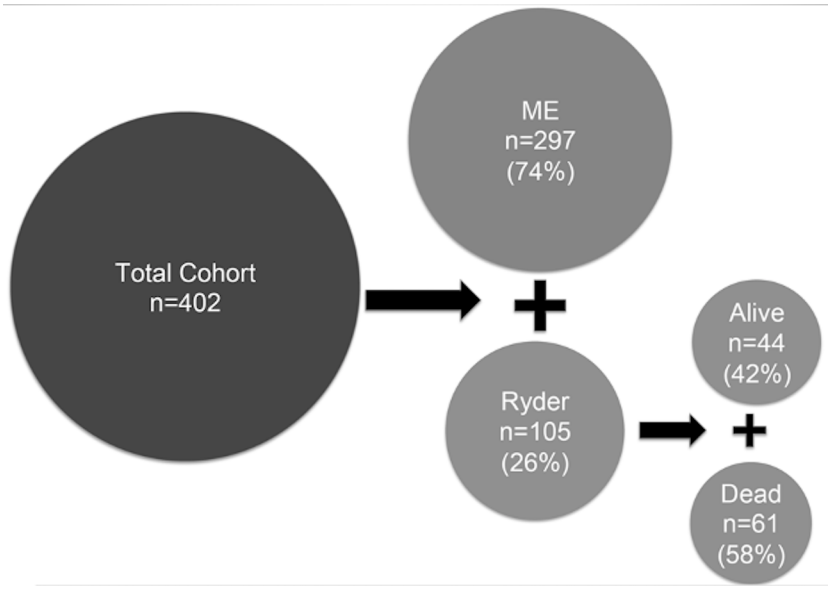
HOMICIDE			SUICIDE		
Residence: p=.0101			**Residence: p=0.3595**		
Zip	GSWH	% Poverty	Zip	GSWH	% Poverty
33147	21	54.27	33147	7	54.27
33127	17	52.4	33162	5	26.82
33150	8	45.97	33169	5	23.66
33142	12	45.42	33012	8	19.92
33054	12	40.2	33144	7	16.14
33161	6	34	33143	5	15.05
33168	5	33.08	33165	6	14.12
33162	6	26.82	33183	6	13.35
33056	14	25.61	33176	5	11.71
33157	5	20.19	33186	5	9.82
Injury: p=.0050			**Injury: p=0.5768**		
Zip	GSWH	% Poverty	Zip	GSWH	% Poverty
33147	25	54.27	33147	5	54.27
33127	13	52.4	33142	5	45.42
33150	14	45.97	33162	7	26.82
33142	13	45.42	33012	12	19.92
33054	12	40.2	33144	8	16.14
33161	5	34	33143	5	15.05
33125	5	32.27	33165	6	14.12
33162	5	26.82	33183	6	13.35
33056	13	25.61	33155	5	11.08
33016	5	20.76	33186	6	9.82

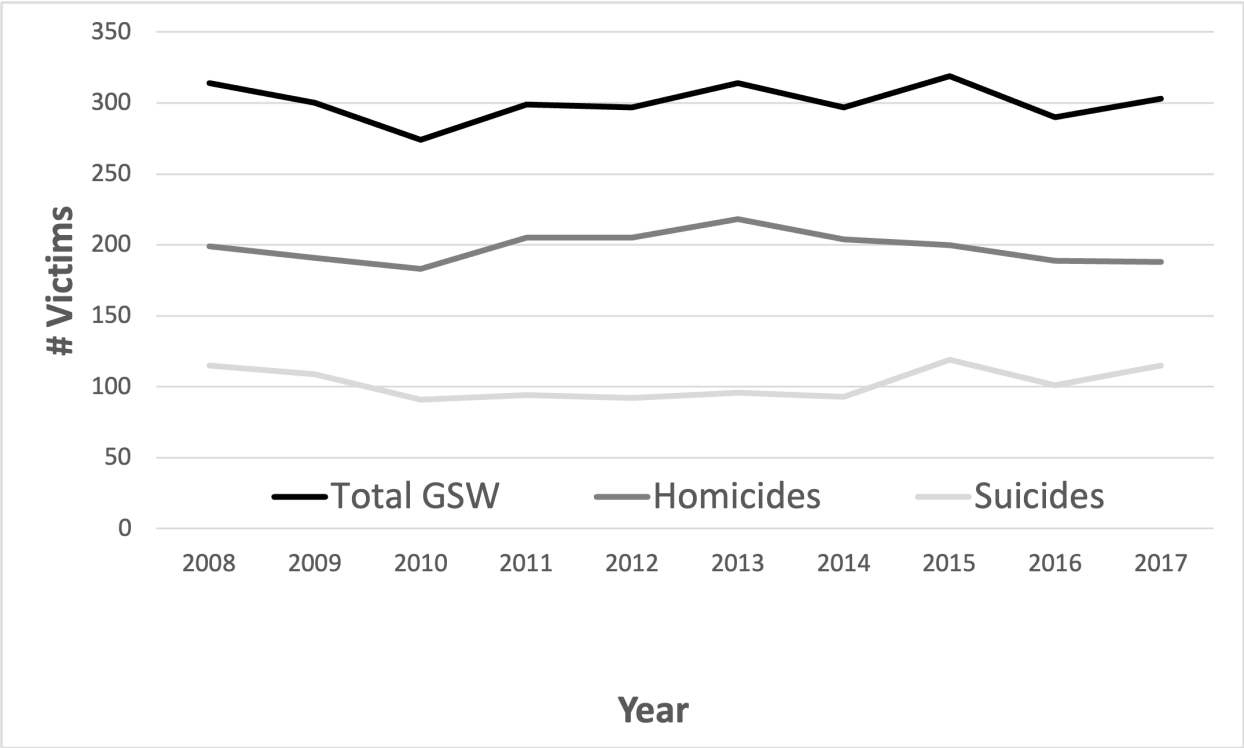
* Stratifying by injury etiology (homicide vs. suicide) yields significant associations between the homicide cohort and both residence (p=0.0101, r^2=0.5392) and injury (p=0.0050, r^2=0.6027) locations. This was not found to be true with the suicide cohort in regard to residence (p=0.3595, r^2=0.0939) or injury (p=0.5768, r^2=0.0406) locations.

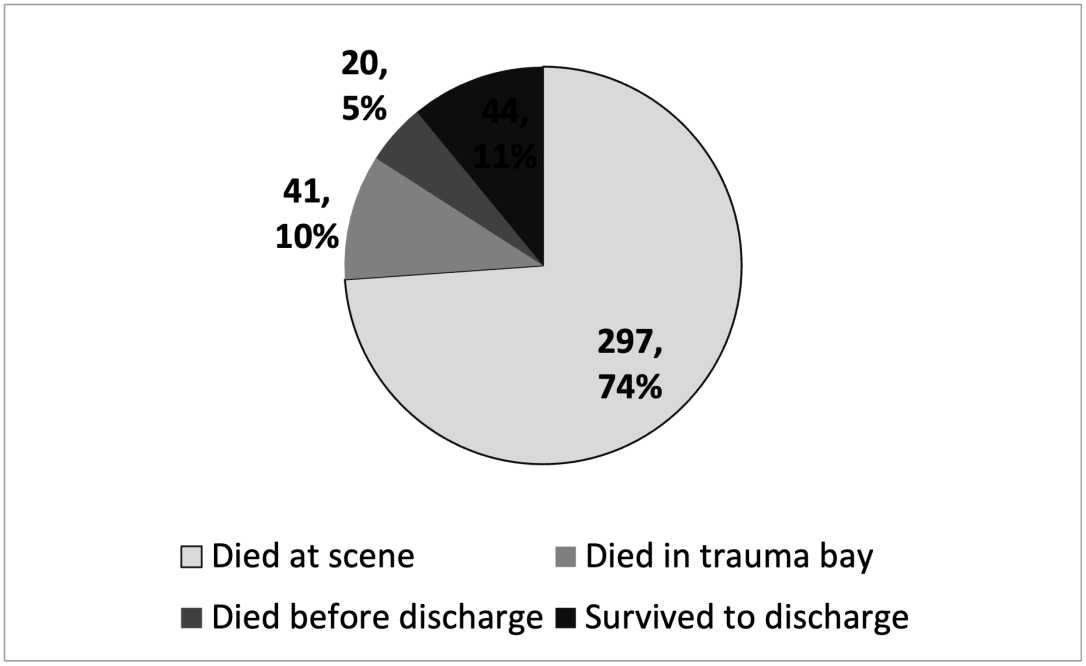
Table 3. Socioeconomic costs of GSWH.

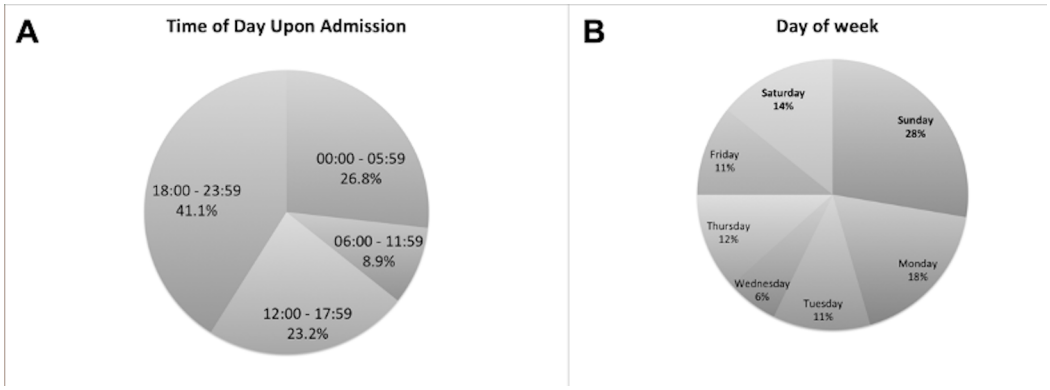
A) n	B) Lost Years	C) Lost Income	D) Adjusted Discount	Total Income Lost Over Lifetime
ME (n=297)	32	34K	3%	202,258,188
Hospital (n=71)	47	24.4K	3%	43,921,310
				$246,179,498

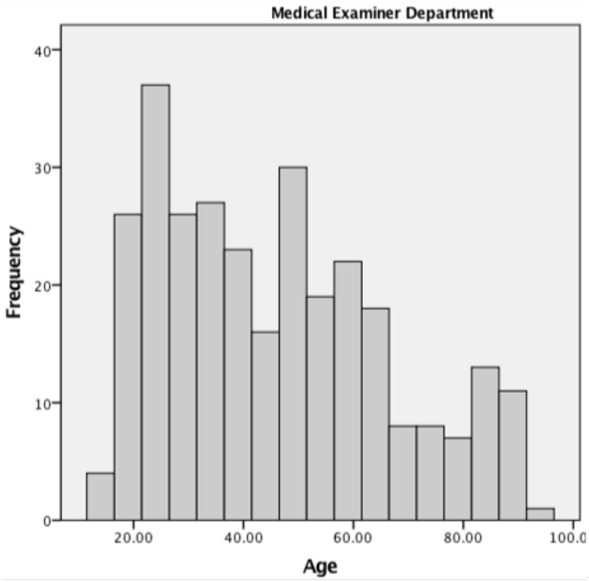
* Socioeconomic costs of GSWH. Total income lost in overall cohort determined to be $1,303,821. Calculations are based on averages of published hospital expenses and socioeconomic census data with an adjusted income discount of 3% per year.[15-17] (K = $1,000, ME = Medical Examiner department)

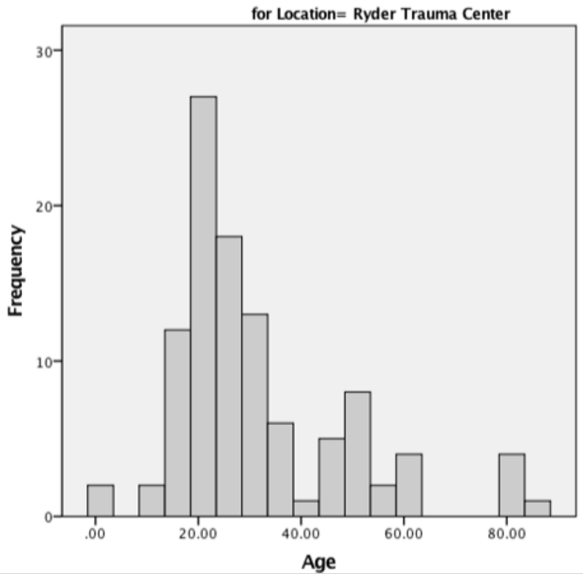

Total Cohort
n=402
ME
n=297
(74%)
Ryder
n=105
(26%)
Alive
n=44
(42%)
Dead
n=61
(58%)

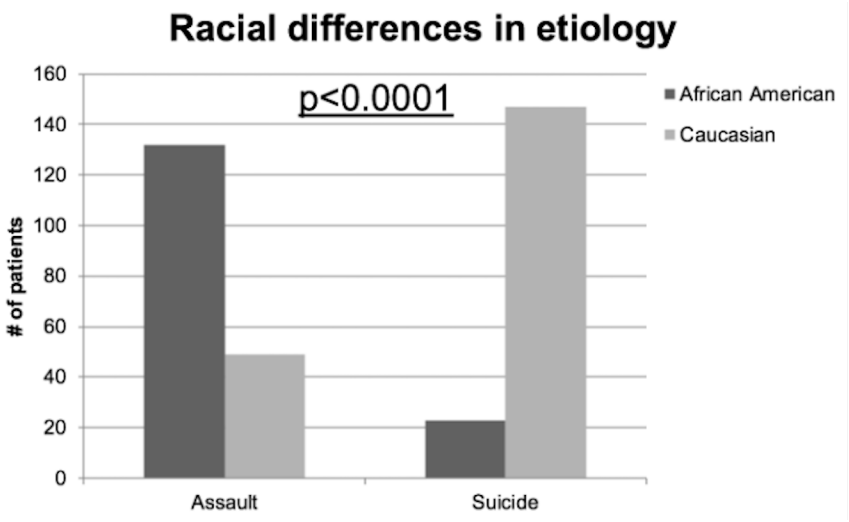

350
300
250
200
150
100
50
0
Victims
Total GSW
Homicides
Suicides
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Year

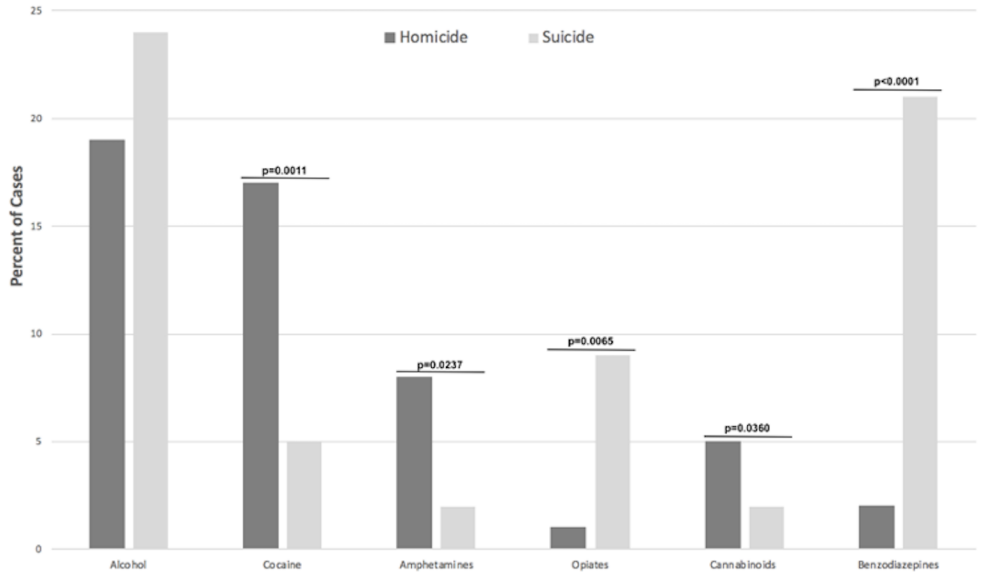

20,
5%
44,
11%
41,
10%
297,
74%
Died at scene
Died in trauma bay
Died before discharge
Survived to discharge

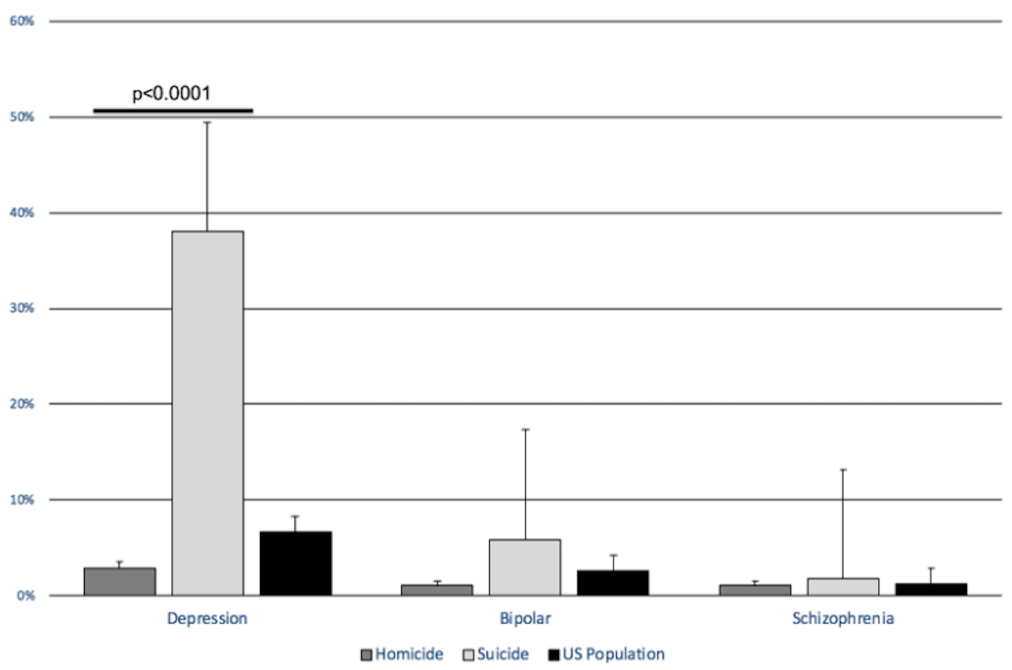

A
Time of Day Upon Admission
00:00 - 05:59
26.8%
06:00 - 11:59
8.9%
12:00 - 17:59
23.2%
18:00 - 23:59
41.1%
B
Day of week
Sunday
28%
Monday
18%
Tuesday
11%
Wednesday
6%
Thursday
12%
Friday
11%
Saturday
14%

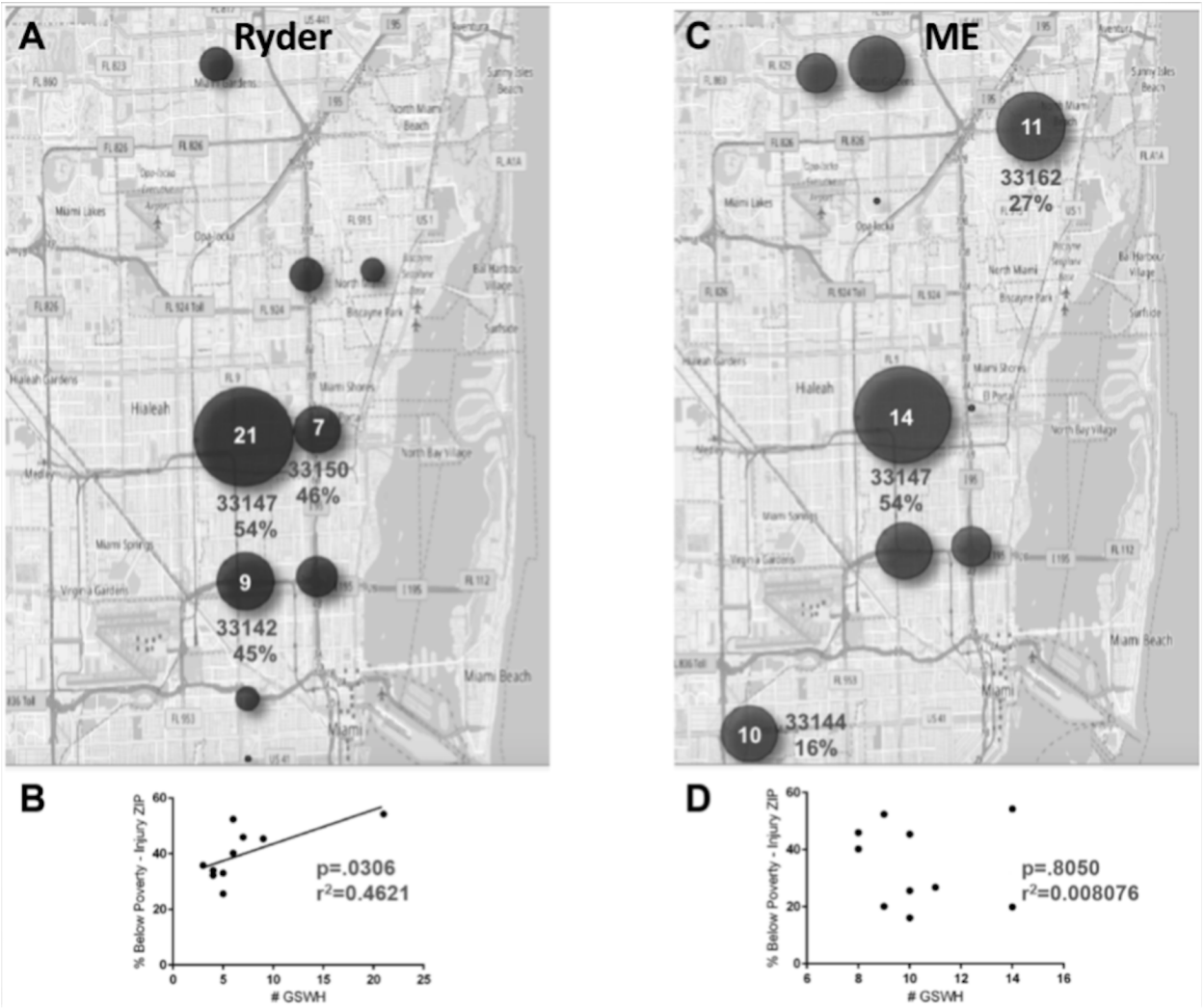

Medical Examiner Department
Frequency
Age
0
10
20
30
40
20.00
40.00
60.00
80.00
100.0


for Location= Ryder Trauma Center
Frequency
Age
0
10
20
30
.00
20.00
40.00
60.00
80.00


Racial differences in etiology
p<0.0001
African American
Caucasian
# of patients
160
140
120
100
80
60
40
20
0
Assault
Suicide


Homicide
Suicide
Percent of Cases
25
20
15
10
5
0
p=0.0011
p=0.0237
p=0.0065
p=0.0360
p<0.0001
Alcohol
Cocaine
Amphetamines
Opiates
Cannabinoids
Benzodiazepines


60%
50%
40%
30%
20%
10%
0%
p<0.0001
Depression
Bipolar
Schizophrenia
Homicide
Suicide
US Population


A
Ryder
21
7
33150
46%
33147
54%
9
33142
45%
Hialeah
Miami Lakes
Opa-locka
Miami Springs
Virginia Gardens
Hialeah Gardens
Miami Shores
North Miami
Biscayne Park
Bal Harbour Village
Surfside
North Bay Village
Miami Beach
Miami
C
ME
11
33162
27%
14
33147
54%
10
33144
16%
Hialeah
Miami Lakes
Opa-locka
North Miami
Biscayne Park
Miami Shores
Miami Springs
Virginia Gardens
Miami Beach
Miami

B
% Below Poverty - Injury ZIP
# GSWH
p=.0306
r²=0.4621
0
20
40
60
0
5
10
15
20
25

D
% Below Poverty - Injury ZIP
# GSWH
p=.8050
r²=0.008076
0
20
40
60
6
8
10
12
14
16

Abbreviations

GSW – Gun shot wound

GSWH – Gun shot wounds to the head

ICU – Intensive care unit

MDC – Miami-Dade County

ME – Medical Examiner

SES – Socioeconomic status

TBI – Traumatic brain injury

Competing Interests

The authors have no relevant financial or non-financial interests to disclose. There are no conflicts of interest.

Author Contributions

All authors contributed to the study conception and design. Material, preparation, data collection, and analysis were performed by Dr. Nathan Schoen, David Matichak, Dr. Valerie Armstrong, and Dr. Shaina Sedighim. The first draft of the manuscript was written by Dr. Schoen and Dr. Richardson; David Matichak, Dr. Armstrong, Dr. Sedighim, Dr. Lew, Dr. Jagid, and Dr. Bullock edited and contributed to the second draft of the manuscript. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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