Perpetration of Interpersonal Violence, Incarceration, and Subsequent Risk for Firearm Suicide

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Abstract

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Suicide is a major public health concern in the United States. The recent growth in the burden of suicide has disproportionately impacted marginalized communities and those of lower socioeconomic status. This dissertation uses administrative data across public health and public safety sectors to assess whether individuals have a heightened risk of suicide after release from custody of a state prison with a goal of highlighting opportunities for intervention and prevention within vulnerable populations. This research primarily focuses on suicide by firearm as these make up the majority of suicide deaths in the United States and can be influenced by unique policy interventions not applicable to other mechanisms of suicide. Furthermore, this dissertation seeks to reduce the burden on public health practitioners as they investigate specific events preceding suicide. These aims are addressed through the construction of a cohort of Washington State prison inmates from 1990 through 2017 linked to death certificates, as well as the application of machine learning techniques to medical examiner investigation narratives.

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CHAPTER 1: BACKGROUND AND SIGNIFICANCE

1.1 EPIDEMIOLOGY OF SUICIDE

In 2017, there were 47,173 suicide deaths in the United States making it the 10th leading cause of death.[1] A recent report from the Centers for Disease Control and Prevention (CDC) notes that this large burden of suicide is the most recent data point in a two-decade long trend in increasing suicide rates.[2] Another CDC report additionally commented that rates of suicide are increasing faster in rural than urban areas.[3] This geographic discrepancy in suicide rates is potentially explained by differences in firearm ownership. Several ecologic studies at different levels of geographic aggregation have found a strong relationship between firearm ownership and suicide rates.[4–6] Studies at the individual-level have found that firearm ownership is associated with an increased risk in suicide for all members of the household.[7,8] This is likely because the case-fatality of suicide attempts with a firearm surpasses that of all other suicide means.[9,10]

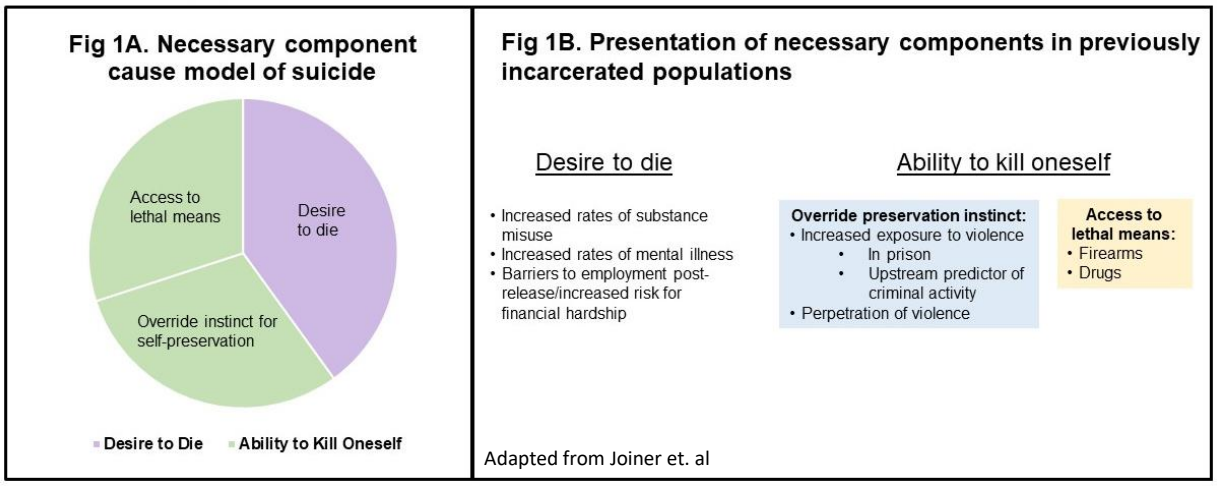
Though differences in suicidality cannot explain differences in suicide rates among individuals who do and do not live in firearm owning households,[11,12] depression, substance misuse, and financial or relationship instability, among other mental illnesses and life circumstances, have an impact on suicide risk. A proposed interpersonal theory of suicide states that loneliness and a sense of being burdensome are necessary for an individual to experience the desire to die.[13] This desire to die can be somewhat fleeting; studies among suicide attempt survivors indicate that many spent fewer than ten minutes considering the decision to take their own lives.[14] The impulsive nature of many instances of suicide ideation and attempts is one reason that lethal means restriction has large potential as a path to suicide prevention. Preventing an individual who is experiencing suicidal thoughts from accessing particularly lethal means, such as a firearm, will reduce their risk of dying by suicide.[15]

1.2 Interpersonal Violence and Suicide

The interpersonal theory of suicide proposes that not only does an individual need to possess the desire to die, they must also be capable of killing themselves in order to die by suicide.[13] I propose that the construct of capability of suicide can be further broken down into two components: 1) an ability to override the instinct for self-preservation—as proposed by Thomas Joiner[13]—and 2) access to lethal means—as described above; this model is depicted in Figure 1A. Perpetration of violence, especially perpetration of violence resulting in felony charges, indicate that an individual has the capability of engaging in outward directed violence in some capacity; this may also be indicative of one's ability to engage in self-directed harm.[16,17]

Suicide and interpersonal violence share several risk-factors; two of these shared upstream components are impulsivity and exposure to violence. As previously mentioned, suicidal ideation tends to be fleeting;[14] similarly, impulsive behavior is frequently associated with violent behavior.[18,19] Impulsivity likely fuels suicidal and violent behavior in that individuals react to a given set of circumstances without considering all potential solutions or long-term consequences.[20] In addition to impulsivity, prior exposure to violence is also a known risk-factor for both self-directed and outward-directed violence. Several studies have explored the relationship between violence exposure or childhood maltreatment and subsequent risk for suicide.[21,22] Similarly, people experiencing childhood maltreatment—including physical, sexual, and verbal abuse—were more likely to be perpetrators of interpersonal violence and violent crime.[22,23]

Figure 1. Necessary components for suicide and their presentation in previously incarcerated populations



Maltreatment at the individual level is not the only way that exposure to violence also increases risk of future self-directed and interpersonal violence; individual residing in violent neighborhoods during adolescence may be more likely to engage in suicidal behavior or violent offences.[24] In addition to exposure during childhood and adolescence, individuals who are incarcerated as a result of violence perpetration are at risk for violence victimization while in custody; fighting, rape, and other forms of violence occur frequently within prisons that correctional facilities are piloting new programs to reduce the incidence of such events; approximately 15% of inmates in state prisons have been injured in a fight since their admission.[25] Given the overlap in precipitating factors for violence and suicide, it is not surprising that individuals with a history of violence may be more likely to engage in self-harming behavior.[16,17]

Perpetration and victimization also feed to the ability to kill oneself and the override of the instinct of self-preservation. It is theorized that through habituation,[26] people can become desensitized to violence over time.[27] Studies of suicidality and suicidal behaviors have found that individuals who were subjected to physical forms of abuse as children (i.e. traditional violence and sexual abuse) were more likely to engage in self-harming behaviors compared to peers that had

experienced verbal or emotional abuse.[27,28] Joiner refers to this as the acquired capacity for violence. The presentation of the components of the interpersonal theory of suicide may exhibit themselves uniquely in previously incarcerated populations; the summary of these presentations can be found in Figure 1B.

1.3 Health of Incarcerated Populations

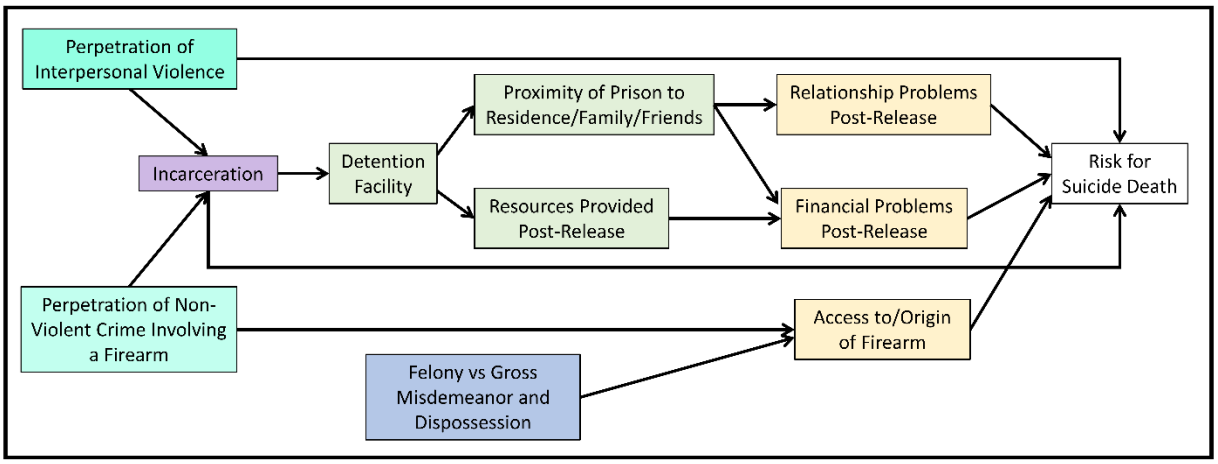
Rates of incarceration have grown substantially in the United States over the past five decades,[29] therefore expanding the size of vulnerable populations. These incarceration rates have not been equally distributed; young men of color and those whose families are economically disadvantaged face a disproportionate burden of imprisonment.[30] Identifying consequences of incarceration and implementing structural policies towards prevention stand as one way to reduce inequities in health outcomes. The impact of imprisonment on health is apparent in both short-term and long-term studies.[31,32] Previous work has identified increased rates of all-cause mortality among previously incarcerated individuals, especially in the period immediately following release from prison.[33–35] The increase in mortality immediately post-release can be attributed to a number of causes; suicide has been observed to be one of the specific causes for which the risk of death increases immediately post-release.[33–35] Increases in suicide rates after incarceration and racial disparity in incarceration rates may partially contribute to the observed discrepancies in peak suicide risk over the life course; non-Hispanic white men are most likely to die by suicide between 45–54 years of age or over the age of 75, while suicide rates are highest between the ages of 25–34 among non-Hispanic Black men—a population that is disproportionately over represented in prisons.[1]

One contributing factor to the increase in suicide after incarceration may be the disparity in mental illness and substance use histories among individuals who are incarcerated compared to the larger population. In a report from the Bureau of Justice Statistics, 56% of individuals incarcerated in a state prison had some history of a mental health issue; among these individuals, 74% met the

criteria for substance dependence or abuse.[25] Nearly 70% had at least one major depressive symptom and 24% reported five or more.[25] These known risk-factors for suicide might be addressed while individuals are incarcerated, however services can vary across correctional facilities. In Washington State, the handbook provided to inmates at intake emphasizes the availability of 12-step programs and similar group-based counseling.[36] The policy regarding mental health services places an emphasis on services that are "medically necessary" or "support correctional objectives," though it is not explicitly stated which treatments constitute medical necessity.[37] Many prior studies have found that diverting offenders to mental health treatment instead of prison is effective at reducing recidivism.[38–40] These same diversion programs offer pathways for reducing the burden of suicide among offenders.

While these mental health programs are effective, the type and quantity of resources available to individuals during incarceration and during transition to community vary greatly. These differences potentially change the health outcomes for incarcerated persons post-release. In Washington State, the resources offered by the Department of Corrections include different levels of mental healthcare, different forms of substance use treatment, and educational opportunities such as vocational training among other resources.[41] The availability of these resources, in addition to the geographic feasibility for an incarcerated individual to spend time with loved ones, are influenced by the specific facility at which an individual is held. A schematic detailing the ways in which history of interpersonal violence and incarceration may influence suicide risk is in Figure 2.

Figure 2. Conceptual model of suicide risk among previously incarcerated populations



Blue-Green: Ability to Kill Oneself | Purple: Potential Mediator | Green: Effect Modifiers
Yellow: Construct Posing Direct Suicide Risk

1.4 Risk-Based Firearm Policy

As firearms are the means in half of suicides in the United States, laws regarding acquisition, possession, and surrender of firearms have influences on suicide risk.[42,43] Nationwide, The Gun Control Act of 1968 prohibits individuals from possessing firearms if they are convicted of a felony, fugitives from justice, drug users, found to be legally incompetent or are committed to mental institutions, undocumented immigrants, dishonorably discharged from the military, have renounced U.S. citizenship, have a restraining order related to domestic violence, or have been convicted of a misdemeanor of domestic violence.[44] In 1994, additional federal legislation was passed requiring federal background checks on firearm purchasers in the United States and imposing five-day waiting periods on purchases.[45] Despite these regulations, there are still gaps for high-risk individuals. One example is the so-called "boyfriend loophole." The federal definition of domestic violence is limited only to violence perpetrated against a spouse, former spouse, or an individual with whom the perpetrator shares a child; however, dating partners, including those who cohabitate, other family members, and stalkers who do not meet the definition of a domestic partner may still legally have access to a firearm.[46]

While these gaps exist in national laws, some states, including Washington, have additional statutes that create restrictions above and beyond those in federal law. The definitions of domestic violence have been expanded in the state to include other types of dating and familial relationships.[47] In 2014, voters in Washington passed an initiative requiring background checks through federally licensed firearm dealers for private sales of firearms.[48] Additionally, prior to returning a confiscated firearm, law enforcement must run a background check.[49] In 2016, an Extreme Risk Protection Order (ERPO) law was passed by ballot initiative in Washington—one of several states to begin implementing "red flag" laws. The Washington ERPO allows household or family members as well as law enforcement officer to petition for the temporary removal of a firearm from someone they fear may be a danger to themselves or others.[50] These laws are particularly relevant as mechanisms by which suicide deaths could be potentially prevented among previously incarcerated individuals.

1.5 Specific Aims

We seek to quantify the relationship between perpetration of crime resulting in prison incarceration and subsequent firearm suicide over the course of several decades in Washington State, with specific attention to violent crime. We propose to determine if this risk varies by age at first release from custody. Additionally, we intend to characterize the circumstances that immediately precede firearm suicides by individuals previously charged with a violent crime, including suicide risk factors such as financial hardship, problems in interpersonal relationships, and concerns about the legal system in general as well as the source of the firearm used in the suicide.

Aim 1: To compare the risk of firearm suicide among previously incarcerated individuals after release from the custody of a state prison with that of the age, sex, and race-matched population of Washington State.

Aim 1.1: To evaluate if this relationship differs by whether the crime committed was violent and, among non-violent offenders, whether the crime was firearm or substance related.

Approach: Cohort study linking Washington State Department of Corrections prison data and Washington State Department of Health vital statistics.

Impact: Findings of this investigation can inform policy on firearm ownership and prohibition after conviction for a crime and enhance service providers (e.g., case workers') awareness of firearm-suicide risk among their clients as they transition back to the community after incarceration.

Aim 2: To develop and evaluate natural language processing algorithms capable of identifying suicide risk factors in Medical Examiner narratives.

Aim 2.1: To explore whether situational factors preceding a firearm suicide vary based on a decedent's criminal and incarceration history.

Approach: Development of random forest classifier natural language processing algorithms to identify suicide risk factors within King County Medical Examiner data. Algorithms will be applied to Medical Examiner narratives to better define circumstances precipitating the suicide death.

Impact: Findings of this investigation can inform service providers (e.g., case workers') awareness of firearm-suicide specific factors that may influence the risk for suicide among their clients as they transition back to the community after incarceration.

1.6 Relevance and Impact

Previously incarcerated individuals make up a particularly vulnerable population. Their criminal record impacts their ability to find work and access healthcare resources. [51] Time spent in custody is time not spent with family and friends, building financial stability, or seeking comprehensive care for other mental health or substance use concerns. Many individuals who are incarcerated were disadvantaged in at least one of these ways prior to custody so these additional consequences of

incarceration itself are compounded with community, health, or fiscal hardships that they previously faced. Determining if suicide rates are higher among previously incarcerated individuals and if so, which incarcerated individuals are most at risk will help identify programs that could be implemented to reduce the burden of suicide. The findings from this study can have impacts on firearm possession policy, resources provided in prisons and during transition to the community, as well as providing an in-depth exploration of the intersection of interpersonal violence and self-directed violence.

CHAPTER 2: PERPETRATION OF INTERPERSONAL VIOLENCE, INCARCERATION, AND RISK FOR FIREARM SUICIDE

2.1 BACKGROUND

Rates of suicide have climbed across the U.S. over the past several years.[2] Individuals of lower socio-economic status have carried a larger burden of these increases,[52–54] as have Black youth.[55,56] Impoverished individuals and communities of color are disproportionately policed and are over represented in the criminal-legal system and prisons.[30] It is plausible that recent increases in incarceration rates and a growing burden of suicide are related.

Formerly incarcerated individuals are a particularly vulnerable population; short-term and long-term health impacts of imprisonment have been previously observed.[31,32] Rate of all-cause mortality is 3.5 times higher among previously incarcerated individuals than the general population, especially in the two weeks immediately following release from prison.[33–35] While attributable to a number of causes, the increase in risk of death after release is partially attributable to suicide.[33–35] Incarceration and racial inequities in the criminal-legal system are perhaps somewhat responsible for the discrepancies in peak suicide risk over the life course; non-Hispanic white men are most likely to die by suicide between 45–54 years of age or over the age of 75, while suicide rates are highest between the ages of 25–34 among non-Hispanic Black men.[1]

Prior research focused on post-incarceration suicide risk has been focused largely on populations in Scandinavia and Australia.[57–60] While this research is informative, it may not be entirely applicable to the U.S. context due to differences in carceral systems, healthcare access, and the availability of firearms. Studies at the individual-level have found that firearm ownership is associated with an increased risk in suicide for all members of the household,[7,8] This is likely—in part—because the case-fatality of suicide attempts with a firearm surpasses that of all other suicide means.[9,10] While national and state laws restrict firearm purchases among those with a criminal

history, some crimes are themselves indicative of extralegal firearm possession. This makes the risk of suicide and firearm-specific suicide among former inmates of public health interest.

We sought to provide a contemporary assessment of suicide risk following incarceration in the U.S. context. By combining records from the Washington State Department of Corrections (DOC) and death certificates from the Washington State Department of Health (DOH), we were able to follow former inmates as they experienced additional incarcerations in the state or until they died. Our primary aim was to determine if former inmates were at a higher risk for suicide by any means and suicide by firearm specifically compared to Washingtonians at large. We also sought to assess if the impact of incarceration on suicide risk was modified by demographic characteristics. Among those with a history of incarceration, we sought to compare survival by age at first incarceration and type of crime committed, as these factors can indicate access to lethal means and may inform future intervention strategies.

2.2 METHODS

The main analytic cohort was derived from DOC records linked to death certificates from DOH. Death certificates were available from January 1, 1983–December 31, 2017 and incarceration records were available beginning January 1, 1985 through the end of the same period as the death certificates. Death certificates included identifying information about the individual, as well as causes and date of death. These are recorded by medical examiners and coroners around the state, and ultimately filed with state vital statistics. The DOC records are maintained for administrative purposes and included files about: each unique individual ever incarcerated in Washington State prisons; details on the dates of admittance and release for each of their incarcerations; and the convictions that led to each incarceration. One variable of interest in our analysis was the total number of incarcerations an individual experienced. To best establish a baseline count of the number of incarcerations, we excluded all incarceration and death records prior to 1990 and excluded any

individuals with an incarceration prior to 1990 from the remaining records (Figure 2.1). We additionally excluded individuals who had a single admission to prison, but no releases as they were assumed to still be in custody. This left total of 140,281 unique individuals with records available for linkage and analysis.

2.2.1 Linkage

Using first, last, and middle names, in addition to sex, date of birth, and social security number, linkages were completed in LinkKing, which is a SAS plugin designed by public health professionals for deterministic and probabilistic record linkage.[61] We used deterministic and probabilistic linkages to maximize the number of matches. We first blocked our data on sex and initials—blocking is a process by which deterministic matches are made based on a subset of variables to minimize the number of pairwise comparisons that are made later in the linkage process and reduce the computational power required for matching. After this, software calculates the deterministic power of all names; common names are down weighted because they have limited power to discriminate between individuals, while rare names can provide more insight. In the final step, weighted comparisons are made with date of birth and social security number in addition to Soundex comparisons of names. This gives more weight to items that are more similar to one another. The incorporation of Soundex comparisons also considers common nicknames and phonetic similarities. After applying a combination of probabilistic and deterministic methods, we manually reviewed 100 records from each certainty level as assigned by LinkKing. For categories with a positive predictive value greater than 90%, all records were accepted as matches. For the category with a positive predictive value less than 20%, all predicted matches were rejected (approximately 9.5% of all matches estimated by the software). The remaining records were manually reviewed. This resulted in a total of 7041 record pairs between death certificates and identification numbers within the Department of Corrections.

2.2.2 Exposure

Our primary exposure was any incarceration in a Washington State prison. An indicator was generated for substance-related crimes (e.g., possession or distribution of controlled substances, driving under the influence), violent crimes (i.e. murder, robbery, rape, and assault as defined by the Federal Bureau of Investigation)[62], and non-violent crimes involving a firearm (e.g. illegal possession, transfer to illegal possessor). These indicators were generated in such a way that individuals could simultaneously have flags for multiple crime types. We additionally included a measure of the total number of prior incarcerations in a Washington prison (1, 2, or 3+). These metrics were time-varying, such that a substance related indicator could be present after a first incarceration, while an indicator for violent crime may not be included until a subsequent arrest and release. A time-invariant measure of an individual's age at their first release was also calculated (<18, 18–24, 25–34, 35–64, 65+). We considered incorporating measures of the duration of incarceration, however, prior research suggests this has little bearing on an individual's risk for suicide.[57,60] Of additional interest was the use of restrictive house/solitary confinement, however, these data were not available in the DOC provided data set.

2.2.3 Outcome and Covariates

Our primary outcome was firearm suicide. The secondary outcome was for suicide by any means. Washington DOH provided ICD-10 codes for all deaths, including those that occurred before the United States officially transitioned to ICD-10 in 1999. For this reason, we were able to use these codes across the entire study period. Preliminary models included covariate terms for calendar time in three-year periods beginning in 1990. In fully adjusted models, we additionally included time-varying measures of age (15-19, 20-24, 25-34, 35-44, 45-54, 55-64, 65-74, 75+), as well as indicators of sex, and race (non-Hispanic white compared to other racial/ethnic groups). For comparisons made using the internal cohort (i.e. other formerly incarcerated individuals), we additionally included all

prison-related exposures of interest including number of prior incarcerations, age at first release, and the types of crimes of which that individual had been convicted of prior to that release. While history of substance use and mental illness as well as marital status were of interest, these details were not available within the DOC records provided.

2.2.4 Statistical Analysis

The number of death events occurring statewide in each three-year window was captured from the CDC WONDER portal.[1] This also allowed us to calculate person-time at risk for the general state population in sex-, age-, and race-specific strata. Among individuals with at least one prison incarceration, we calculated person-time data based on time between release from prison and death or a subsequent admission. If an individual was readmitted to prison, they were censored, but upon an additional release they could continue to contribute person time (Figure 2.2). This follow-up time was binned in three-year periods to allow us to adjust for temporal changes in suicide rates over the past several decades. Poisson regression was used to compare the rate of suicide death among those with a history of incarceration to the incidence of suicide in the entire State of Washington. We repeated these analyses for the subset of individuals belonging to each sex, age, and race category to assess the possibility of effect measure modification by any of these demographic characteristics.

Among persons with at least one incarceration, we also used Cox proportional hazards regression to estimate the hazard ratio of suicide and firearm specific suicide as a function of demographic characteristics and characteristics of their prior incarcerations. Individuals were categorized by age, sex, race/ethnicity (non-Hispanic White, American Indian/Alaska Native, Asia, Black, Hispanic, and other/not classified), number of prior incarcerations, and whether the individual had ever been incarcerated for a substance related crime (yes/no), a non-violent firearm involved crime (yes/no), or a violent crime (yes/no). Cox models assume proportional hazards for all groups for the duration of follow-up. This means that while the rate of failure event does not need to remain

constant for the duration of follow-up, there should be no relative change in the failure rate between treatment groups for the study period. These assumptions were visually assessed by crime type for risk of suicide by any means (Figure 2.3) and suicide by firearm (Figure 2.4). While the models make this assumption, it is noted that this is rarely met within the medical literature—this is seen in our data where the hazard is initially much higher in some groups, but the divergence dissipates over time. For this reason, hazards ratios should be interpreted with caution and the results of Poisson models should also be used to aid in interpretation.[63] Because individuals with a history of incarceration are at a higher risk of all-cause mortality,[33] we additionally included Fine and Gray competing risk specifications.[64] This specification ensures that deaths attributable to other causes are not given the same weight as censoring events, which may lead to incorrect assessments about the hazard of experiencing our failure events of interest.

Analyses were done in R version 3.6.2 (Copyright © 2019 The R Foundation for Statistical Computing) and Stata version 16.1 (Copyright © 2019 StataCorp LLC). The University of Washington and Washington State Institutional Review Boards approved this study.

2.3 Results

Over the course of the study period (1990–2017), there were 140,281 unique individuals released from prison in Washington State and eligible for analysis (Table 2.1). These individuals were predominantly male (82.83%). Compared to the overall Washington population in 2010—the most recent census measurement—individuals with an incarceration were disproportionately Black (14.94% vs 3.70%) or Hispanic (14.46% vs 8.87%). Incarcerated individuals tended to be younger than the general population, though 15–17-year-olds were not frequently incarcerated or subsequently released from adult prisons. Individuals with a prison incarceration were most likely to have committed a violent crime followed by substance involved crimes. Non-violent firearm crimes were perpetrated by the fewest number of individuals.

2.3.1 Suicide Risk Compared to Washington State

Among all incarcerated individuals, 484 died by suicide of whom 111 used a firearm. Among Washingtonians during this time, the rate of suicide was 17.2 per 100,000 person-years and the risk of firearm suicide was 9.0 per 100,000 person-years (Table 2.2). Risk of suicide by any means among individuals with a prior incarceration was 1.62 times that of the general population, after adjusting for calendar time, age, sex, and race/ethnicity (95% CI: 1.46–1.79). This risk was especially pronounced among individuals who were incarcerated for a non-violent firearm crime (RR: 2.27; 95% CI: 1.79–2.89) or a violent crime (RR: 1.96; 95% CI: 1.70–2.26). The risk for dying by suicide increased with number of prior incarcerations; individuals with a single incarceration had a 42% increased risk of suicide, individuals with two incarcerations had a 67% increase in risk, and those with three or more incarcerations were at 113% higher risk of suicide compared to the general population of Washington State. Risk of firearm suicide tended to be lower among individuals with a history of incarceration compared to the general population. However, compared to the Washington population, the risk of suicide by firearm was higher among individuals incarcerated for a non-violent, firearm-involved crime (RR: 1.55; 95% CI: 1.01–2.37) and individuals who were released from prison for the first time prior to the age of 18 (RR: 15.98; 95% CI: 5.95–42.91).

2.3.2 Effect Modification of Suicide among Formerly Incarcerated Compared to Washington General Population

We found some evidence of effect measure modification by demographic characteristics on suicide by any means (Table 2.3) and firearm suicide (Table 2.4). The impact of incarceration on risk for suicide was especially pronounced among those under the age of 35; when restricting to firearm suicide, the association between incarceration and suicide was strongest among those under the age of 25. Compared to the general population, incarceration was more strongly associated with suicide among female Washingtonians (RR: 2.15; 95% CI: 1.56–2.95) which was especially high when they

had been incarcerated for a firearm involved crime (RR: 7.29; 95% CI: 2.72–19.54). Similarly, while most male Washingtonians with a history of incarceration were at decreased risk for firearm suicide compared to the general population, their female counterparts tended to have an increased rate of firearm suicide compared to the general population, though these estimates were not statistically significant. Association between incarceration and firearm suicide did not vary notably by race, though the risk of suicide by any means was higher among Non-Hispanic White individuals previously convicted of a violent crime than among their Non-White counterparts.

2.3.3 Suicide Risk Within Formerly Incarcerated Populations

Among those with a history of incarceration, some factors tended to be associated with higher risk for suicide (Table 2.5). Those having been charged with a non-violent firearm involved crime had 1.54-fold increased risk in suicide compared to other incarcerated individuals without the same history (95% CI: 1.16–2.04); the relationship was even stronger for risk of firearm suicide (HR: 2.23; 95% CI: 1.37–3.65). Incarceration for a violent crime was also associated with a 47% increase in the hazard for suicide (95% CI: 1.21–1.79) and 50% increase in the hazard for firearm suicide (95% CI: 1.01–2.22). Among incarcerated individuals, having a first release prior to the age of 18 was associated with the highest hazard of suicide (HR: 4.54; 95% CI: 1.67–12.33) and firearm suicide (HR: 11.79; 95% CI: 4.19–33.18) compared to individuals who were released from prison for the first time between ages 18 and 24. These estimates did not differ notably when analyses were conducted without the competing risk specification (Table 2.6).

2.4 DISCUSSION

We found that the risk of suicide is higher among individuals who have been previously incarcerated compared to the population of Washington State. Compared to the overall population of Washingtonians, the risk of firearm suicide was lower for former inmates unless the person had been convicted of a firearm involved crime. To our knowledge, this is the first population-based study of

firearm suicide among formerly incarcerated individuals in Washington State. This is also one of the largest studies of suicide risk for former prison populations which allowed us to focus on means-specific suicide death. This is especially important in the U.S. context where half of all suicides involve a firearm.[1]

Our findings are congruent with prior research which suggests that people are at higher risk of suicide death after release from prison compared to the general population.[33,58] The finding that the number of prior incarcerations is positively associated with risk for suicide is similar to results from prior population-based studies in Australia and Sweden.[59,60] Other existent research has found that mental illness is more common among prisoners than in the general population.[25,57,59] In a report from the Bureau of Justice Statistics, 56% of individuals incarcerated in a state prison had some history of a mental health problem; among these individuals, 74% met the criteria for substance dependence or abuse.[25] Nearly 70% had at least one major depressive symptom and 24% reported five or more.[25] This may suggest that individuals who are at higher risk for suicide are incarcerated more frequently than those who are not, rather than the experience of incarceration having a causal impact on suicide risk. Regardless of the causal pathway, prisons may be one system through which suicide prevention and mental health interventions can be delivered.

We found that the group with the highest risk for suicide after incarceration were people incarcerated prior to the age of 18. That the youngest group was at 7.6 times the risk of suicide by any means and 16 times the risk of firearm suicide compared to the general population is of great public health concern. Our study is not the first to find that suicide risk is higher among individuals who have been incarcerated in adult prisons at a young age.[65] This is particularly relevant in Washington State where around 100 juveniles are processed through the adult courts every year.[66] While the state had previously dedicated 150 housing units specifically to youth,[67] more recent infrastructure projects have resulted in the closure of this facility resulting in limited capacity in the

remaining juvenile facilities and the incarceration of some youth within adult prisons.[68] As Washington and other states move forward and consider juvenile justice reform, these findings will be crucial. It will be critical to ensure that youth who have contact with the criminal-legal system are provided with necessary resources through a trauma-informed lens, not only to prevent recidivism, but to improve mental health and reduce the risk of subsequent suicide.

Finally, our results suggest mixed efficacy of certain laws around firearm ownership for individuals with a prior prison incarceration. While the risk for firearm suicide was lower on average among former inmates, individuals who were incarcerated as juveniles or charged with a nonviolent firearm-related offense were at the highest risk for firearm suicide. Recent legislation passed by voter initiative in Washington may reduce some risk, especially among youth populations, by holding firearm owners liable in the event that their weapon is used by a prohibited person and was found to have been stored in an unsecure manner.[69] Further laws improving background checks, locally and nationwide, may reduce prohibited individuals access to firearms. Other steps to reduce this risk, in addition to providing increased mental health and substance use resources (e.g. medication assisted therapy for addiction) in the prison environment, might include more active dispossession policies rather than predominantly relying on surrender of weapons. These changes in policy are just some structural changes that could reduce the burden of firearm suicide.

2.4.1 Limitations

The primary limitations of this study stem from incomplete data. While we have complete data on deaths occurring within the State of Washington, it is plausible that some prior inmates relocated to other states. However, we have limited reason to believe that those who relocated were more or less likely to die by suicide than individuals who stayed in Washington State. Because their deaths or readmissions to prison are not captured in our data, individuals who moved out of state contributed additional person-time to the analysis, thereby deflating the measured risk of suicide among former

prisoners. Prior analyses have found that the risk of all-cause death following incarceration is highest in the two weeks immediately after release.[33,58] This suggests that among those inmates who do go on to die by suicide, the risk is greatest while they are still in the state in the days and weeks just after their release.

In addition to losing some individuals due to relocation, there are several relevant details about an inmate's personal history that are relevant in this analysis. Prior research has shown that mental-health diagnoses at time of incarceration are relevant to risk for subsequent suicide, as is the accessibility of mental health and substance use resources after release.[57,59] Information on individual inmates' health history is not available and in the absence of a national health registry, it is difficult to establish who becomes connected with treatment programs. Factors related to social support and wellbeing, such as marital status or time spent in restrictive housing, have also been found to be important in assessing an inmate's risk for suicide upon release, but were unavailable for analysis.[60] Continuing to explore these details of incarceration and their association with risk of suicide after prison release is an important area of study as it may shed light on existing programs that can be expanded to increase their impact.

2.4.2 Public Health Implications

Suicide is a growing public health problem in the United States.[2] These increases in suicide rates disproportionately impact vulnerable populations,[52–54] including those with a history of incarceration. Our findings demonstrate that this problem is relevant in the context of the U.S. healthcare and criminal-legal systems. This is especially relevant as conversations around policing and prison have reached a tipping point nationwide leading to increasing calls for reform within the legal system.

This research supports the need for additional mental health resources in the prison setting and as former inmates transition back to the community to reduce the risk of suicide after release. Mental health and substance use treatment has already been proposed as an effective alternative to

incarceration in reducing recidivism.[38–40] Expanding access to these programs, and continuing to study their impacts on other mental health outcomes, may provide an additional benefit of reducing risk for suicide.

2.5 RELEVANT TABLES

Table 2.1 Characteristics of Washington State Population by Incarceration History, 1990–2017

	All Washington Adults (2010) (n = 5,416,773)		**Washington Prison Inmates**									
			Substance Related (n = 51,566)		Non-Violent Firearm (n = 16,494)		Violent (n = 60,322)		Other (n = 40,823)		Total* (n = 140,281)	
	N	%	N	%	N	%	N	%	N	%	N	%
Male	2,680,200	49.48%	40,383	78.31%	15,528	94.14%	54,979	91.14%	31,874	78.08%	116,196	82.83%
Race/Ethnicity												
White	3,991,914	77.62%	35,282	68.42%	9,685	58.72%	35,892	59.50%	25,114	61.52%	88,872	63.35%
Black	190,413	3.70%	7,186	13.94%	3,238	19.63%	11,501	19.07%	5,076	12.43%	20,951	14.94%
Asian	428,915	8.34%	1,138	2.21%	581	3.52%	2,118	3.51%	993	2.43%	3,936	2.81%
Hispanic	456,355	8.87%	5,516	10.70%	2,206	13.37%	7,607	12.61%	8,285	20.29%	20,282	14.46%
AIAN	75,589	1.47%	2,071	4.02%	708	4.29%	2,824	4.68%	1,051	2.57%	5,224	3.72%
Other/Not Classified	—**	—	373	0.72%	76	0.46%	380	0.63%	304	0.74%	1,016	0.72%
Age* **												
15–17	273,587	5.05%	56	0.11%	81	0.49%	224	0.37%	27	0.07%	269	0.19%
18–24	650,053	12.00%	14,440	28.00%	7,225	43.80%	20,020	33.19%	10,208	25.01%	39,929	28.46%
25–34	933,781	17.24%	19,696	38.20%	5,748	34.85%	20,634	34.21%	14,105	34.55%	49,721	35.44%
35–64	2,731,675	50.43%	16,935	32.84%	3,265	19.80%	18,498	30.67%	15,839	38.80%	48,486	34.56%
65+	827,677	15.28%	77	0.15%	52	0.32%	573	0.95%	461	1.13%	1,101	0.78%
Deaths												
All Cause	47491	0.88%	2,095	4.06%	522	3.16%	3,022	5.01%	2361	5.78%	7,041	5.02%
Died by Suicide	932	0.02%	128	0.25%	65	0.39%	252	0.42%	129	0.32%	484	0.35%
Firearm Suicide	452	0.01%	35	0.07%	21	0.13%	56	0.09%	28	0.07%	111	0.08%

*Numbers do not sum to total as categories are not mutually exclusive

**Classifications differ by data source

***For Incarcerated Populations, Age at First Release

AIAN: American Indian/Alaska Native

Table 2.2 Relative Risk of Suicide and Firearm Suicide Among Previously Incarcerated Individuals Compared to All Washingtonians

	All Suicide					Firearm Suicide				
	Incidence	RR*	CI	RR**	CI	Incidence	RR*	CI	RR**	CI
General Population	17.2	1.00	Ref	1.00	Ref	9.0	1.00	Ref	1.00	Ref
Prison Incarceration										
Any	36.3	2.06	(1.76–2.41)	1.62	(1.46–1.79)	8.3	0.95	(0.74–1.22)	0.78	(0.64–0.95)
Substance Involved Crime	33.4	1.88	(1.50–2.36)	1.49	(1.24–1.80)	9.1	1.04	(0.72–1.51)	0.89	(0.63–1.24)
Firearm Involved Crime	55.7	3.15	(2.40–4.12)	2.27	(1.79–2.89)	18.0	2.05	(1.30–3.23)	1.55	(1.01–2.37)
Violent Crime	47.1	2.67	(2.22–3.22)	1.96	(1.70–2.26)	10.5	1.19	(0.87–1.62)	0.91	(0.70–1.18)
Number of Incarcerations										
1	31.4	1.80	(1.50–2.16)	1.42	(1.24–1.64)	7.5	0.85	(0.63–1.16)	0.70	(0.54–0.92)
2	37.6	2.14	(1.64–2.79)	1.67	(1.32–2.10)	7.3	0.83	(0.50–1.40)	0.69	(0.42–1.13)
3+	49.9	2.77	(2.22–3.47)	2.13	(1.79–2.54)	11.6	1.31	(0.89–1.94)	1.08	(0.76–1.52)
Age at First Release										
<18	146.4	8.36	(3.09–22.59)	7.62	(2.84–20.46)	146.4	16.69	(6.15–45.35)	15.98	(5.95–42.91)
18–24	36.5	2.08	(1.12–1.66)	1.71	(1.42–2.06)	11.0	1.25	(0.86–1.79)	1.09	(0.78–1.51)
25–34	33.3	1.89	(1.51–2.36)	1.52	(1.26–1.83)	6.9	0.78	(0.53–1.15)	0.70	(0.50–0.99)
35–64	38.5	2.19	(1.79–2.67)	1.62	(1.38–1.90)	6.7	0.77	(0.52–1.13)	0.57	(0.40–0.81)
65+	43.7	2.49	(0.84–7.42)	1.27	(0.43–3.72)	14.6	1.65	(0.23–11.96)	0.55	(0.08–4.03)

*Adjusted for Calendar Time

** Adjusted for Calendar Time, Age, Race, Sex

All Incidence Rates expressed per 100,000 person-years

Table 2.3 Relative Risk of Suicide Among Previously Incarcerated Individuals Compared to All Washingtonians, Stratified by Demographic Characteristics

	Washington Population	**Any Prison Incarceration**		**Substance Involved Crime**		**Firearm Involved Crime**		**Violent Crime**	
	Incidence	RR	CI	RR	CI	RR	CI	RR	CI
Age									
15-19	10.5	8.16	(1.14–58.50)	—	—	—	—	13.01	(1.80–94.07)
20-24	16.2	2.63	(1.85–3.74)	1.96	(0.92–4.18)	2.68	(1.11–6.44)	2.44	(1.52–3.89)
25-34	15.9	1.96	(1.63–2.36)	1.44	(1.02–2.02)	2.46	(1.66–3.63)	2.35	(1.85–2.99)
35-44	17.2	1.45	(1.19–1.77)	1.69	(1.20–2.37)	2.20	(1.42–3.40)	1.86	(1.40–2.46)
45-54	19.3	1.62	(1.34–1.95)	1.4	(0.99–1.99)	2.28	(1.32–3.94)	2.03	(1.55–2.65)
55-64	17.8	1.08	(0.79–1.48)	1.25	(0.72–2.18)	0.63	(0.09–4.36)	1.21	(0.75–1.92)
65-74	17.1	1.09	(0.54–2.20)	—	—	7.64	(2.17–26.92)	1.41	(0.69–2.92)
75+	24.7	1.18	(0.43–3.26)	—	—	—	—	—	—
Sex									
Male	27.5	1.63	(1.47–1.82)	1.49	(1.22–1.83)	2.25	(1.75–2.89)	1.99	(1.72–2.30)
Female	7.2	2.15	(1.56–2.95)	1.98	(1.20–3.27)	7.29	(2.72–19.54)	3.27	(1.88–5.71)
Race/Ethnicity									
Non-Hispanic White	18.9	1.79	(1.60–2.01)	1.64	(1.33–2.01)	2.27	(1.71–3.01)	2.12	(1.81–2.49)
Non-White	10.2	1.18	(0.94–1.48)	1.01	(0.63–1.63)	2.35	(1.47–3.76)	1.56	(1.17–2.09)

All Incidence Rates expressed per 100,000 person-years
— Indicates no events occurred within this stratum

Table 2.4 Relative Risk of Firearm Suicide Among Previously Incarcerated Individuals Compared to All Washingtonians, Stratified by Demographic Characteristics

	Washington Population	Any Prison		Substance Involved Crime		Firearm Involved Crime		Violent Crime	
	Incidence	RR	CI	RR	CI	RR	CI	RR	CI
Age									
15-19	5.3	14.93	(2.07–107.60)	—	—	—	—	23.49	(3.23–171.05)
20-24	8.5	2.04	(1.14–3.63)	1.32	(0.34–5.14)	3.18	(1.01–9.98)	1.29	(0.47–3.55)
25-34	7.6	1.01	(0.73–1.41)	1.11	(0.64–1.92)	1.65	(0.83–3.30)	1.20	(0.79–1.82)
35-44	7.5	0.71	(0.48–1.03)	0.91	(0.49–1.69)	1.49	(0.68–3.25)	0.93	(0.57–1.51)
45-54	8.9	0.53	(0.34–0.84)	0.55	(0.24–1.23)	0.79	(0.20–3.03)	0.63	(0.33–1.23)
55-64	9.7	0.57	(0.30–1.07)	1.08	(0.45–2.59)	—	—	0.78	(0.35–1.75)
65-74	11.3	0.48	(0.11–2.02)	—	—	11.45	(3.25–40.39)	—	—
75+	18.2	0.50	(0.08–3.23)	—	—	—	—	—	—
Sex									
Male	15.9	0.77	(0.63–0.95)	0.83	(0.58–1.18)	1.55	(1.00–2.39)	0.90	(0.69–1.18)
Female	2.3	1.51	(0.75–3.03)	2.31	(0.98–5.44)	6.51	(0.91–46.34)	2.96	(0.95–9.25)
Race/Ethnicity									
Non-Hispanic White	10.1	0.80	(0.64–1.00)	0.88	(0.60–1.28)	1.44	(0.87–2.37)	0.99	(0.74–1.31)
Non-White	4.1	0.72	(0.48–1.10)	0.93	(0.45–1.94)	1.89	(0.85–4.20)	0.63	(0.33–1.22)

All Incidence Rates expressed per 100,000 person-years
— Indicates no events occurred within this stratum

Table 2.5. Fine-Gray Hazard Ratio of All-Means and Firearm Suicide Among Formerly Incarcerated Individuals in Washington State

	Any Suicide					Firearm Suicide				
	N	HR	CI	HR*	CI	N	HR	CI	HR*	CI
Substance Involved Crime										
No	361	1.00	Ref	1.00	Ref	76	1.00	Ref	1.00	Ref
Yes	123	1.02	(0.83–1.26)	0.97	(0.77–1.23)	35	1.26	(0.84–1.88)	1.39	(0.88–2.20)
Firearm Involved Crime										
No	427	1.00	Ref	1.00	Ref	90	1.00	Ref	1.00	Ref
Yes	57	1.71	(1.30–2.27)	1.54	(1.16–2.05)	21	2.78	(1.73–4.48)	2.23	(1.35–3.71)
Violent Crime										
No	260	1.00	Ref	1.00	Ref	55	1.00	Ref	1.00	Ref
Yes	224	1.62	(1.35–1.95)	1.47	(1.20–1.79)	56	1.66	(1.14–2.24)	1.49	(1.00–2.23)
Number of Incarcerations										
1	241	1.00	Ref	1.00	Ref	62	1.00	Ref	1.00	Ref
2	71	1.22	(0.93–1.59)	1.15	(0.87–1.50)	15	1.00	(0.57–1.75)	0.86	(0.48–1.52)
3+	132	1.58	(1.27–1.96)	1.46	(1.15–1.85)	33	1.56	(1.02–2.39)	1.20	(0.76–1.90)
Age at First Release										
<18	4	4.46	(1.64–12.13)	4.58	(1.69–12.47)	4	14.07	(5.01–39.48)	11.91	(4.30–32.96)
18–24	128	1.00	Ref	1.00	Ref	41	1.00	Ref	1.00	Ref
25–34	144	0.91	(0.71–1.15)	0.95	(0.75–1.20)	33	0.65	(0.41–1.03)	0.70	(0.44–1.12)
35–64	164	1.03	(0.82–1.29)	1.04	(0.82–1.32)	31	0.67	(0.38–0.97)	0.70	(0.43–1.14)
65+	3	0.94	(0.30–2.94)	0.79	(0.25–2.51)	1	0.98	(0.13–7.10)	1.15	(0.15–8.50)
Sex										
Male	405	2.10	(1.51–2.91)	2.00	(1.43–2.81)	102	2.56	(1.25–5.27)	2.13	(1.03–4.42)
Race/Ethnicity										
AIAN	16	0.77	(0.47–1.27)	0.72	(0.44–1.19)	4	0.82	(0.30–2.23)	—	—
Asian	9	0.59	(0.30–1.14)	0.54	(0.28–1.05)	2	0.55	(0.14–2.24)	—	—
Black	26	0.27	(0.19–0.41)	0.25	(0.17–0.38)	10	0.45	(0.24–0.87)	—	—
Hispanic	24	0.26	(0.17–0.39)	0.27	(0.17–0.41)	8	0.36	(0.14–0.75)	—	—
Other/Not Classified	4	1.39	(0.52–3.72)	1.46	(0.54–3.93)	0	—	—	—	—
White	365	1.00	Ref	1.00	Ref	86	1.00	Ref	—	—

* Adjusted for present categories and computed with competing risk specification
AIAN: American Indian and Alaska Native
Note: Race has been excluded from the proportional-hazard models of firearm suicide due to small numbers within strata

Table 2.6. Hazard Ratio of All-Means and Firearm Suicide Among Formerly Incarcerated Individuals in Washington State

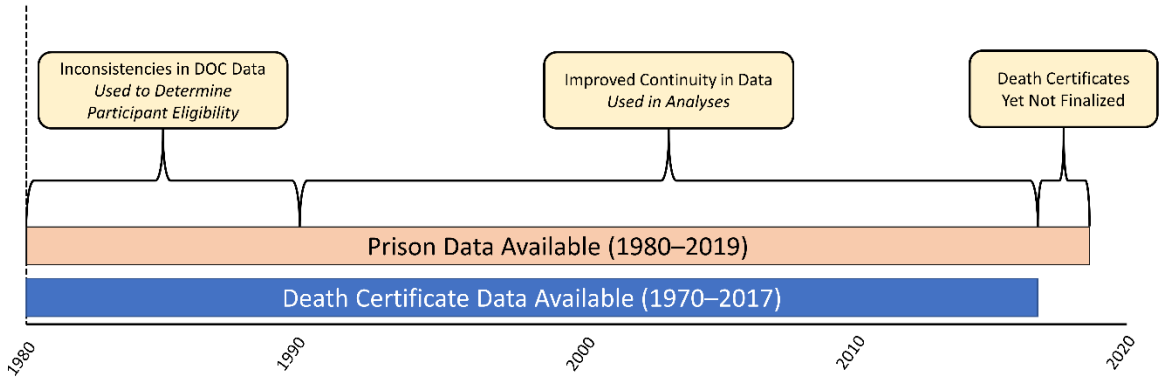
	Any Suicide					Firearm Suicide				
	N	HR	CI	HR*	CI	N	HR	CI	HR*	CI
Substance Involved Crime										
No	361	1.00	Ref	1.00	Ref	76	1.00	Ref	1.00	Ref
Yes	123	1.03	(0.83–1.26)	0.98	(0.78–1.23)	35	1.27	(0.85–1.90)	1.40	(0.90–2.18)
Firearm Involved Crime										
No	427	1.00	Ref	1.00	Ref	90	1.00	Ref	1.00	Ref
Yes	57	1.71	(1.30–2.26)	1.54	(1.16–2.04)	21	2.78	(1.73–4.48)	2.23	(1.37–3.65)
Violent Crime										
No	260	1.00	Ref	1.00	Ref	55	1.00	Ref	1.00	Ref
Yes	224	1.62	(1.35–1.95)	1.47	(1.21–1.79)	56	1.66	(1.14–2.41)	1.50	(1.01–2.22)
Number of Incarcerations										
1	241	1.00	Ref	1.00	Ref	62	1.00	Ref	1.00	Ref
2	71	1.22	(0.94–1.59)	1.15	(0.88–1.50)	15	1.00	(0.57–1.76)	0.86	(0.48–1.53)
3+	132	1.59	(1.28–1.97)	1.47	(1.16–2.04)	33	1.58	(1.02–2.43)	1.21	(0.75–1.94)
Age at First Release										
<18	4	1.49	(1.64–11.98)	4.54	(1.67–12.33)	4	13.94	(4.99–38.92)	11.79	(4.19–33.18)
18–24	128	1.00	Ref	1.00	Ref	41	1.00	Ref	1.00	Ref
25–34	144	0.91	(0.72–1.15)	0.95	(0.75–1.21)	33	0.65	(0.41–1.03)	0.71	(0.44–1.12)
35–64	164	1.05	(0.84–1.33)	1.07	(0.84–1.35)	31	0.62	(0.39–1.00)	0.72	(0.45–1.16)
65+	3	1.10	(0.35–3.47)	0.94	(0.30–2.95)	1	1.15	(0.16–8.36)	1.36	(0.19–9.92)
Sex										
Male	405	2.10	(1.51–2.92)	2.01	(1.44–2.82)	102	2.57	(1.25–5.28)	2.14	(1.03–4.43)
Race/Ethnicity										
AIAN	16	0.77	(0.47–1.28)	0.72	(0.44–1.19)	4	0.82	(0.30–2.24)	—	—
Asian	9	0.58	(0.30–1.12)	0.54	(0.28–1.04)	2	0.54	(0.13–2.21)	—	—
Black	26	0.27	(0.18–0.41)	0.25	(0.17–0.37)	10	0.45	(0.23–0.87)	—	—
Hispanic	24	0.25	(0.17–0.38)	0.26	(0.17–0.40)	8	0.35	(0.17–0.73)	—	—
Other/Not Classified	4	1.37	(0.51–3.68)	1.45	(0.54–3.89)	0	—	—	—	—
White	365	1.00	Ref	1.00	Ref	86	1.00	Ref	—	—

* Adjusted for present categories and computed without competing risk specification

Note: Race has been excluded from the proportional-hazard models of firearm suicide due to small numbers within strata

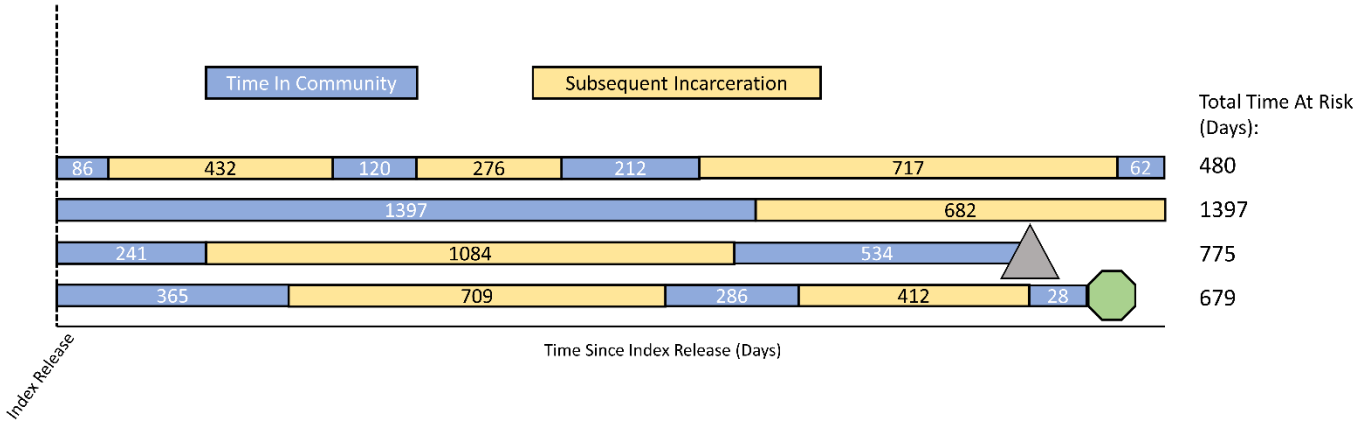
2.6 RELEVANT FIGURES

Figure 2.1 Timeline of data used in analysis



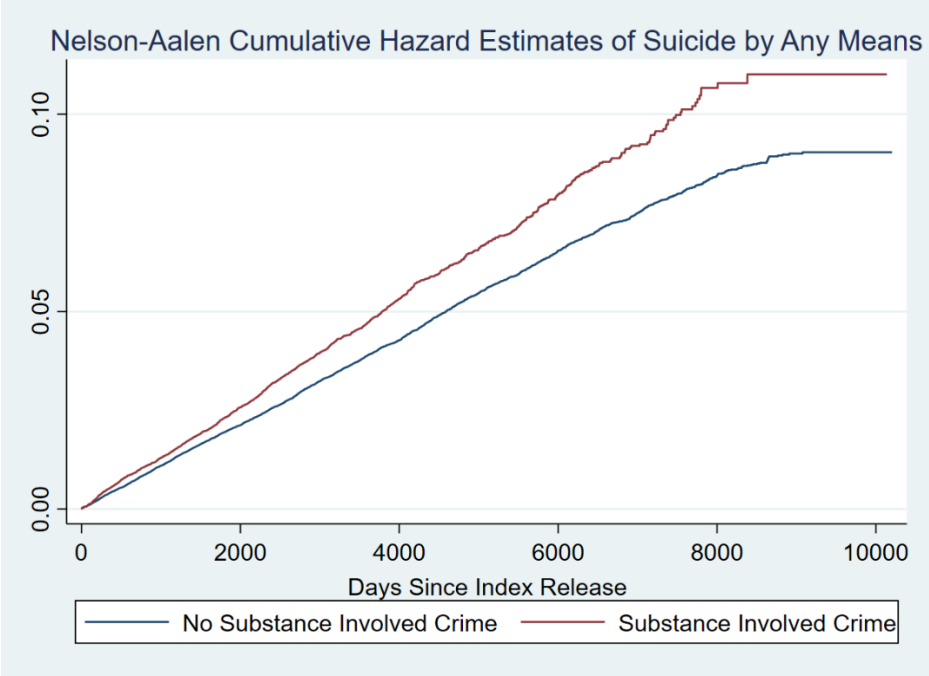
The data recorded by DOC from 1980–1990 was less consistent in the recording of dates of admission and release and therefore not suitable for analysis. This was used to determine participant eligibility based on whether or they had any prior incarcerations in a Washington State prison. We began our study in 1990 and restricted individuals with no incarcerations in the prior decade. The measure of number of prior incarcerations only included incarcerations subsequent to 1990.

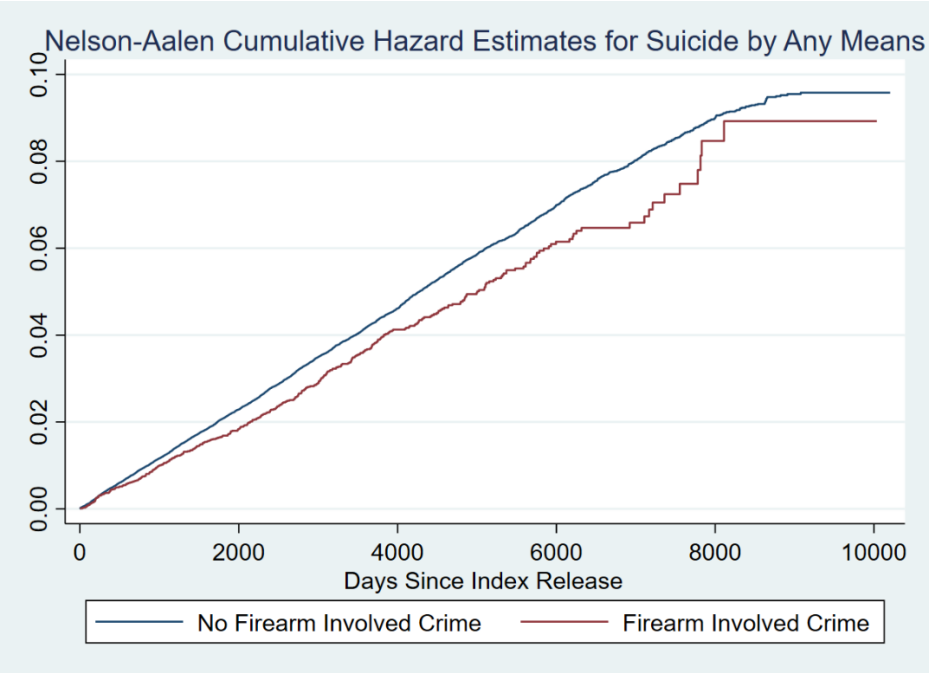
Figure 2.2 Calculation of Time at Risk Subsequent to Release from Prison



Example calculation of time at risk after index incarceration. Yellow indicates subsequent incarceration when an individual is not in the risk pool; blue indicates time in the community when an individual is accruing time at risk. Grey Triangle indicates competing risk; green octagon indicates death by firearm suicide.

Figure 2.3 Nelson-Aelen Cumulative Hazard Estimates of Suicide by Any Means





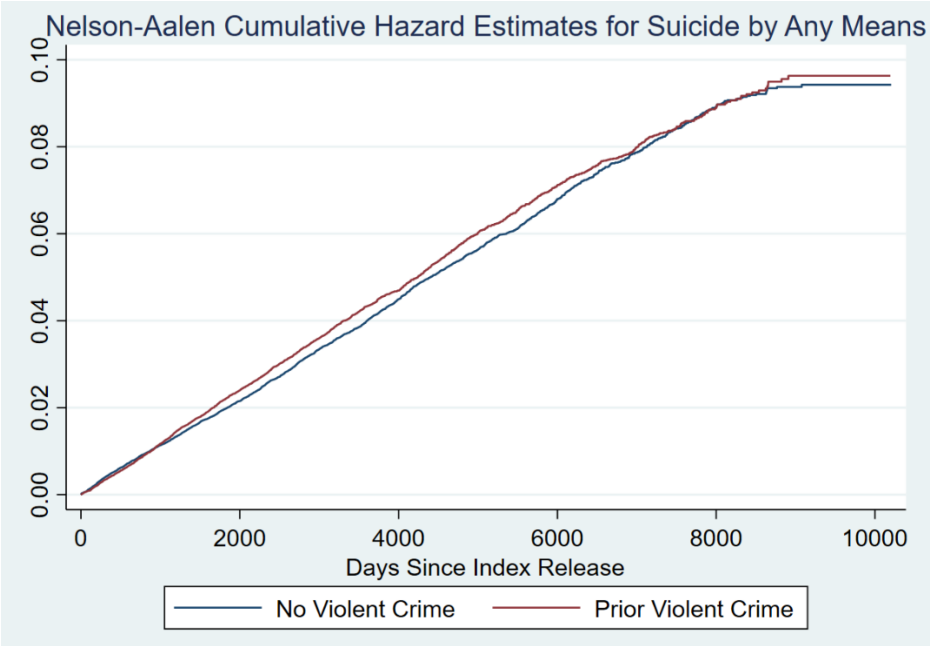
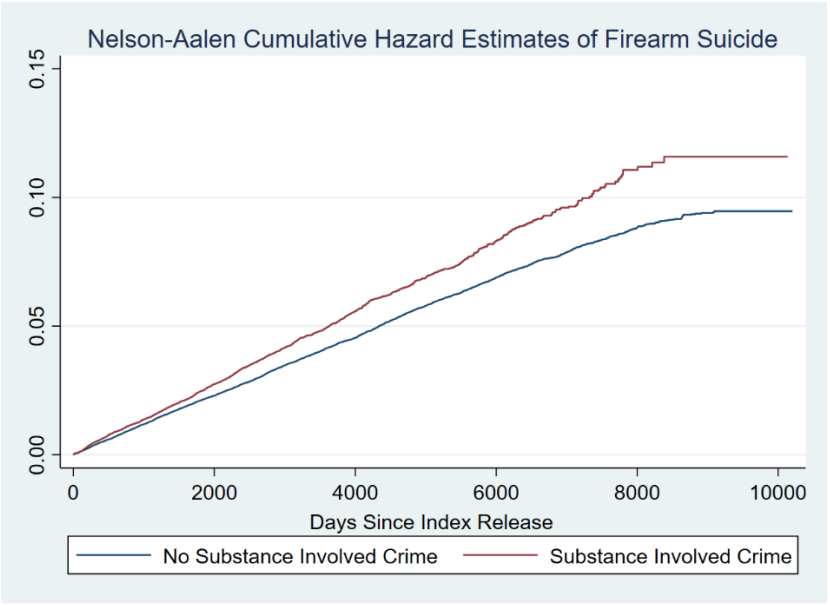
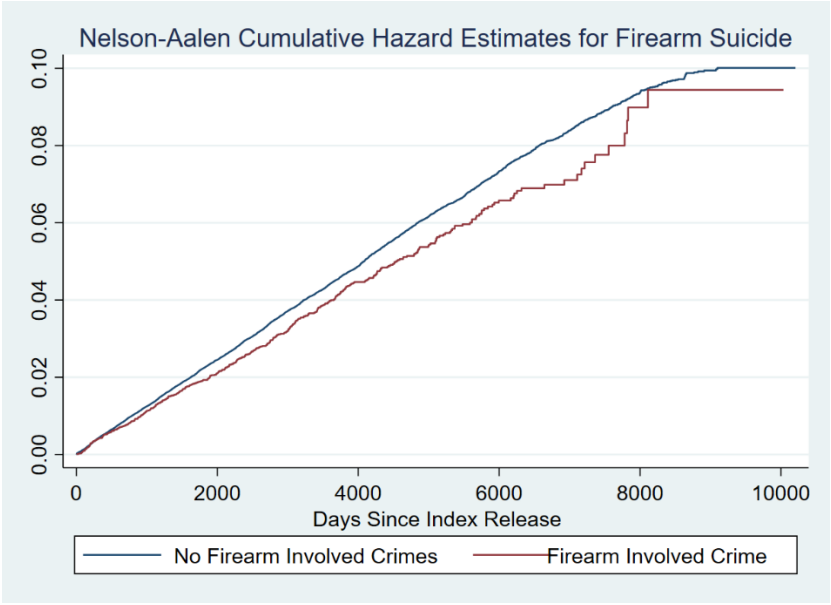
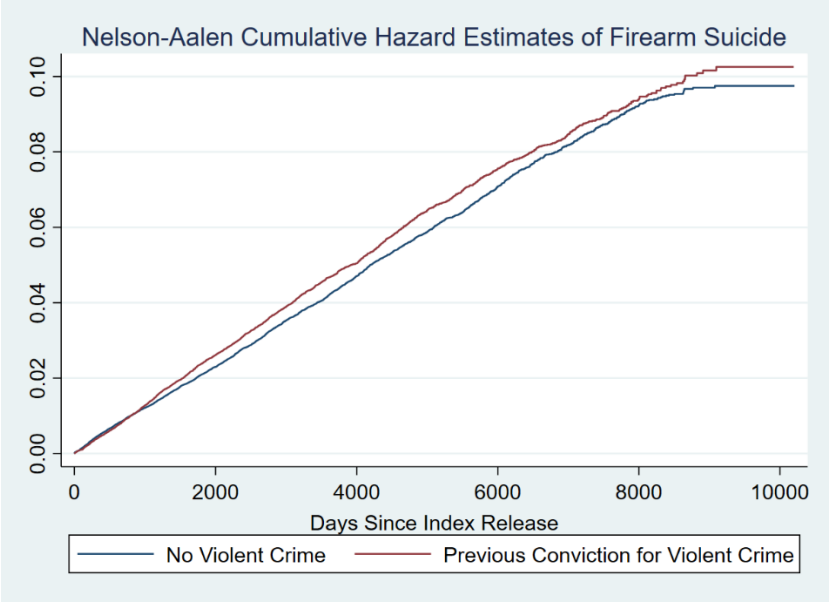


Figure 2.4 Nelson-Aelen Cumulative Hazard Estimates of Suicide by Firearm







CHAPTER 3: NATURAL LANGUAGE PROCESSING IN SURVEILLANCE OF FIREARM SUICIDE

3.1 Background and Purpose

Currently, there are limited systems for ascertaining detailed information regarding the circumstances of deaths, including those attributable to external causes. The National Violent Death Reporting System (NVDRS) is one data system that augments death certificates with collection of information from law enforcement and death investigators across the country on details of violent death, including all firearm deaths.[70] Due to the detailed information collected in NVDRS, researchers have been excited about its potential for better understanding injury-related deaths.[71] While this system is a promising source of death data nationwide, it does have some limitations. There can be long delays between the finalization of death certificates and the availability of data through NVDRS. Additionally, the system relies on manual abstraction of summaries of law enforcement and death investigator reports. Using summaries can decrease the labor burden on abstractors but may result in an incomplete coding of circumstances.

Natural language processing (NLP)—a machine learning technique specific to text analytics—is increasingly of interest and may be one solution to improving data quality and lessening the burden of abstraction on NVDRS. NLP has previously been used to assess electronic medical records for the purposes of classifying encounter-based clinical events from free text fields.[72] One such application of this was to assess provider adherence to clinical guidelines in assisting patients with smoking cessation.[73] More recently, researchers have been interested in applying these methods to glean information on lethal means counseling provided during emergency department visits or to apply these methods to investigative reports following a suicide death.[74] An increase in efficiency of review via NLP algorithms would allow NVDRS data abstractors to use the full text of law enforcement case reports or death investigator narratives, thus providing more complete information on death circumstances.

In 2018, suicide was the tenth leading cause of death nationwide and eighth leading cause of death in the State of Washington.[1] While there is a large existent literature on suicide risk-factors broadly, less is known about factors specific to firearm suicide. The combination of being somewhat common—relative to other external causes of death—and a collection of known risk-factors makes suicide a compelling example application of NLP methods. A better understanding of specific antecedents of suicide is of interest to researchers and public health practitioners alike to help in generating tailored interventions and prevention strategies for those who might be most at risk.

We sought to develop machine learning algorithms using open source software that could assist in generating concrete indicators of suicide circumstance for quantitative analysis from free text narratives. Using full death investigation narratives from the King County Medical Examiner's Office (KCMEO), we built algorithms to code risk-factors based on those included in NVDRS, such as financial stress, problems in interpersonal relationships (i.e. intimate partners, family, friends, colleagues), substance use, and impending legal problems—among other known antecedents of suicide.[75] By developing these algorithms and assessing their accuracy, we hope to provide other investigators with guidance regarding the types of variables and data sources that may be suitable for NLP thereby improving the efficiency of these important investigations.

3.2 METHODS

Death investigation narratives were provided electronically by the KCMEO. Presently, King County is the 13th most populous county in the country and one of six counties in Washington State to have a medical examiner.[76] The KCMEO determines the cause and intent of death for all individuals who die suddenly or unexpectedly and are in King County at the time of death. The Medical Examiner is responsible for investigation of all deaths due to firearms that occur in King County. When a firearm death is reported to law enforcement, investigators from the KCMEO are deployed to determine the intent of the death. As part of this determination, details are collected about the events preceding the

death based on information provided by next-of-kin, individuals who were nearby at the time of death, evidence at the location of death, and any available 911 calls though these sources are not always accessible. We limited our study to firearm suicides occurring between January 1, 1996 and December 31, 2018 as investigations in this timeframe were readily available in the current KCMEO data systems; after applying these restrictions, there were 2367 records for analysis. A summary of the entire NLP process is illustrated in Figure 3.1.

3.2.1 Generation of Training and Testing Datasets

To train classifier algorithms, NLP requires datasets labeled with a "gold-standard" indicator of the true classification. A random 10% of narratives (n=236) were selected without replacement to undergo manual coding for use as the training dataset. After generating an algorithm and assessing its performance on the training data, an additional 10% of narratives were selected to be manually coded for use as a testing dataset. The application of the classifier algorithm to a secondary dataset and comparison with gold-standard measurements helps assess its validity when applied to novel data and ensures that models are not being overfit to training data. Frequency distribution of demographic characteristics and firearm type in the testing and training data sets were compared to the overall data set to assess quality of random sampling.

3.2.2 Antecedents of Suicide

A total of 24 circumstances that may precede suicide death were selected *a priori* based on a variety of sources from the literature (circumstances listed in Table 3.1). Risk factors of interest included substance use, relationship problems, financial stressors, health stressors, and involvement with the criminal legal system. Relationship problems were dichotomized by whether they included a romantic partner or were issues with a familial or friend relationship. Financial stressors included general concerns over pecuniary stability, unstable employment, and unstable housing. Health problems could be any health problem the decedent was experiencing, a terminal illness experienced

by the decedent, a decline in health or recent death of a loved one, and evidence of a suicide attempt or death of a friend or family member. Definitions of these risk factors were adapted from the NVDRS coding scheme.[75] Other circumstances of interest included details about the firearm used in the suicide—if it was explicitly mentioned to have been typically stored locked and if it had been acquired within the past month—and whether the suicide was part of a homicide-suicide. We additionally assessed characteristics of the suicide itself, such as whether the decedent left a note, disclosed suicidal intent, had a history of suicidal ideation or behavior, and had evidence of ongoing depression. These 24 circumstances were manually coded in the aforementioned subset of narratives by a single coder to generate a gold-standard measure; the coding scheme was largely based on the guidance provided to NVDRS abstractors and examples of coded text are available in Table 3.1.[75] Data were coded in Atlas.ti 8 (ATLAS.ti Scientific Software Development GmbH, Berlin Germany).

3.2.3 Text Preparation

The terms within the narrative first underwent stemming wherein words can be derived to their roots reducing the overall number of features while retaining the same semantics (e.g. “depressed,” “depression,” etc. would become “depress”). Medical examiner narratives were then tokenized into unigrams, bigrams, and trigrams—which is to say, variables were created for each one-, two-, and three-word sequence found within the text. Several stop words that provide little to no power in distinguishing situational factors were removed (e.g. "a", "an", "by", "of", "to", "and", "aforementioned", "on", "the", "be", "as", "is", and "was") to reduce the required computational power. While other NLP practices may apply stop words prior to tokenization, we did not want to remove any negation terms from bigrams or trigrams as these may be informative in this analysis. Finally, prior to analysis, features (columns of the matrix) were weighted through Term Frequency Inverse Document Frequency (TF-IDF)—a common technique that weights values based on how often they appear in a single narrative and how many narratives contain that feature. Term Frequency

weighting upweights terms that show up several times within a single document or narrative to convey the relative importance of that particular term in analysis. Inverse Document Frequency weighting decreases the weight given to terms that occur frequently within the collection of documents as they have little discriminating power; within our data, nearly every investigative narrative concludes “the subject was transferred to the office for further investigation,” therefore sequences from this sentence provide little information in distinguishing events specific to that death. The TF-IDF method of weighting has been described in detail elsewhere.[77]

3.2.4 Training and Evaluation of Classifier Algorithms

We used Random Forest classifiers for each of the aforementioned indicators using five-fold cross-validation repeated ten times. The Random Forest classifiers uses several decision trees (in this case 500 trees) to generate a binary prediction of each classification. These classifiers are trained on a random subset of the data to predict the remaining data. The iterative process aims to reduce risk of overfitting. The performance of the classifier is first estimated within the training data—on the subset excluded from training—in a process called cross-validation. Then the classifier algorithm is applied to the testing data, which has undergone the same transformations as the training data, to evaluate its performance on new data. We calculated the sensitivity, specificity, and positive and negative predictive values of each of the indicators. All analyses were done in R version 3.6.2 (Copyright © 2019 The R Foundation for Statistical Computing)—and utilized the following packages: "e1071", "caret", "quanteda", "irlba", and "randomForest." The University of Washington Institutional Review Board approved this study.

3.3 RESULTS

Over the 23-year study period, 2367 firearm suicides were investigated by the KCMEO. The general characteristics of firearm suicide decedents are presented in Table 3.2. The death investigations sampled for the training and testing sets are relatively representative of the underlying pool of

decedents indicating success in random sampling; this should assure that suicide antecedents that are more common among specific subpopulations (e.g., health problems among older adults) are suitably captured in training and test data. The most notable deviation within the randomly selected data is a slight underrepresentation of decedents under the age of 18 within the training data as compared to the testing data and underlying survey of firearm suicides.

In the training data, the most common contributing circumstances were substance use (present in 27.1% of narratives) with 24.2% of all narratives specifically referencing alcohol use, having a relationship problem or argument in any type of relationship (21.2% of deaths), and 21.6% of reports indicated that there was evidence of a health problem (Table 3.3). Overall, the models tended to be highly specific, but low in sensitivity. In the training data, algorithms performed well in detecting indicators of ongoing depression (80.9% sensitivity and 96.3% specificity). They also performed less well in detecting alcohol use (68.4% sensitivity and 95.5% specificity), any type of substance use (57.8% sensitivity and 94.8% specificity) and having left a suicide note (56.7% sensitivity and 97.2% specificity). For all other factors, the sensitivity was less than 50%.

The most common suicide risk-factors in the testing data were very similar to those occurring in the training dataset, though most were less prevalent, suggesting potential weaknesses in the allocation of training and testing data (Table 3.3). Substance use was referenced in 17.4% of these narratives and 13.1% specifically mentioned alcohol. Many indicated that a relationship problem had recently preceded the death (16.1%) and 23.3% of investigation reports referenced a health concern. The same items that were well detected in the training data were well detected in the testing algorithm. The best performance was by the algorithm for alcohol use (90.3% sensitive and 92.2% specific) followed by indicators of ongoing depression (76.5% sensitivity and 95.7% specificity). Models did not perform as well in their ability to predict indicators of any substance use (73.2% sensitivity and 93.3% specificity), if a firearm was recently acquired (61.9% sensitivity and 98.1%

specificity), and whether an individual left a note (58.1% sensitivity and 95.7% specificity). The models had sensitivities of less than 50% for all other factors of interest.

3.4 Discussion

Our development of natural language processing algorithms yielded high accuracy prediction models for some risk factors associated with suicide. The models were able to successfully identify narratives that described deaths in which use of alcohol or other substances were contributing factors. They also regularly detected indicators of ongoing depression, whether an individual left a suicide note, and if the firearm used in their death had been recently acquired. These algorithms were less sensitive for identification of other known suicide risk factors or circumstances such as financial instability, relationship problems, or health concerns.

Our findings indicate that some precipitating circumstances pertaining to firearm suicide may be well suited for evaluation by NLP, while others may require other methods of NLP or manual appraisal to detect. This is potentially partially attributable to some classifications that can be indicated by a small number of key words versus those that must be detected through nuances in language and technical terminology. For instance, most narratives referencing alcohol referred specifically to “alcohol,” “ethanol,” or “bottle.” This is compared to suicides in which the decedent had an underlying terminal illness where the condition may have been noted by any of several specific medical conditions; improvement of algorithms used to detect these terminal conditions may require the application of large medical dictionaries that could determine the severity of the illness based on the mention of a specific diagnosis. While there may be other textual indicators that someone faced a terminal diagnosis, notes by the medical examiner investigators are frequently clinical suggesting that there may be benefit to inclusion of a medicalized dictionary. The need for precise and specialized dictionaries is especially important as NLP is expanded to assess deaths attributable to other intents in addition to suicide.

Much of the prior literature applying NLP in the health sciences has focused on electronic health records.[73,78,79] These records may generate models with better performance because they typically originate not only within a single institution but also over a limited period of time, thus the records may be more likely to share a similar structure. Electronic health records also provide more complete records, whereas our records were frequently missing the text of any notes left by the decedent. Additionally, electronic health records may span several visits, which increases the number of records available to train models in addition to providing more information about specific individuals. Similarly, these electronic records include ICD codes that facilitate classification into specific disease related outcomes (i.e. an alcohol use disorder); typically, these would not be listed as a pertinent cause of death on the death certificate. This is another reason why classification algorithms for death narratives are especially important as there are no equivalent alternatives for measuring these details in a death record.[80]

3.4.1 Limitations

This project had two primary limitations. The sample of firearm suicides came from one county in Washington State. While the most populous of the state's 39 counties, the sample may not be representative of other populations. The sample size was also somewhat limited in part due to the feasibility of manual coding of death investigation narratives. The classifications that the algorithms were able to detect well were those that occurred somewhat frequently in the data, while rarer measures were less likely to be detected. With a larger sample size and therefore larger number of these uncommon events, it may be easier to generate a predictive model. However, given that these are a subset of all suicides, it is likely that smaller jurisdictions may not have many events, even over a long period of time, though this is likely only of concern outside of the US context where the algorithms developed here would not be culturally relevant.

The other concern is whether the sample is representative of the United States. While we are confident that, due to random selection of training and testing data from the entire population of decedents who died from firearm suicide, our sample is likely to be representative of firearm suicide deaths occurring within King County, these cases may differ from other localities across the country. King County—which encompasses 39 cities, including Seattle, and unincorporated areas—is geographically and politically diverse, with a higher prevalence of gun ownership in the eastern portion of the county.[81] Given the association between household firearm ownership and firearm suicide,[7] variation in firearm ownership across the county is important in assessing how representative these firearm suicide deaths may be. Future work in this area should expand the jurisdictions of investigation to include additional geopolitical diversity where risk factors may vary in frequency and additionally include jurisdictions that rely on a coroner rather than a medical examiner.

An additional limitation to this approach lies in its reductive nature. Suicide and other forms of violent death are multifactorial; simple classifications may not fully capture important components of the narratives related to those deaths. In one instance where a firearm was typically stored locked, the investigative report specified that the decedent had been unable to locate the keys to the gun safe and ultimately took his life with a different firearm stored in a bedside table. Regardless of how sophisticated an NLP algorithm becomes, these nuanced stories are valuable for policy makers, but will be unlikely to be captured by classification methods. Depending on the question at hand, NLP will not always be a suitable substitute for manual abstraction. However, to develop a snapshot and understand patterns when assessing a large number of violent deaths, NLP may be an attractive initial approach.

3.4.2 Implications

Many practitioners in the field have faced budget cuts; funding for firearm research is also limited. Finding a way to reduce the labor and financial burden on already overwhelmed interventionists while still extracting important data is crucial. As suicide rates continue to rise, deciding where to target suicide prevention interventions is increasingly of public health importance. NLP and machine learning algorithms may be one way to shed light on general areas for suicide prevention programs. While a relatively new approach to surveillance of health conditions, NLP has the potential to increase timeliness of injury mortality public health surveillance.[82,83] For circumstances where random forest predictive models do not perform well, alternative approaches might include more complex natural language processing algorithms such as neural networks or working with death investigators to decide on key indicators that could be collected as Boolean outcomes in the field as part of the death investigation process.[79,84] These categorizations of narratives will help us better quantify circumstances surrounding external causes of death, not just limited to firearm suicide, and improve efficiency in allocating resources while creating tailored interventions that may be relevant to specific populations.

3.5 RELEVANT TABLES

Table 3.1 Classifications and Corresponding Narrative Text

Classification	Example Narrative Text
Murder Suicide	"The — family, consisting of the father, mother and two [children], were found lying in an upstairs room"; "began shooting people at the home at approximately 0703H and was then approached by patrol officer, who witnessed the male shoot himself"; "recent aggressive outbursts and rage-filled comments made towards family members... decedent was found obviously deceased in [step-sister's] bedroom along with [step-sister]"
Veteran	"decedent was a Gulf War veteran with the US Marines"; "a US Military issue Remington"; " WWII vet with handgun experience"
Suicide	
Left Note	"[investigator] removed the paper and found it to be a note of intent apparently signed by the deceased"; "Notes of intent were found taped to the door of the bathroom and sink counter"; "A possible note of intent was observed in the decedent's residence"; "note of intent was present near the decedent on a desk"
Disclosed Suicidal Intent	"police stated that the decedent reportedly called out of state relatives and made a statement of intent"; "family had received a disturbing call from a relative visiting [King County]...was now threatening to kill himself"; "In the morning hours of [date of death], the decedent expressed suicidal intent to his wife"
Ongoing Depression	"the decedent's wife, said that her husband had suffered from Depression"; "The decedent has recently been depressed because he has been forgetting 'everyday' things"; "Hx of depression from failing health"; "Per [decedent's wife], the decedent suffered from depression"
Ongoing Suicidal Ideation	"[decedent] told [wife] that he wanted to kill himself. Since he makes threats on a regular basis, she did not considered this significant"; "Over the last year [decedent] has made several suicidal threats to her daughter but has not attempted any suicidal methods"; "[Decedent] had made several suicidal threats in past, but he never seemed serious"
Substance Use	
Any Substance Use	—see below categories—
Alcohol	"According to the decedent's brother...his brother seemed drunk"; "The decedent...was drinking most of the day at a local bar"; "the decedent had left a six-pack of beer hanging from the door handle of his apartment"
Marijuana	"[decedent and friend] decided to smoke some marijuana"; "Marijuana pipes and a commercially fabricated marijuana cigarette were observed"
Opioids	"The incident occurred in a residence known for heroin activity"; "the decedent's depression was due to his longtime addiction to prescription pain killers"; "he was also prescribed with Percocet"
Other Substances	"Large quantities of methamphetamine and cash were located in the home"; "Sleeping aid medication containers were found in the kitchen trash"; "A glass pipe was found between the driver's seat and the driver's door"
Relationship Problems	
Any Relationship	—see below categories—
Romantic Relationship	"decedent and his wife had been arguing earlier in the day over parenting issues"; "The decedent had recently split with his girlfriend"; "the decedent had been in an argument with his partner"

Familial/Friendly Relationship	" As [decedent's brother] turned down the music, [decedent] woke up and started another fight"; "the decedent's daughter moved back in with her father, after which the decedent became increasingly depressed"; "The decedent reportedly got into a verbal argument with a female friend and asked her to leave"
Financial Stressors	
General Financial Problems	"the decedent had been out of work for some time and was deep in debt"; "decedent was recently undergoing employment changes and was very low on money"; "[decedent] was found by his landlord when she received calls from friends unable to reach him, and he had not pay his rent"
Unstable Employment	"decedent had been out of work"; "the deceased was a street musician"
Unstable Housing	"An eviction notice was taped on a late rental payment was taped to the door of the unit"; "the decedent was told by the owner of the residence that if he could not pay rent he would have to leave"
Health Stressors	
Decedent had Poor Health	"According to his friend and executor, [decedent] had been upset about his failing health"; "[decedent] was recovering from Esophageal Cancer and a feeding tube was removed two months ago"; "two typed pages were present detailing emergency contacts and health issues"
Decedent had Terminal Diagnosis	"Neighbors also indicated that the decedent was having difficulty with mobility lately due to terminal cancer"; "[decedent] was distressed about his issue with brain tumor"; " the decedent's health and condition had rapidly deteriorated in the past several months due to his multiple sclerosis"
Poor Health/Death of Friend/Family Member	"Family members took the decedent's father, who lives with the decedent and requires medical assistance, to stay with them"; "[decedent] had been taking care of his bedridden mother for the past several days as she is suffering from cancer"; "[decedent's] mother had died last year"
Attempted Suicide/Suicide Death of Friend Family Member	"the decedent's father had committed suicide by hanging and his mother had died last year"; "[decedent's] girlfriend attempted suicide by slashing last night and taken to [hospital]"
Firearm Ownership	
Firearm Stored Locked	"the decedent had removed his semi-automatic handgun from the gun safe at [mother's] house"; "An open gun locker was observed near the decedent"; "Weapon was owned by the decedent and was usually locked in a cabinet"
Firearm Recently Acquired	"A receipt for the pistol, showing a purchase date of [two weeks prior to death]"; "Two receipts for the purchase of the weapon at [pawn shop] was discovered in the decedent's pants pocket"; "[Decedent] and his friend went to his car...to look at two new handguns he had acquired"
Criminal Justice Involvement	
Potential Criminal Activity	"According to police, [decedent] was wanted in connection with a robbery"; "the decedent and his wife are separated and she has a no contact order against him"; "the decedent's girlfriend filed a 'no contact/Restraining Order'"

Table 3.2 Description of Datasets

	All KCMEO Firearm Suicides (n=2367)	Training (n = 236)	Testing (n = 236)
Male	87.7% (2077)	88.6% (209)	90.3% (213)
King County Event*	91.8% (2172)	90.3% (213)	93.6% (221)
Race/Ethnicity			
AIAN	1.1% (26)	0.4% (1)	1.3% (3)
Asian/Pacific Islander	4.9% (116)	5.9% (14)	3.8% (9)
Black	3.8% (91)	4.2% (10)	3.4% (8)
Hispanic	1.9% (46)	3.4% (8)	0.8% (2)
White	87.6% (2074)	85.6% (202)	90.3% (213)
Other	0.6% (14)	0.4% (1)	0.4% (1)
Gun Type			
Handgun	75.0% (1776)	72.0% (170)	74.2% (175)
Shotgun	10.1% (239)	8.9% (21)	12.3% (29)
Rifle	8.0% (189)	8.9% (21)	8.5% (20)
Unspecified	6.9% (163)	10.2% (24)	5.1% (12)
Age			
<18	2.6% (61)	0.4% (1)	2.1% (5)
18–24	10.4% (245)	11.4% (27)	11.0% (26)
25–34	16.1% (380)	19.1% (45)	15.3% (36)
35–44	15.5% (366)	17.4% (41)	12.7% (30)
45–54	18.5% (437)	19.5% (46)	21.6% (51)
55–64	13.7% (324)	12.3% (29)	14.4% (34)
65–74	9.8% (233)	8.5% (20)	10.6% (25)
75–84	9.5% (225)	9.3% (22)	8.9% (21)
85+	4.1% (96)	2.1% (5)	3.4% (8)

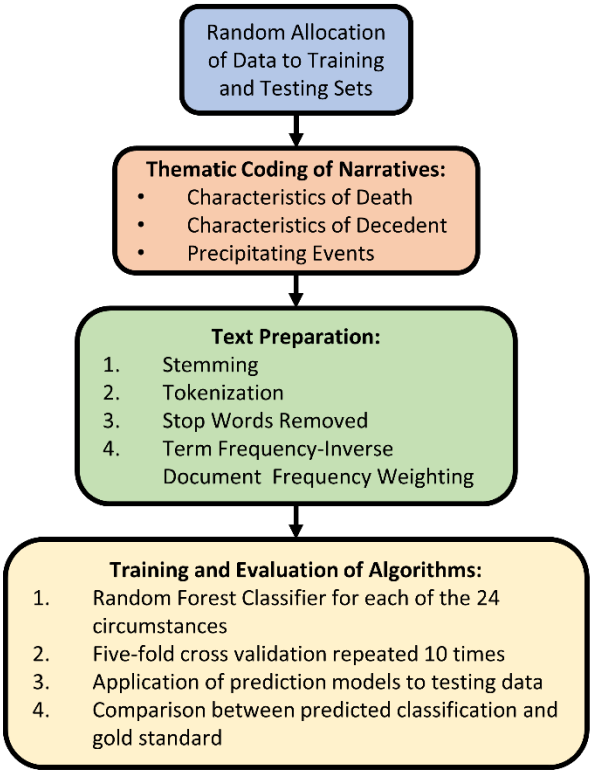
*Some records detail incidents where the firearm was discharged in another county, but the individual ultimately died in King County or incidents that were investigated by the King County Medical Examiner's Office on behalf of another jurisdiction
AIAN: American Indian and Alaska Native

Table 3.3 Performance of Random-Forest Natural Language Processing in Identifying Suicide Antecedents Compared with Gold Standard

			Performance in Training Data						Performance in Testing Data			
Classification	*N*	*%*	*Sensitivity*	*Specificity*	*PPV*	*NPV*	*N*	*%*	*Sensitivity*	*Specificity*	*PPV*	*NPV*
Murder Suicide	8	3.4%	0.0%	100.0%	—	96.6%	9	3.8%	11.1%	99.6%	50.0%	96.6%
Veteran	5	2.1%	0.0%	100.0%	—	97.9%	6	2.5%	0.0%	100.0%	—	97.5%
Suicide												
Left Note	60	25.4%	56.7%	97.2%	87.2%	86.8%	74	31.4%	58.1%	95.7%	86.0%	83.3%
Disclosed Suicidal Intent	23	9.7%	21.7%	99.5%	83.3%	92.2%	34	14.4%	11.8%	97.5%	44.4%	86.8%
Ongoing Depression	47	19.9%	80.9%	96.3%	84.4%	95.3%	51	21.6%	76.5%	95.7%	83.0%	93.7%
Ongoing Suicidal Ideation	35	14.8%	5.7%	100.0%	100.0%	85.9%	22	9.3%	18.2%	96.7%	36.4%	92.0%
Substance Use												
Any Substance Use	64	27.1%	57.8%	94.8%	80.4%	85.8%	41	17.4%	73.2%	93.3%	69.8%	94.3%
Alcohol	57	24.2%	68.4%	95.5%	83.0%	90.5%	31	13.1%	90.3%	92.2%	63.6%	98.4%
Marijuana	2	0.8%	0.0%	100.0%	—	99.2%	2	0.8%	0.0%	100.0%	—	99.2%
Opioids	5	2.1%	0.0%	100.0%	—	97.9%	5	2.1%	0.0%	100.0%	—	97.9%
Other Substances	6	2.5%	0.0%	100.0%	—	97.5%	6	2.5%	0.0%	100.0%	—	97.5%
Relationship Problems												
Any Relationship	50	21.2%	12.0%	99.5%	85.7%	80.8%	38	16.1%	15.8%	99.0%	75.0%	86.0%
Romantic Relationship	39	16.5%	2.6%	99.5%	50.0%	83.8%	29	12.3%	10.3%	100.0%	100.0%	88.8%
Familial/Friendly Relationship	11	4.7%	0.0%	100.0%	—	95.3%	7	3.0%	0.0%	100.0%	—	97.0%
Financial Stressors												
General Financial Problems	12	5.1%	0.0%	100.0%	—	94.9%	12	5.1%	0.0%	100.0%	—	94.9%
Unstable Employment	3	1.3%	0.0%	100.0%	—	98.7%	10	4.2%	0.0%	100.0%	—	95.8%
Unstable Housing	15	6.4%	0.0%	100.0%	—	93.6%	15	6.4%	0.0%	100.0%	—	93.6%
Health Stressors												
Decedent had Poor Health	51	21.6%	33.3%	98.4%	85.0%	84.3%	55	23.3%	38.2%	98.3%	87.5%	84.0%
Decedent had Terminal Diagnosis	6	2.5%	0.0%	100.0%	—	97.5%	7	3.0%	0.0%	100.0%	—	97.0%
Poor Health/Death of Friend/Family Member	7	3.0%	0.0%	100.0%	—	97.0%	9	3.8%	0.0%	100.0%	—	96.2%
Attempted Suicide/Suicide Death of Friend Family Member	2	0.8%	0.0%	100.0%	—	99.2%	1	0.4%	0.0%	100.0%	—	99.6%
Firearm Ownership												
Firearm Stored Locked	8	3.4%	0.0%	100.0%	—	96.6%	6	2.5%	0.0%	100.0%	—	97.5%
Firearm Recently Acquired	8	3.4%	12.5%	99.1%	33.3%	97.0%	21	8.9%	61.9%	98.1%	76.5%	96.3%
Criminal Justice Involvement												
Potential Criminal Activity	21	8.9%	0.0%	100.0%	—	91.1%	24	10.2%	0.0%	100.0%	—	89.8%

3.6 RELEVANT FIGURES

Figure 3.1 Step-by-Step Summary of Natural Language Processing



CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS

4.1 KNOWLEDGE GENERATED

This research has provided insight on suicide and firearm suicide risk following incarceration in the context of the prison and healthcare systems of the United States. In addition to identifying important opportunities for intervention, it highlights the need for continued collaboration between researchers and practitioners. Overall, we find an increase in the risk for suicide among individuals who have been incarcerated in a state prison. This was especially true for individuals incarcerated at a young age and those who had been sentenced for non-violent firearm involved crimes or a violent offense. While firearm suicide occurred less frequently among the previously incarcerated population than among the general population of Washington State, those who were incarcerated at a young age and those who were convicted with a firearm-related crime were at increased risk for firearm suicide. This is perhaps indicative of weaknesses in the current policies and systems intended to limit access to firearms after incarceration. Further investigation is warranted with analytic tools to specifically evaluate the relevance of firearm policy, especially the recently enacted laws surrounding Extreme Risk Protection Orders in 2016.

Many individuals who died by suicide following incarceration had also been found guilty of a substance-related crime—largely possession or driving under the influence, both of which are suggestive of substance use. Substance use was also a common thread in suicide narratives coded for NLP. The shared notion of substance use—including alcohol—in both study populations is concerning and indicates an opportunity for intervention. Other factors which commonly precipitate firearm suicide, while still observed in narratives, were more difficult to detect via NLP using random forest algorithms. Further work expanding NLP to include neural networks may be more appropriate for these types of data and allow researchers and practitioners to more easily utilize the rich data generated in death investigations.

Due to the limited performance of the NLP algorithms implemented, we were unable to apply them to further determine if situational factors preceding a firearm suicide vary based on a decedent's incarceration history, leaving Aim 2.1 unanswered. Continuing to improve these models will help determine best application of NLP to identify which risk factors occur most frequently among individuals with a history of incarceration, or within other populations of interest, and may provide insight as to which interventions may most appropriately address the health needs of a prison population.

4.2 Directions for Future Research

From this dissertation, there are many potentials for future research. One such opportunity includes expansion of the NLP methodology to include more complex methods such as neural networks. We have laid the groundwork for these next steps by establishing examples for coding narratives from medical examiner investigations, highlighting which circumstances occur frequently, and determining what types of outcomes may be suitable for a simpler approach. Neural networks are more complex than random-forest algorithms and require additional expertise in informatics and computer sciences. We aim to collaborate with experts in these fields to further this work to alleviate some burden of data management on those in the practice and research communities. After the development of higher quality algorithms, we can begin to apply these machine learning methods to larger samples of death investigation data and continue to better assess the relationship between incarceration history and specific antecedents of suicide.

In addition to building on our NLP algorithms, the dataset created for the cohort study lends itself to many future investigations. While only prison and death data were examined for this dissertation, additional data from the state patrol, jails, and courts have been linked to create a comprehensive dataset. This rich dataset will allow for further investigation of a multitude of questions, including some entirely unrelated to suicide or firearm safety. Some future analyses of

interest include the implications of pleading from a felony charge to a misdemeanor on risk of firearm suicide, as the severity of the charge has implications for legal firearm purchases. Future research may also investigate other periods during the criminal-legal process where individuals may be at increased risk for suicide, such as the time between arraignment and future court appearances. Further understanding the implications of the criminal-legal system on suicide risk will be complex, but it can provide additional insight as to where and how systems can be changed to improve the wellbeing of individuals involved in these systems.

Finally, while our work highlights the need for suicide intervention programs in prisons, it is unclear what interventions may be most effective. Ongoing work by research teams with clinically relevant backgrounds currently seeks to test some interventions in the jail setting.[85] The results of this work are still forthcoming and, if successful, it remains unclear whether the intervention under study will translate to the prison setting. This is an opportunity for clinicians and researchers to collaborate with correctional facilities to develop interventions that resonate with a prison population, to evaluate the efficacy of such interventions, and determine how to implement them in such a way that they are feasible and still impactful. As conversations about criminal justice reform continue and suicide prevention improves, the issues of adapting interventions to this vulnerable population should be revisited and will likely evolve to meet changing needs.

4.3 Policy and Public Health Implications

Our findings on suicide after release from prison suggest that inmates may benefit from additional mental health and substance use treatment during incarceration. Adding new evidence-based services—such as replacing or augmenting 12-step programs with medication assisted therapy for addiction that was recently piloted in a subset of Washington prisons—and improving upon existing programs—such as expanding healthcare to include all facets of mental health, not just those conditions deemed medically necessary—could be one step in transforming prisons from a punitive

measure to a rehabilitation experience. In addition to providing access to suicide interventions within prisons, it is imperative that everyone have access to care before crises escalate to the point of legal intervention and incarceration. Improving access to care, especially as it relates to mental health and substance use in the criminal-legal context, is a matter of equity. Given the high prevalence of mental illness in prisons,[25] incarceration rates could potentially be reduced by ensuring that heath care options are available to everyone. The existent literature supports mental health and substance use treatment as an effective *alternative* to incarceration that reduces recidivism.[38–40] These programs may also help reduce the burden of suicide—especially among individuals who cannot otherwise access mental health or substance use treatment. Offering them as alternative to prison improves accessibility to historically marginalized and minoritized groups and does not penalize oppressed populations for any mental illnesses or substance use problems they may be encountering. Ensuring this care is ongoing and that access to these resources is not revoked after the conclusion of a prison sentence or diversion program is also beneficial for overall health and wellbeing.[86] Diverting people from prison can have several other positive impacts on their lives—ranging from improved employment prospects to heathier and more meaningful relationships—which are inherently beneficial and can, in-turn, reduce risk of suicide.

To improve health outcomes and reduce risk of suicide, especially among former prison inmates, partners from public health, public safety, and academia will need to continue to work together. Collaboration between these entities will allow the development of interventions that are impactful in reducing suicide risk and improving mental health while additionally being feasible to deliver to the populations that need them the most. Data from this research and the research to follow can serve as evidence for policy makers seeking avenues for harm reduction—ranging from risk-based firearm policy to prison diversion programs. Improvements to the current criminal-legal system and delivery of mental health care and substance use treatment can vastly improve the lives of

millions and potentially prevent hundreds of suicides. Envisioning and implementing these crucial systems will rely on alliances between researchers, practitioners, and policy makers alike.

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