North Carolina Firearm-Related Injury Surveillance Through Emergency Rooms (NC-FASTER) CDC-RFA-CE20-2005

Linking North Carolina Violent Death Reporting System and NC DETECT Emergency Department Visit Data for Firearm Deaths

A Preliminary Report

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Prepared By:
Lucas M. Neuroth, Lois C. Johnson, Michael Dolan Fliss, and Anna E. Waller

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NC DETECT, Carolina Center for Health Informatics, Department of Emergency Medicine
Injury Prevention Research Center
University of North Carolina at Chapel Hill

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1. BACKGROUND, PURPOSE, AIMS

Background

In 2020, more than 45,000 people in the United States sustained fatal firearm-related injuries, with 53% of all suicides and 79% of all homicides involving a firearm [1]. Even more individuals suffer from nonfatal firearm-related injuries, which often result in long-term health consequences ranging from physical disability and paralysis, to chronic mental health issues including post-traumatic stress disorder. To address this public health crisis, Healthy People 2030 proposed violence prevention objectives targeting the reduction of firearm-related injuries.

In North Carolina (NC), firearms are the leading method of violent death. According to 2020 NC Violent Death Reporting System (NC-VDRS) data, 68% of violent deaths (n=1,651) involved firearms– approximately 60% of suicides and 82% of homicides. In 2021, according to the NC Disease Event Tracking and Epidemiologic Collection Tool (NC DETECT), the annual firearm injury emergency department (ED) visit rate in NC was 43.0 per 100,000 person-years (n=4,561 firearm injury visits), indicating the need for further surveillance of, and investigation into, firearm injuries treated in the ED to ultimately support prevention and intervention efforts.

Purpose

This project seeks an enhanced understanding of firearm deaths captured in the NC-VDRS. To accomplish this task, we are investigating the feasibility of linking these deaths with their most proximate ED visit (i.e., the ED visit immediately preceding death) captured in NC DETECT. Secondly, among decedents with linked NC-VDRS and ED visit records, we will attempt to identify and describe additional ED visits by the decedent to the same ED within 12 months of death.

Specific aims

Aim 1: Link firearm deaths captured in NC-VDRS to emergency department visits captured in NC DETECT that occurred in the year prior to death.

Aim 2: Identify and describe additional emergency department visits in the year prior to death for firearm injuries resulting in death in the ED.

Aim 3: Identify potential prevention opportunities using the linked NC-VDRS and ED visit data.

2. DATA CLEANING AND HARMONIZATION

North Carolina Violent Death Reporting System Data

The NC-VDRS is part of a national fatal injury active surveillance system, collecting information on resident and non-resident decedents within the state [2]. Trained coders review death certificates, coroner/medical examiner reports, and law enforcement reports, along with secondary data elements including hospital records and crime lab data, to abstract details surrounding fatal events meeting the case definition of a violent death [2]. After obtaining a Data User Agreement, we received the NC-VDRS data for violent deaths occurring from January 1st, 2019, through December 31st, 2020, identifying 4,768 decedents. Each record underwent an extensive data cleaning and harmonization process to derive potential linkage-relevant variables (Table 1).

Table 1. Key variables across NC-VDRS and ED visit data

Data Source	Variable Type	Variable Definition
North Carolina Violent Death Reporting System (NC-VDRS)	Age	Age of decedent in integer years
	Date of Birth	Decedent date of birth
	Date of Death	Decedent date of death
	Sex	Decedent sex (male or female only)
	Race/Ethnicity	Decedent race/ethnicity
	Residential Zip Code	First five digits of decedent's zip code of residence
	Residential County	Decedent's county of residence
	Residential City	Decedent's city of residence
	Residential State	Decedent's state of residence
	Mechanism	Weapon or means used to inflict the injury of decedent
	Intent	Intent of injury
	Place of Death	Decedent location of death
NC DETECT Emergency Department (ED) Visit Data	Age	Age of decedent in integer years
	Date of Birth	Decedent date of birth
	Sex	Decedent sex (male or female only)
	Race/Ethnicity	Decedent race/ethnicity
	Residential Zip Code	First five digits of decedent's zip code of residence
	Residential County	Decedent's county of residence
	Residential City	Decedent's city of residence
	Residential State	Decedent's state of residence
	Internal Tracking ID	Identifier associated with medical record number that uniquely identifies a patient and can be used to track repeat visits to the same facility/system
	Mechanism	Mechanism of injury, derived from ICD-10-CM injury mechanism codes and chief complaint free text
	Intent	Intent of injury, derived from ICD-10-CM injury mechanism codes
	ED Disposition	Anticipated location or status of patient following ED visit
	Date of Death	Decedent date of death

Table 1 provides a comprehensive list of the key variables used for 1) linkage and 2) describing demographic and injury characteristics of NC-VDRS firearm deaths, firearm-related ED visits, and firearm deaths in the ED.

The decedent's date of birth was converted into a character string (YYYY-MM-DD), as well as discrete day (1-31), month (1-12), and year indicators. Decedent age (integer), sex (Male/Female), race (White/Black/Asian/American Indian or Alaskan Native/Unknown), and ethnicity (Hispanic/Non-Hispanic) required no changes. The decedent's state of residence (two-character abbreviation) and county of residence (title-case string) were derived from state and county FIPS codes. Harmonized ZIP code of residence was collected as both 3-digit and 5-digit character strings, with codes 99999 and 88888 treated as unknown. Lastly, city of residence was treated as a title-case string, with various non-name values (example: . or /) set to unknown.

The intent behind the decedent's injury was determined based on their manner of death. This harmonized intent variable featured the following levels: intentional self-harm (suicide or intentional self-harm), assault (homicide), unintentional (unintentional firearm - inflicted by other person, unintentional firearm - self-inflicted, or unintentional firearm - unknown who inflicted), legal intervention (legal intervention (by police or other authority)), and undetermined. Injury mechanism was based on the first listed weapon type and collapsed to firearm, sharp instrument, asphyxiation, poisoning, other, and unknown. Event date, which in the case of the NC-VDRS records was the decedent's date of death, was treated as both a character string (YYYY-MM-DD) and a numeric value (the number of days from January 1st, 1970). The decedent's place of death was also coded, though not used as a linkage variable.

North Carolina Emergency Department Data

ED visit data were obtained from NC DETECT. NC DETECT is a statewide syndromic surveillance system that uses data from several data sources, including ED visits, EMS encounters, poison center calls, death certificates, school absenteeism, and the NC Health Information Exchange, NC HealthConnex. NC DETECT captures data from all 24/7 acute care, civilian, hospital-affiliated EDs within North Carolina [3]. Data are received through a data aggregator from participating hospitals (126 during 2018/2019; 127 during 2020) three times per day and provided through an automated data feed from each healthcare system's information system [4]. NC DETECT ED visit data were obtained through a Data Use Agreement and included 14,441,628 ED visits occurring from January 1st, 2018, through December 31st, 2020.

Patient date of birth was converted into a character string (YYYY-MM-DD), as well as discrete day (1-31), month (1-12), and year indicators. The patient's age (integer) was treated as unknown if implausibly large (>110 years). Sex was collapsed to three levels: male, female, and unknown. Patient race (White/Black/Asian/American Indian or Alaskan Native/Native Hawaiian or Pacific Islander/Other/Unknown) required no changes. To remain consistent with the NC-VDRS coding scheme for ethnicity, the patient's harmonized ethnicity was coded as Hispanic/Non-Hispanic, with Non-Hispanic including all individuals categorized as Non-Hispanic, Unknown, or missing ethnicity data. State of residence was converted from its full name to a two-character abbreviation, while county and city of residence required conversion to title-case and the removal of non-name strings. Lastly, ZIP code of residence was converted to a 3-digit and 5-digit string, with 99999 and 88888 treated as unknown.

The patient's injury intent was based on their reported International Classification of Diseases – 10th Version – Clinical Modification (ICD-10-CM) codes. ICD-10-CM codes were categorized using the Council of State and Territorial Epidemiologists (CSTE) guidelines for ED visits [5-7] and featured the following levels: intentional self-harm, assault, unintentional, legal-intervention, undetermined, injury diagnosis (no intent specified), non-injury diagnosis code. Intent classification was applied hierarchically in the order listed above, meaning any visits that did not qualify as intentional self-harm were then searched for the next series of codes. Eligible ICD-10-CM codes for each intent classification are collected in Table 2.

Injury mechanism was also based on ICD-10-CM codes, with case definitions again applied hierarchically. Firearm-related visits were identified using version two of the CDC's Firearm – all intents syndrome [8]. Sharp-instrument, asphyxiation, and poisoning-related visits were identified using ICD-10-CM codes collected in Table 2. Visits with an injury diagnosis code but none of the above mechanisms were coded as "other." Any remaining visits were coded as no injury diagnosis or mechanism. Event date, which in the case of the ED records was the patient's ED visit date, was treated as both a character string (YYYY-MM-DD) and a numeric value (the number of days from January 1st, 1970). Lastly, patient disposition when discharged from the ED was collapsed to left against or without medical advice, discharged home, transferred to another

facility, admitted to the hospital affiliated with that ED, died in the ED, and unknown, ED disposition was not used in the linkage process.

Table 2. Regular expression ICD-10-CM definitions for harmonized intent and mechanism variables

Variable	ICD-10-CM codes
Intent	
Intentional self-harm	(^|\\s)X7[1-9], (^|\\s)X8[0-3], (^|\\s)(T3[679]9|T4[123579]9)2, (^|\\s)(T5[12346789]9|T58[01]|T6[01235]9|T6[14][01])2, (^|\\s)(T3[6-9]|T[4-5][0-9]|T6[0-5]).{2}2, (^|\\s)T71.{2}2, (^|\\s)T1491
Assault	(^|\\s)X9[2-9], (^|\\s)Y0[0-9], (^|\\s)(T3[679]9|T4[123579]9)3, (^|\\s)(T5[12346789]9|T58[01]|T6[01235]9|T6[14][01])3, (^|\\s)(T3[6-9]|T[4-5][0-9]|T6[0-5]).{2}3, (^|\\s)T71.{2}3, (^|\\s)T7[46], (^|\\s)Y38
Unintentional	(^|\\s)[VW][0-9][0-9], (^|\\s)X[0-4][0-9], (^|\\s)X5[0-8], (^|\\s)(T3[679]9|T4[123579]9)1, (^|\\s)(T5[12346789]9|T58[01]|T6[01235]9|T6[14][01])1, (^|\\s)(T3[6-9]|T[4-5][0-9]|T6[0-5]).{2}1, (^|\\s)T71.{2}1
Legal intervention	(^|\\s)Y[3][5-8]
Undetermined	(^|\\s)Y2[1-9], (^|\\s)Y3[0-3], (^|\\s)(T3[679]9|T4[123579]9)4, (^|\\s)(T5[12346789]9|T58[01]|T6[01235]9|T6[14][01])4, (^|\\s)(T3[6-9]|T[4-5][0-9]|T6[0-5]).{2}4, (^|\\s)T71.{2}4
Injury diagnosis, no intent specified[a]	(^|\\s)S[0-9][0-9], (^|\\s)T0[7-9], (^|\\s)T[12][0-9], (^|\\s)T3[0-4, (^|\\s)T3[6-9], (^|\\s)T[4-6][0-9], (^|\\s)T7[0-6], (^|\\s)T79, (^|\\s)M97, (^|\\s)O9A[2-5], (^|\\s)T8404, (^|\\s)[V-W][0-9][0-9], (^|\\s)X[0-4][0-9], (^|\\s)X5[0-8], (^|\\s)X7[1-9], (^|\\s)X8[0-3], (^|\\s)X9[2-9], (^|\\s)Y0[0-9], (^|\\s)Y2[1-9], (^|\\s)Y3[0-8]
Non-injury diagnosis code	Any other ICD-10-CM code
Mechanism	
Firearm	CDC "Firearm injury – All intents" Version 2
Sharp instrument	(^|\\s)(W25|W26|X78|X99|Y28|Y354)
Asphyxiation	(^|\\s)T71
Poisoning	(^|\\s)(T3[6-9]|T[4-5][0-9]|T6[0-5])
Other injury	Injury diagnosis with none of the above mechanism codes
No injury diagnosis or mechanism	Non-injury diagnosis code

[a] Injury-related code with none of the abovementioned intent categories.

Descriptive analysis of data sources

To better understand the structure of the NC-VDRS and NC DETECT ED visit data and identify expected links, we undertook a descriptive analysis restricted to linkage eligible years of data (2019-2020). Statistics for potential linkage-relevant and dataset-specific variables were calculated within the following subsets of data: NC-VDRS – all records, NC-VDRS – firearm-related records, ED – all visits, ED – firearm-related visits, ED – firearm-related deaths in the ED.

All NC-VDRS deaths and NC-VDRS firearm deaths

Table 3 presents demographic and injury characteristics for all deaths and firearm deaths in NC-VDRS from 1/1/2019 – 12/31/2020. Most violent deaths were firearm deaths (65.6%, n=3,128), and most firearm deaths were suicides (54.2%, n=1,696). The mean age for all NC-VDRS deaths was 42.1 (SD=19.2), compared to 41.6 (SD=19.4) for firearm deaths. 58.9% (n=1,842) of firearm decedents were identified as White and 36.1% (n=1,129) were identified as Black.

Table 3. Demographic and injury characteristics for all deaths and firearm deaths in NC-VDRS from 1/1/2019 – 12/31/2020

	All NC-VDRS Deaths	NC-VDRS Firearm Deaths
Descriptive Variables	**Frequency (Percent)**	**Frequency (Percent)**
N	4,768 (100%)	3,128 (65.6%)
Age		
Mean (SD)	42.1 (19.2)	41.6 (19.4)
0-14	130 (2.7%)	59 (1.9%)
15-18	213 (4.5%)	164 (5.2%)
19-24	645 (13.5%)	493 (15.8%)
25-44	1,756 (36.8%)	1,155 (36.9%)
45-64	1,353 (28.4%)	789 (25.2%)
65+	671 (14.1%)	468 (15%)
Sex		
Male	3,752 (78.7%)	2,663 (85.1%)
Female	1,016 (21.3%)	465 (14.9%)
Race		
White	3,066 (64.3%)	1,842 (58.9%)
Black	1,435 (30.1%)	1,129 (36.1%)
Asian	76 (1.6%)	33 (1.1%)
American Indian/Alaskan Native	72 (1.5%)	48 (1.5%)
Missing	119 (2.5%)	76 (2.4%)
Ethnicity		
Hispanic	229 (4.8%)	146 (4.7%)
Non-Hispanic	4,537 (95.2%)	2,982 (95.3%)
Missing	2 (0%)	0 (0%)
Intent		
Assault	1,644 (34.5%)	1,303 (41.7%)
Intentional self-harm	2,884 (60.5%)	1,696 (54.2%)
Legal intervention	74 (1.6%)	68 (2.2%)
Undetermined	125 (2.6%)	20 (0.6%)
Unintentional	41 (0.9%)	41 (1.3%)
Mechanism[a]		
Asphyxiation	700 (14.7%)	--
Firearm	3,128 (65.6%)	3,128 (100%)
Other injury	295 (6.2%)	--
Poisoning	440 (9.2%)	--
Sharp instrument	201 (4.2%)	--
Unknown	4 (0.1%)	--
Place of Death		
Dead on arrival	51 (1.1%)	36 (1.2%)
ED/outpatient	627 (13.2%)	466 (14.9%)

Home	2,222 (46.6%)	1,387 (44.3%)
Hospice	22 (0.5%)	7 (0.2%)
Hospital inpatient	481 (10.1%)	262 (8.4%)
Nursing home, long-term care facility	10 (0.2%)	1 (0%)
Other[b]	1,355 (28.4%)	969 (31%)

[a] Mechanism represents the first or primary weapon type or means used to inflict the fatal injury.
[b] *Other* represents a situation where the place of death was the scene of the death and includes places such as bridge, road, and forest.

All ED visits, firearm-related ED visits, and firearm deaths in the ED

Table 4 presents demographic and injury characteristics for all ED visits, firearm-related visits, and firearm-related ED visits with a disposition of Died in the ED (firearm deaths in the ED) in NC DETECT from 1/1/2019 – 12/31/2020. Of the 9,356,642 ED visits from 2019 – 2020, 10,533 (0.1%) were associated with firearm injury syndromes. The mean age for all ED visits was 42.9 (SD=23.8), compared to 31.0 (SD=14.4) for firearm-related visits and 33.2 (SD=17.1) for firearm deaths in the ED. While females comprise the majority of ED visits overall (55.9%, n=5,226,881), males make up 84.7% (n=8,921) of firearm-related visits and 82.4% (n=322) of firearm deaths in the ED. 55.7% (n=5,213,927) of all ED visits were by individuals identified as White and 33.2% (n=3,106,844) were from individuals identified as Black. For firearm-related visits, 60.1% (n=6,332) of the ED visits were by patients identified as Black and 27.6% (n=2,904) were by patients identified as White. In comparison, 49.1% (n=192) of firearm deaths in the ED were Black and 23.8% (n=93) were White. The proportion of firearm-related visits with a disposition of Died in the ED (3.7%, n=391) was higher than the proportion of all ED visits with a disposition of Died in the ED (0.1%, n=11,451).

Table 4. Demographic and injury characteristics for all ED visits, firearm-related ED visits, and firearm deaths in the ED (NC DETECT) from 1/1/2019 – 12/31/2020

	All ED Visits	**Firearm-Related ED Visits**	**Firearm Deaths in the ED**
Descriptive Variables	**Frequency (Percent)**	**Frequency (Percent)**	**Frequency (Percent)**
N	9,356,642	10,533	391
Age			
Mean (SD)	42.9 (23.8)	31.0 (14.4)	33.2 (17.1)
0-14	1,153,805 (12.3%)	363 (3.4%)	16 (4.1%)
15-18	343,208 (3.7%)	1,192 (11.3%)	36 (9.2%)
19-24	828,225 (8.9%)	2,587 (24.6%)	85 (21.7%)
25-44	2,682,640 (28.7%)	4,632 (44%)	166 (42.5%)
45-64	2,337,019 (25%)	1,304 (12.4%)	49 (12.5%)
65+	2,009,701 (21.5%)	361 (3.4%)	28 (7.2%)
Missing	2,044 (0%)	94 (0.9%)	11 (2.8%)

Sex			
Male	4,126,573 (44.1%)	8,921 (84.7%)	322 (82.4%)
Female	5,226,881 (55.9%)	1,480 (14.1%)	56 (14.3%)
Missing	3,188 (0%)	132 (1.3%)	13 (3.3%)
Race			
White	5,213,927 (55.7%)	2,904 (27.6%)	93 (23.8%)
Black	3,106,844 (33.2%)	6,332 (60.1%)	192 (49.1%)
American Indian/Alaskan Native	135,858 (1.5%)	242 (2.3%)	18 (4.6%)
Asian	59,814 (0.6%)	25 (0.2%)	0 (0%)
Native Hawaiian/Pacific Islander	5,866 (0.1%)	4 (0%)	0 (0%)
Other	602,396 (6.4%)	651 (6.2%)	41 (10.5%)
Missing	231,937 (2.5%)	375 (3.6%)	47 (12%)
Ethnicity			
Hispanic	591,323 (6.3%)	442 (4.2%)	10 (2.6%)
Non-Hispanic	8,765,319 (93.7%)	10,091 (95.8%)	381 (97.4%)
Intent[a]			
Assault	62,015 (0.7%)	1,820 (17.3%)	56 (14.3%)
Injury diagnosis, no intent specified	553,808 (5.9%)	1,153 (10.9%)	33 (8.4%)
Intentional self-harm	24,236 (0.3%)	158 (1.5%)	35 (9%)
Legal intervention	681 (0%)	19 (0.2%)	2 (0.5%)
Non-injury diagnosis[b]	7,496,818 (80.1%)	1,022 (9.7%)	24 (6.1%)
Undetermined	6,965 (0.1%)	130 (1.2%)	7 (1.8%)
Unintentional	1,212,119 (13%)	6,231 (59.2%)	234 (59.8%)
Mechanism[a]			
Asphyxiation	1,105 (0%)	--	--
Firearm	10,533 (0.1%)	10,533 (100%)	391 (100%)
Poisoning	138,124 (1.5%)	--	--
Sharp instrument	45,901 (0.5%)	--	--
Other injury[c]	1,665,183 (17.8%)	--	--
Non-injury diagnosis[b]	7,495,796 (80.1%)	--	--
ED Disposition			
Admitted	1,505,166 (16.1%)	3,110 (29.5%)	--
Died	11,451 (0.1%)	391 (3.7%)	391 (100%)
Discharged	7,127,460 (76.2%)	5,499 (52.2%)	--
Left	254,701 (2.7%)	154 (1.5%)	--
Transferred	226,361 (2.4%)	995 (9.4%)	--
Unknown	54,777 (0.6%)	87 (0.8%)	--
Missing	176,726 (1.9%)	297 (2.8%)	--

[a] Intent and mechanism for ED visits was derived from ICD-10-CM injury mechanism codes and chief complaint free text. See Table 2 for more details.
[b] Mechanism and intent were coded as *non-injury diagnosis* for ED visits with neither an injury diagnosis nor an injury mechanism ICD-10-CM code.
[c] Mechanism was coded as *other* for ED visits with an injury diagnosis code but a mechanism type that was not one of: asphyxiation, firearm, poisoning, or sharp instrument. See Table 2 for more details.

Firearm ED visits, firearm deaths in the ED, and NC-VDRS firearm deaths

Table 5 presents demographic and injury characteristics for firearm-related ED visits, firearm-related ED visits resulting in death, and firearm deaths in NC-VDRS from 1/1/2019 –

12/31/2020. The mean age for NC-VDRS firearm deaths (41.6, SD=19.4) was higher than for firearm-related ED visits (31.0, SD=14.4) and firearm deaths in the ED (33.2, SD=17.1). While 27.6% (n=2,904) of firearm-related ED visits and 23.8% (n=93) of ED firearm deaths in the ED were for White individuals, 58.9% (n=1,842) of firearm decedents in NC-VDRS were White. While 60.1% (n=6,332) of firearm-related ED visits and 49.1% (n=192) of firearm deaths in the ED were for Black individuals, 36.1% (n=1,129) of firearm decedents in NC-VDRS were Black. Compared to 1.3% (n=41) of NC-VDRS firearm deaths that were classified as unintentional, the majority of firearm-related ED visits (59.2%, n=6,231) and firearm deaths in the ED (59.8%, n=234) were classified as unintentional.

Table 5. Demographic and injury characteristics for firearm-related ED visits, firearm deaths in the ED (NC DETECT), and firearm deaths (NC-VDRS) from 1/1/2019 – 12/31/2020

	Firearm-Related ED Visits	Firearm Deaths in the ED	NC-VDRS Firearm Deaths
Descriptive Variables	**Frequency (Percent)**	**Frequency (Percent)**	**Frequency (Percent)**
N	10,533	391	3,128
Age			
Mean (SD)	31.0 (14.4)	33.2 (17.1)	41.6 (19.4)
0-14	363 (3.4%)	16 (4.1%)	59 (1.9%)
15-18	1,192 (11.3%)	36 (9.2%)	164 (5.2%)
19-24	2,587 (24.6%)	85 (21.7%)	493 (15.8%)
25-44	4,632 (44%)	166 (42.5%)	1,155 (36.9%)
45-64	1,304 (12.4%)	49 (12.5%)	789 (25.2%)
65+	361 (3.4%)	28 (7.2%)	468 (15%)
Missing	94 (0.9%)	11 (2.8%)	0 (0%)
Sex			
Male	8,921 (84.7%)	322 (82.4%)	2,663 (85.1%)
Female	1,480 (14.1%)	56 (14.3%)	465 (14.9%)
Missing	132 (1.3%)	13 (3.3%)	0 (0%)
Race			
White	2,904 (27.6%)	93 (23.8%)	1,842 (58.9%)
Black	6,332 (60.1%)	192 (49.1%)	1,129 (36.1%)
Asian	25 (0.2%)	0 (0%)	33 (1.1%)
American Indian/Alaskan Native	242 (2.3%)	18 (4.6%)	48 (1.5%)
Native Hawaiian/Pacific Islander	4 (0%)	0 (0%)	0 (0%)
Other	651 (6.2%)	41 (10.5%)	0 (0%)
Missing	375 (3.6%)	47 (12%)	76 (2.4%)
Ethnicity			
Hispanic	442 (4.2%)	10 (2.6%)	146 (4.7%)
Non-Hispanic	10,091 (95.8%)	381 (97.4%)	2,982 (95.3%)
Intent[a]			
Assault	1,820 (17.3%)	56 (14.3%)	1,303 (41.7%)
Injury diagnosis, no intent specified	1,153 (10.9%)	33 (8.4%)	0 (0%)
Intentional self-harm	158 (1.5%)	35 (9%)	1,696 (54.2%)
Legal intervention	19 (0.2%)	2 (0.5%)	68 (2.2%)
Unintentional	6,231 (59.2%)	234 (59.8%)	41 (1.3%)
Non-injury diagnosis[b]	1,022 (9.7%)	24 (6.1%)	0 (0%)

Undetermined	130 (1.2%)	7 (1.8%)	20 (0.6%)

[a] Intent for ED visits was derived from ICD-10-CM injury mechanism codes and chief complaint free text. See Table 2 for more details.
[b] Intent was coded as *non-injury diagnosis* for ED visits with neither an injury diagnosis nor an injury mechanism ICD-10-CM code.

Expected firearm-related links between data sources

During the linkage eligible period, 3,128 violent deaths were firearm related. Of these 3,128 NC-VDRS records, 728 had a place of death listed as within a medical facility (466 in an ED/outpatient facility; 262 in a hospital/inpatient facility). We expected most NC-VDRS records with an "ED/outpatient" place of death to have a high-quality link to ED records with a disposition of "died", as they should have been admitted to an ED/outpatient facility (generating an ED record) and died there (not moving to a different part of the medical facility), according to the NC-VDRS coding of "place of death." We also expected a high proportion of "hospital/inpatient" place of death NC-VDRS records to link to ED visits with a disposition of "admitted," as the ED is one of the entry points for hospital admission. Links between NC-VDRS records and ED visits with a disposition of 'transferred" were also expected, reflecting scenarios where the first medical facility would be underequipped to handle the decedent's fatal injury.

Additionally, we anticipated fewer high-quality links for decedents with a place of death at home (n=1,387), as deceased individuals should not be transported to the ED. However, we expected that some of these NC-VDRS records may link to ED visits with a disposition of "discharged home" or "left without or against advice." Given decedents could link to ED visits within 31 days of their date of death, it is possible they were discharged or left an ED prior to a violent death outside of a medical facility.

3. DATA LINKAGE PROCESS

Pre-linkage data filtering

Following data cleaning and harmonization, records were restricted to the linkage eligible period of January 1st, 2019, through December 31st, 2020. While a linkage could be undertaken between the two datasets as is, the large number of comparisons necessary (4,768 NC-VDRS records each compared to 9,346,642 ED visits) would be computationally inefficient, requiring significant amounts of time for the model to converge and output potential links.

To reduce the number of comparisons, the ED dataset underwent an additional pre-filtering stage. For each unique internal tracking ID, only visits occurring on the most recent date were eligible for the linkage process. This was done to prevent many-to-one linkages that would be identified through the one-year look-back period. For example, if a patient associated with an internal tracking ID had visits on June 30th, July 12th, and December 3rd, 2019, only the December 3rd visit would be eligible for linkage. Through the application of this filter, the number of linkage eligible ED visits was reduced from 9,346,642 to 5,086,654 (Figure 1).

Linkage approach

While we initially proposed a deterministic linkage process, we observed that ED visits where the patient died in the ED tended to have poorer data quality, particularly surrounding linkage-relevant variables, than visits with other dispositions, with more missing information. Given the differences in ED data quality and completeness by disposition and that this is an initial investigation into the feasibility of linking NC-VDRS and ED data, we felt a probabilistic linkage process would be more appropriate, especially given this method's performance when data quality is questionable [9].

The linkage between eligible NC-VDRS records and ED visits utilized the fastLink program within RStudio (4.2.0). fastLink is a probabilistic data linkage framework that accounts for missing data among linkage variables [9]. Each potential link between an NC-VDRS record and ED visit produces an agreement pattern across the proposed linkage variables [10]. Agreement patterns are then aggregated and used to estimate model parameters that produce each link's linkage probability– the probability that the two records belong to the same individual [10].

Figure 1. Summary of the NC-VDRS and ED data linkage process

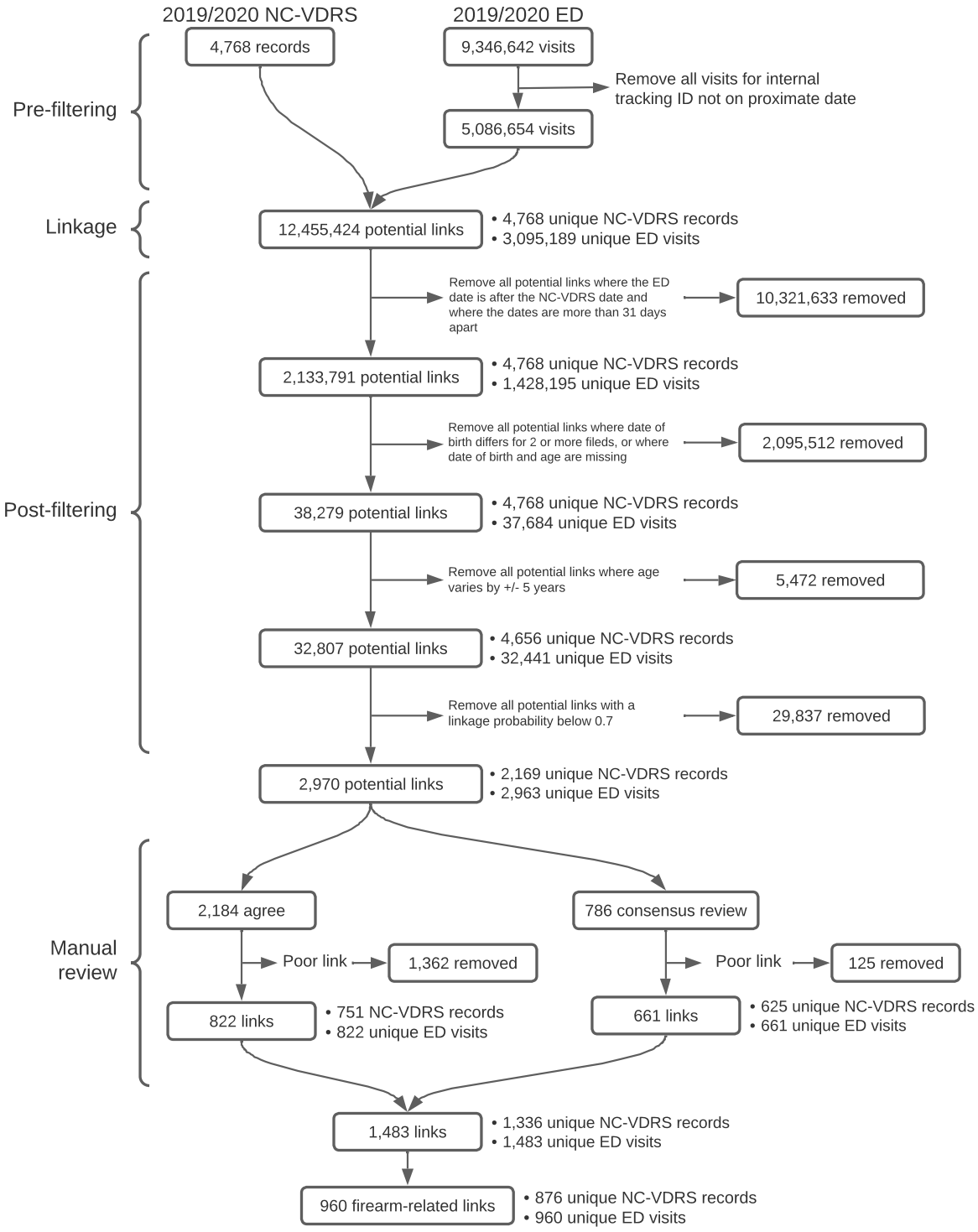


Figure 1 is a flow diagram of the various stages involved in the preliminary linkage process between NC-VDRS records and ED visit data. Each data source went through a pre-filtering process before the linkage identified potential links. Potential links were then filtered and manually reviewed to determine a final dataset of high-quality links.

We selected seven harmonized variables based upon their discriminatory power for use in the linkage model: date of birth (character string), age, sex, 3-digit ZIP code of residence, county of residence, mechanism of injury, and event date (numeric). Exact matching (agree/disagree) was specified for date of birth, sex, ZIP code, county, and mechanism. Age and event date were modeled using numeric matching with partial agreement; a difference of +/- 1 was considered agreement, while a difference of 2 was partial agreement and 3+ was disagreement.

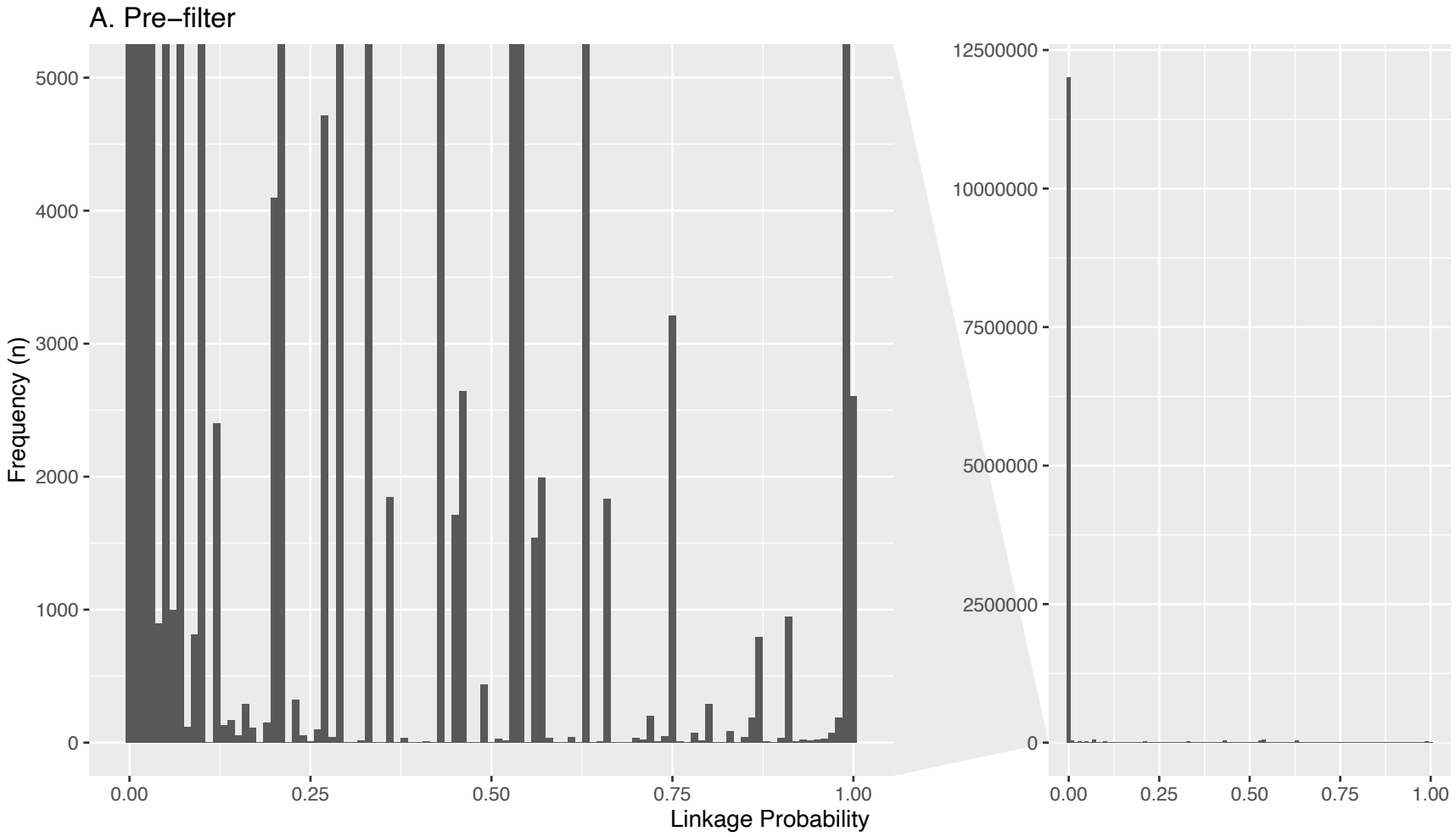
While fastLink allows for linkage probability thresholds and automatic deduplication of many-to-one links, we opted to collect all potential links to better evaluate linkage performance. Following the initial implementation of our linkage model we identified 12,455,424 potential links of varying quality, representing 4,768 unique NC-VDRS records and 3,095,189 unique ED visits.

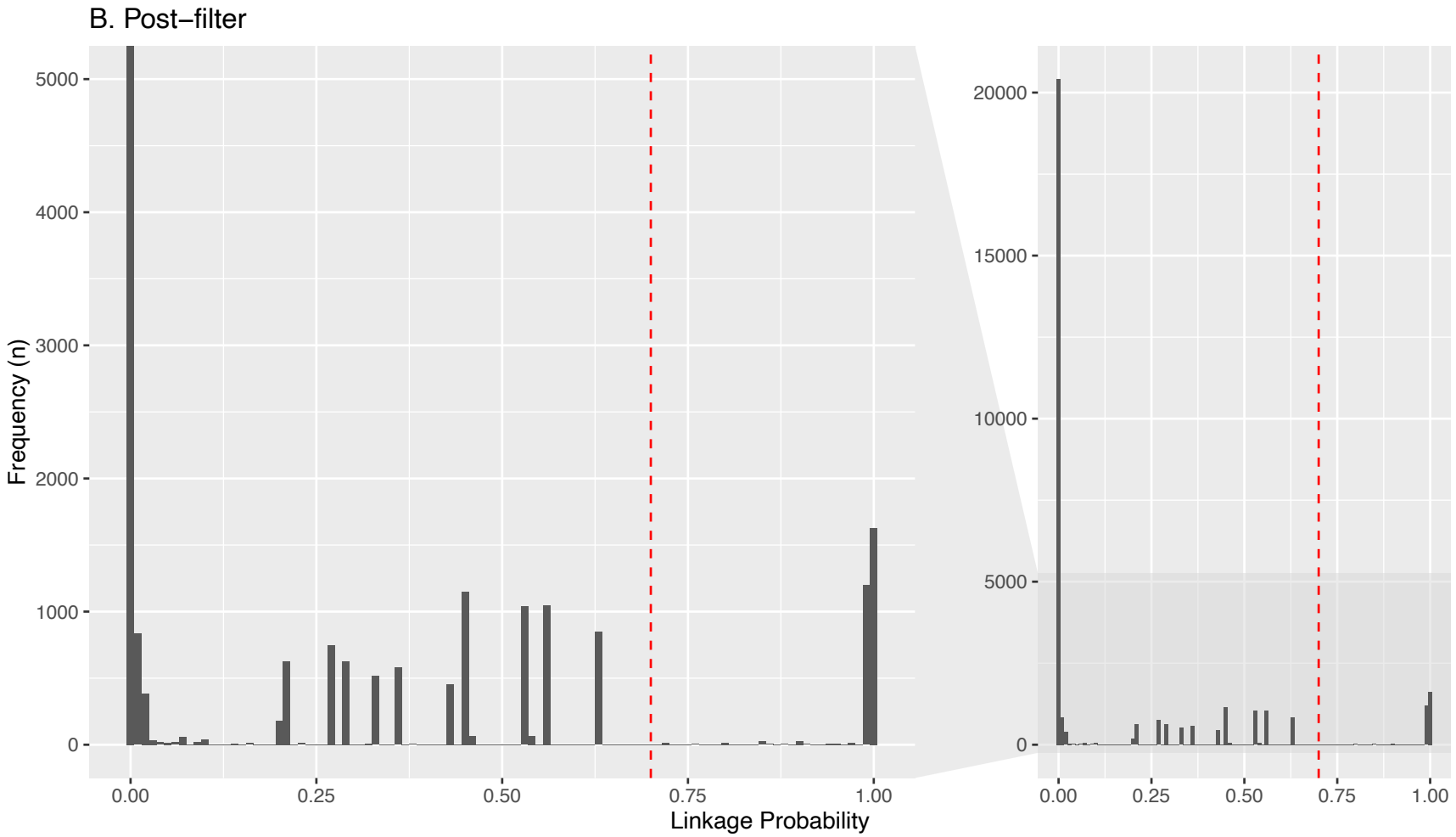
Post-linkage data filtering

Of the 12,455,424 potential links identified, 12,033,960 had a linkage probability of less than 0.01 (Figure 2A). To separate potentially high-quality links from the large number of poor-quality links, a series of post-linkage data filters were implemented. The first filter required the potential link's ED visit to be within the 31 days prior to its NC-VDRS death date and excluded any observation where the ED visit date occurred *after* the NC-VDRS death date, reducing the number of potential links from 12,455,424 to 2,133,791.

The second filter involved date of birth, requiring the date of birth from the two data sources to differ on no more than one element (day, month, or year) or, for potential links with a missing date of birth, to not be missing age in either dataset. For example, a potential link differing on day of birth but not month or year of birth would be included, while one differing on month and day of birth but not year would be excluded. This filter further reduced the number of potential links to 38,279. With the third and final filter, any potential link with age differing by +/- 5 years between the data sources was excluded, reducing the number of potential links to 32,807.

Figure 2. Linkage probabilities at various points in the post-linkage cleaning process




B. Post−filter
Frequency (n)
5000
4000
3000
2000
1000
0
0.00
0.25
0.50
0.75
1.00
Linkage Probability
20000
15000
10000
5000
0
0.00
0.25
0.50
0.75
1.00

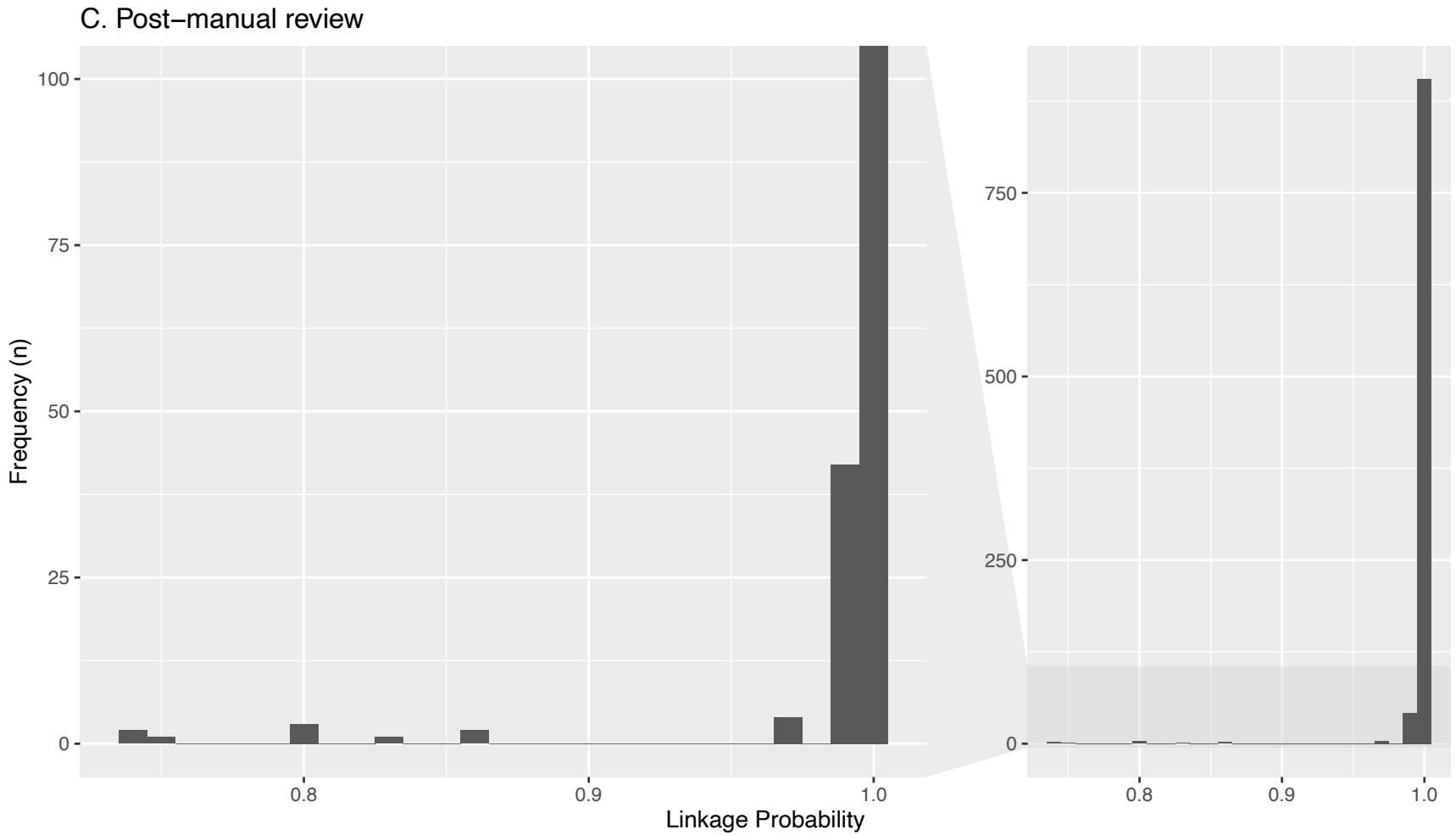


Figure 2 presents histograms of linkage probabilities throughout the post-linkage data cleaning process. (A) All potential links output from fastLink prior to filtering; (B) All potential links after applying filters, with the vertical red line representing the 0.70 probability threshold; (C) All high-quality links identified during the two-part manual review process.

After the application of the three post-linkage filters, clear clustering was observed among the remaining potential links along the linkage probability histogram (Figure 2B). Clusters around a linkage probability of 0.00 and 0.15 to 0.65 identified as poor links, while those above 0.70 indicated potentially high-quality links. Therefore, we restricted the remaining potential linkages to those with a linkage probability of above 0.70, resulting in 2,970 potential high-quality links.

Manual review process

The 2,970 potentially high-quality links were then subjected to a two-stage manual review process. In the first stage, two research assistants independently reviewed each potential link, utilizing its agreement pattern for the linkage variables, as well as data-source-specific variables, including NC-VDRS place of death and ED disposition. Each potential link was labeled as either a high-quality link, potentially a high-quality link, or not a high-quality link by each reviewer independently. Following the first stage of the review, the reviewers agreed on 76.8% of links (Table 6).

Table 6. Agreement between reviewers – manual review stage 1

	Reviewer 2		
Reviewer 1	**High-quality**	**Potentially high-quality**	**Not high-quality**
High-quality	822	326	70
Potentially high-quality	62	97	76
Not high-quality	36	119	1362

Green shading indicates links finalized in the first stage of the manual review process, while cells shaded in red indicate those progressing to the second stage consensus review.

Of the 2,281 potential links in which the reviewers agreed, 822 were identified as high-quality, while 1,362 were not high-quality and excluded from further analysis. The 689 potential links in which the reviewers did not agree, along with the 97 both reviewers identified as potentially high quality were subjected to a second round of the manual review process. In the second-round review, reviewers discussed together each potential observation until a consensus was met, with links being either high quality or not. At the end of the second round of review, an additional 125 potential links were excluded, while 661 were identified as high quality. In total, 1,483 high quality links were identified through the manual review process (Figure 2C), with 960 involving a firearm-related NC-VDRS record.

Linkage results

From December 31st, 2019, through January 1st, 2020, we identified 4,768 NC-VDRS records and 5,086,654 ED visits that were eligible for data linkage. After applying the linkage algorithm, implementing a multi-stage post-linkage filtering process, and conducting two rounds of manual review, we identified 1,483 high-quality links. Of these high-quality links, 960 involved an NC-VDRS record with a firearm-related mechanism, representing 876 unique NC-VDRS records and 960 unique ED visits, and are the focus of this preliminary report.

Table 7. Characteristics of firearm-related NC-VDRS records and linked NC-VDRS records

	All firearm-related records[a]		Linked firearm-related records		Percentage linked
Variable	**Frequency**	**Percent[b]**	**Frequency**	**Percent[b]**	**Percent[c]**
N	3128	--	876	--	28.0
Age					
Mean (SD)	41.6 (19.4)	--	37.2 (18.9)	--	--
0 - 14 years	59	1.9	31	3.5	52.5
15 - 18 years	164	5.2	73	8.3	44.5
19 - 24 years	493	15.8	163	18.6	33.1
25 - 44 years	1155	36.9	347	39.6	30.0
45 - 64 years	789	25.2	156	17.8	19.8
65+ years	468	15.0	106	12.1	22.6
Sex					
Male	2663	85.1	751	85.7	28.2
Female	465	14.9	125	14.3	26.9
Race					
White	1842	58.9	391	44.6	21.2
Black	1129	36.1	429	49.0	38.0
Asian	33	1.1	10	1.1	30.3
American Indian/Alaskan Native	48	1.5	31	3.5	64.6
Unknown	76	2.4	15	1.7	19.7
Hispanic Ethnicity					
Hispanic	146	4.7	28	3.2	19.2
Non-Hispanic	2982	95.3	848	96.8	28.4
Intent					
Assault	1303	41.7	469	53.5	36.0
Intentional self-harm	1696	54.2	354	40.4	20.9
Legal intervention	68	2.2	24	2.7	35.3
Undetermined	20	0.6	4	0.5	20.0
Unintentional	41	1.3	25	2.9	61.0
Place of Death					
Dead on arrival	36	1.2	26	3.0	72.2
ED/outpatient	466	14.9	416	47.5	89.3
Home	1387	44.3	147	16.8	10.6
Hospice	7	0.2	3	0.3	42.9
Hospital inpatient	262	8.4	192	21.9	73.3
Nursing home, long-term care facility	1	0.0	0	0.0	0.0
Other[d]	68	2.2	24	2.7	35.3

[a] NC-VDRS records from January 1st, 2019, through December 31st, 2020 with a firearm-related injury mechanism.

[b] Column percentage.
[c] Percentage linked calculated as (frequency linked records / frequency all records) * 100.
[d] Other represents a situation where the place of death was the scene of the death and includes places such as bridge, road, and forest.

In total, 28.0% of firearm-related NC-VDRS records linked to at least one ED visit (Table 7). Linked firearm-related decedents tended to be younger, with a mean age of 37.2 years, compared to all records. More high-quality links were identified for younger decedents compared to older decedents, with the percent linked decreasing with age. Males were similarly overrepresented among high quality links and all firearm-related NC-VDRS records, accounting for approximately 85% of decedents. There was no noticeable difference in linkage percentage by sex.

While the majority of firearm-related NC-VDRS records were White (58.9%), Black decedents were most common among the linked records (49.0%). Decedents of American Indian/Alaskan Native race had the highest proportion of high-quality links with 64.6% of firearm-related NC-VDRS records linking to at least one ED visit. Black decedents had a linkage proportion of 38.0%, while only 21.2% of White decedents had a high-quality link. Non-Hispanic decedents were more common among the linked records, accounting for 96.8% of links and had a higher percentage of high-quality links compared to Hispanic decedents.

Assaults accounted for the majority (53.5%) of linked records, while intentional self-harm was the most numerous intent classification among all firearm-related NC-VDRS records. While only accounting for 1.3% of records, 61.0% of decedents who died due to an unintentional firearm-related injury had at least one high-quality link. On the other hand, of the 1,696 intentional self-harm firearm-related violent deaths, only 20.9% had a high-quality link to an ED visit.

Of the decedents who died in an ED/outpatient facility, 416 of 466 had a high-quality link– a linkage proportion of 89.3%. Records where the decedent's location of death was a hospital/inpatient facility linked at a rate of 73.3% (192 of 262 records) and those who were dead on arrival linked at a rate of 72.2% (26 of 36 records). Records with a non-medical facility place of death, such as home or other, linked at much lower rates.

Table 8. Linkage performance by NC-VDRS intent; Firearm-related deaths 2019-2020

	Place of Death Percent linked (frequency linked | total records)		
Intent	**All Records**	**Medical Facility[a]**	**Other Location[b]**
Assault	36.0 (469|1303)	81.7 (388|475)	9.8 (81|828)
Intentional self-harm	20.9 (354|1696)	85.8 (181|211)	11.6 (173|1485)
Legal intervention	35.3 (24|68)	87.0 (20|23)	8.9 (4|45)
Undetermined	20.0 (4|20)	75.0 (3|4)	6.3 (1|16)
Unintentional	61.0 (25|41)	82.6 (19|23)	33.3 (6|18)

[a] Medical facilities include decedents with a place of death in ED/oupatient, hospital inpatient, hospice, or nursing/long-term care facilities;
[b] Other places of death include Dead on Arrival, Home, and Other;
NA - Mechanism/intent pairing was not present.

Linkage performance was generally higher among NC-VDRS deaths occurring in a medical facility (defined as an ED/outpatient, hospital inpatient, hospice, or nursing/long-term care facility) compared to other locations, regardless of the fatal injury's intent (Table 8). Among decedents within a medical facility, the percentage of records linked ranged from 75% (undetermined intent) to 87% (legal intervention). Similarly, firearm-related violent deaths occurring in an "other" location with an undetermined intent had the lowest linkage percentage (6.3%), while unintentional injury had the highest (33.3%). The lower linkage percentage among decedents in other locations is primarily driven by the large number of individuals dying in their home and not surviving long enough for transport to a medical facility. While linkage performance may seem poor for certain subgroups, such as deaths in a medical facility with an undetermined intent, in many instances there are relatively few records available for linkage. When considering linkage performance, readers should not only consider reported linkage percentages, but the underlying frequencies as well.

Lastly, of the 876 unique firearm-related NC-VDRS records with a high-quality link, 796 linked to only one ED visit on their proximate visit date (Table 9). We identified 80 many (ED) to one (NC-VDRS) links, with 76 NC-VDRS records each linking to two ED visits and four records each linking to three visits. The most common disposition across linked records was died in the ED (52.5%), followed by admitted (18.4%) and unknown (12.0%). Among many-to-one links, the most common disposition was "admitted | transferred," indicating scenarios when the

decedent was transferred from one institution to another, then admitted from the ED or died at the second institution.

Table 9. Selected proximate ED visit characteristics for linked NC-VDRS records

Variable	Frequency (Percent)
Proximate ED visits linked[a]	
1	796 (90.9)
2	76 (8.7)
3	4 (0.5)
Disposition[b]	
Admitted	161 (18.4)
Admitted | Admitted	5 (0.6)
Admitted | Died	5 (0.6)
Admitted | Died | Discharged	1 (0.1)
Admitted | Discharged	8 (0.9)
Admitted | Discharged | Unknown	1 (0.1)
Admitted | Transferred	26 (3.0)
Admitted | Transferred | Unknown	1 (0.1)
Admitted | Unknown	4 (0.5)
Died	460 (52.5)
Died | Died	7 (0.8)
Died | Died | Transferred	1 (0.1)
Died | Discharged	2 (0.2)
Died | Left	1 (0.1)
Died | Transferred	5 (0.6)
Died | Unknown	7 (0.8)
Discharged	63 (7.2)
Discharged | Transferred	2 (0.2)
Left	1 (0.1)
Transferred	6 (0.7)
Transferred | Unknown	3 (0.3)
Unknown	105 (12.0)
Unknown | Unknown	1 (0.1)

[a] The number of unique ED visits linking to a unique NC-VDRS record on their proximate visit date

[b] The collapsed ED dispositions across all of each NC-VDRS record's linked ED visits, with "|" delineating each discrete visit's disposition.

4. INVESTIGATION OF ED VISITS IN THE YEAR PRIOR TO DEATH

Identification of ED visits in the year prior to death

Through our data linkage model, multiple post-linkage filters, and a two-stage manual review process, we identified high-quality links between 876 unique firearm-related deaths in the NC-VDRS records and 960 unique ED visits. Each linked ED visit features an internal tracking ID that allows for the identification of all of that patient's visits to the given medical facility's ED. We queried the 14,441,628 ED visits occurring from January 1st, 2018, through December 31st, 2020, to identify ED visits occurring in the 365 days prior to each NC-VDRS record's date of death using their linked internal tracking IDs.

The number of ED visits in the 365 days prior to the decedent's date of death were summed and used to dichotomize NC-VDRS records into (1) single visit – those with only one ED visit in the year prior to their death, and (2) multiple visits – those with two or more ED visits in the year prior to death. "Last ED visit" indicated if the patient's final (proximate) ED visit was on their death date or before their death date. "Any self-harm (SH) or suicidal ideation (SI)" indicated if any of the decedent's past-year ED visits were flagged for: only SH, only SI, both SH and SI, or no prior SH or SI. "Prior SH or SI" indicated whether the decedent had an ED visit prior to their date of death with an SI flag, SH flag, or both. For example, if a decedent presented to the ED a week prior to their death with suicidal ideation, they would be flagged as "prior SI," while a decedent presenting with self-harm only on the day of their death would be flagged "no prior SI or SH." SI and SH flags were based on the ED visit's ICD-10-CM codes. Lastly, the number of days elapsed since the patient's first ED visit in the year prior to death was calculated for each of their subsequent ED visits as the difference between the two visit dates.

Descriptive analysis of ED visits in the year prior to death

For the 876 linked firearm-related NC-VDRS records, we identified 1,312 ED visits occurring in the 365 days prior to the decedent's date of death. About 78% of NC-VDRS records only had one ED visit associated with their internal tracking IDs (n=679), while 197 records had two or more prior-year ED visits (Table 10). The majority (53.3%) of decedents with multiple prior-year ED visits only had two, with a range from two to nineteen visits. Over 90% of those with multiple ED visits in the year prior to death had 2-5 visits. Decedents often had a date of death

concordant with their final ED visit date. This was more common for single prior-year decedents (81.6%) vs. multiple visit decedents (72.6%). Any indication of SH or SI across all ED visits was more common for multiple visit decedents, with 13.2 % reporting only SH, 9.1% reporting only SI, and 1.5% reporting SH and SI. Similarly, prior SH or SI was more common among decedents with multiple prior-year visits (18.3%) compared to those with a single visit (2.5%).

Table 10. Characteristics of prior-year ED visits for linked NC-VDRS records by prior-year visit frequency

	Overall	Single ED visit	Multiple ED visits
	Frequency (Percent)	Frequency (Percent)	Frequency (Percent)
N	876	679	197
Prior-year ED visits			
1	679 (77.5)	679 (100.0)	--
2	105 (12.0)	--	105 (53.3)
3	40 (4.6)	--	40 (20.3)
4	21 (2.4)	--	21 (10.7)
5	12 (1.4)	--	12 (6.1)
6	7 (0.8)	--	7 (3.6)
7	4 (0.5)	--	4 (2.0)
8	2 (0.2)	--	2 (1.0)
10	2 (0.2)	--	2 (1.0)
11	2 (0.2)	--	2 (1.0)
12	1 (0.1)	--	1 (0.5)
19	1 (0.1)	--	1 (0.5)
Last ED Visit[a]			
On date of death	697 (79.6)	554 (81.6)	143 (72.6)
Before date of death	179 (20.4)	125 (18.4)	54 (27.4)
Any ED visit with SH or SI[b]			
No SH or SI	777 (88.7)	627 (92.3)	150 (76.1)
Only SH	74 (8.4)	48 (7.1)	26 (13.2)
Only SI	22 (2.5)	4 (0.6)	18 (9.1)
SH and SI	3 (0.3)	0 (0.0)	3 (1.5)
Prior ED visit with SH or SI[c]			
No Prior SH or SI	823 (93.9)	662 (97.5)	161 (81.7)
Only Prior SH	28 (3.2)	13 (1.9)	15 (7.6)
Only Prior SI	23 (2.6)	4 (0.6)	19 (9.6)
Prior SH and SI	2 (0.2)	0 (0.0)	2 (1.0)

Prior-year ED visits are those occurring within 365 days of the decedent's date of death.

[a] Indicates whether the decedent's date of death the same as the date of their most recent (proximate) ED visit.

[b] Indicates whether any of the decedent's prior-year ED visits were flagged as self-harm (SH) or suicidal ideation (SI).

[c] Indicates whether the decedent had an ED visit with an SI or SH flag prior to their date of death. This could include their proximate ED visit if occurring on a date before their date of death.

Demographically, single-visit and multiple visit decedents were relatively similar. Single-visit decedents were slightly younger than their multiple visit counterparts, with a mean age of 36.7 years compared to 39.1 years, which seems to be driven by a higher proportion of 0-to-14-year-olds (Table 11). Males make up the majority of decedents, regardless of prior-year ED visit status, accounting for about 85% of all linked firearm-related NC-VDRS records. Black decedents are the most numerous for single-visit decedents (49.6%), followed by White decedents (43.5%). For those with multiple visits, White and Black decedents each make up approximately 47% of records. Interestingly, only one Hispanic decedent (0.5%) had multiple prior-year visits, while 4% of single-visit decedents (n=27) were of Hispanic ethnicity.

Table 11. Characteristics of linked NC-VDRS records by prior-year ED visit frequency

	Overall	Single ED visit	Multiple ED visits
Variable	**Frequency (Percent)**	**Frequency (Percent)**	**Frequency (Percent)**
N	876	679	197
Age			
Mean (SD)	37.2 (18.9)	36.7 (18.8)	39.1 (19.1)
0 - 14 years	31 (3.5)	27 (4.0)	4 (2.0)
15 - 18 years	73 (8.3)	62 (9.1)	11 (5.6)
19 - 24 years	163 (18.6)	123 (18.1)	40 (20.3)
25 - 44 years	347 (39.6)	271 (39.9)	76 (38.6)
45 - 64 years	156 (17.8)	118 (17.4)	38 (19.3)
65+ years	106 (12.1)	78 (11.5)	28 (14.2)
Sex			
Male	751 (85.7)	587 (86.5)	164 (83.2)
Female	125 (14.3)	92 (13.5)	33 (16.8)
Race			
White	391 (44.6)	297 (43.7)	94 (47.7)
Black	429 (49.0)	337 (49.6)	92 (46.7)
Asian	10 (1.1)	7 (1.0)	3 (1.5)
AI/AN	31 (3.5)	24 (3.5)	7 (3.6)
NA	15 (1.7)	14 (2.1)	1 (0.5)
Hispanic Ethnicity			
Hispanic	28 (3.2)	27 (4.0)	1 (0.5)
Non-Hispanic	848 (96.8)	652 (96.0)	196 (99.5)
Intent			
Assault	469 (53.5)	373 (54.9)	96 (48.7)
Intentional self-harm	354 (40.4)	269 (39.6)	85 (43.1)
Legal intervention	24 (2.7)	14 (2.1)	10 (5.1)
Undetermined	4 (0.5)	4 (0.6)	0 (0.0)

Unintentional	25 (2.9)	19 (2.8)	6 (3.0)
Place of Death			
DOA	26 (3.0)	14 (2.1)	12 (6.1)
ED/outpatient	416 (47.5)	349 (51.4)	67 (34.0)
Home	147 (16.8)	102 (15.0)	45 (22.8)
Hospice	3 (0.3)	3 (0.4)	0 (0.0)
Hospital inpatient	192 (21.9)	144 (21.2)	48 (24.4)
Other[a]	92 (10.5)	67 (9.9)	25 (12.7)

This table collects demographics for linked NC-VDRS records, stratified by number of ED visits in the 365 days prior to death (one visit vs. multiple visits).

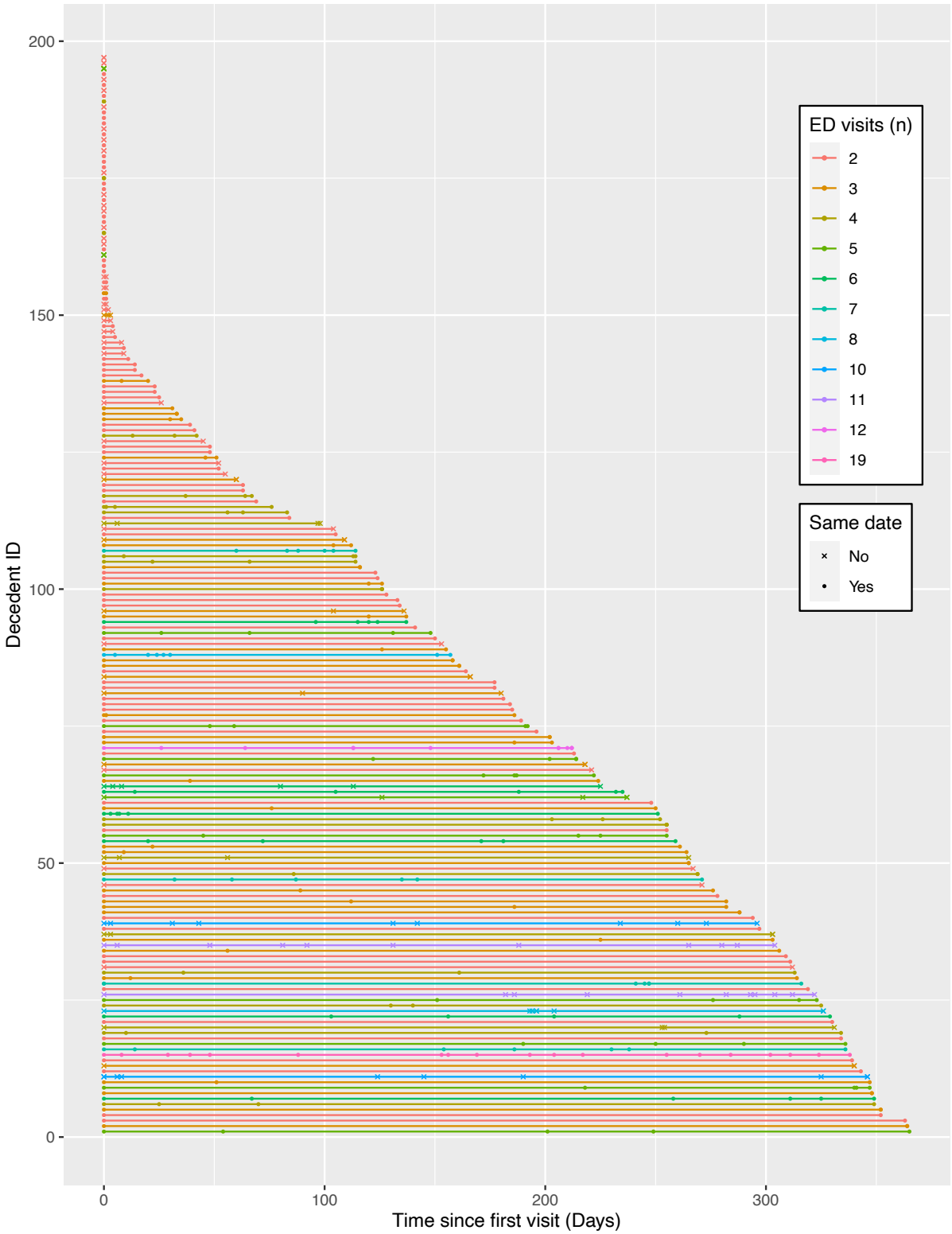
[a] Other represents a situation where the place of death was the scene of the death and includes places such as bridge, road, and forest.

The intent behind their fatal injury was also similar between decedents with single or multiple prior-year ED visits. Both primarily consisted of assaults (single visit: 54.9%, multiple visit: 48.7%), followed by intentional self-harm-related fatal injuries. A higher percentage of decedents with multiple prior-year ED visits died due to legal intervention (5.1%) than single-visit decedents (2.1%). Finally, place of death varied by prior-year ED visit frequency. Over half of the decedents who had a single ED visit in the year prior to death died in the ED or an outpatient facility, compared to 34.0% of those with multiple prior-year ED visits. About 25% of decedents died in a hospital/inpatient facility, regardless of prior-year visit frequency.

Figure 3 collects the number of days between the decedent's first ED visit and their proximate ED visit for the 197 decedents with multiple prior-year ED visits. The time elapsed between the decedent's first and proximate ED visit ranged from 0 days to 365 days, with a median of 128 days. For decedents whose proximate ED visit was on the same day as their date of death (n=143), the median time elapsed between their first and last ED visit was 150 days, while decedents with a discordant proximate visit and death dates had a median of 35.5 days.

Forty decedents had all ED visits on their proximate visit date, meaning their visits occurred on the same day and that was the only date in which they were in an ED during the year prior to their death. Of these 40 decedents, 35 had two visits and primarily were transfers from one ED to another. Lastly, prior-year visits tended to cluster temporally. Among decedents with multiple prior-year ED visits, 58.9% (n=116) had at least two visits within ten days of each other, while the remaining 81 visits did not.

Figure 3. ED visit frequency and person-time (days) among decedents with 2+ visits



This figure collects all ED visits within 365 days of a decedent's date of death for those with two or more visits (n=197). Person-time is calculated as the time elapsed (days) from their first recorded visit to the visit indicated. Colors correspond to the decedent's total number of ED visits. Decedents with a date of death equal to their proximate visit date are labeled with a circle, while those with discordant dates are labeled with an "X."

5. LESSONS LEARNED, LIMITATIONS, NEXT STEPS

Lessons learned

After an extensive data cleaning and harmonization process, we identified 4,768 eligible NC-VDRS records and 5,086,654 ED visits with which we conducted a preliminary probabilistic data linkage. The linkage algorithm identified 12,455,424 potential links that were filtered down to 2,970 high-quality potential links. Through our two-stage manual review process, we determined 1,483 of the high-quality potential links were in fact valid links, accounting for 1,336 unique NC-VDRS records and 1,483 ED visits. Of the 1,483 valid and high-quality links we identified, 960 involved a firearm-related NC-VDRS record (n=876 unique NC-VDRS records). Further, through the utilization of internal tracking IDs from the linked ED visits, we were able to identify 1,312 additional ED visits occurring in the 365 days prior to the linked firearm-related decedents' dates of death.

These results demonstrate the feasibility of a firearm-specific NC-VDRS to ED visit data linkage. Approximately 64% of linked NC-VDRS firearm death records had a place of death within a medical facility, the majority of which were ED/outpatient facilities. Additionally, one in 10 linked NC-VDRS firearm death records linked to more than one ED visit in the 365 days prior to death. This allowed us to identify the decedent's prior-year ED visits across multiple facilities and highlights the importance, and validity, of one-to-many links. Many (77.5%) of the linked NC-VDRS firearm death records had only one ED visit in the 365 days prior to their date of death. Among linked records with two or more prior-year ED visits (n=197), 157 had visits on different dates; 116 had two or more visits within 10 days of each other. These prior-year visits can provide insight into potential prevention opportunities for firearm-related violent deaths.

Limitations

This study has several limitations. As we did not have access to unique shared patient identifiers across data sources (ex. name or social security number) we relied on a probabilistic linkage framework to identify potential links. While our linkage performance was high for decedents with a place of death within a medical facility, only 49.9% (1,483/2,970) of the high-quality potential links identified using the probabilistic linkage were determined to be valid links through the manual review process. In our ED visit data, injury mechanism and intent are

derived from the ICD-10-CM codes for each ED visit. This may impact our identification of firearm injury and intent categorization for both linked and prior-year ED visits, if the ICD-10-CM coding is incomplete, inaccurate, or imprecise (i.e. use of generic unspecified codes). This is a particular issue for firearm-related deaths where the individual died in the ED, as they tended to have poorer data quality and completeness for linkage fields than individuals with other dispositions. Lastly, decedents may have sought care at a different ED than their proximate ED. As this would generate an additional internal tracking ID we could not identify, prior-year visit frequencies may be underestimated. However, we found several one-to-many links among decedents with ED transfers, providing additional internal tracking IDs to identify past ED visits.

Next steps

Linkage and Analysis

Given the importance of the post-linkage filtering process and our two-stage manual review, we recommend further iteration on the data linkage process focusing specifically on sustainability. While we were able to produce a dataset of high-quality links for 2019 and 2020 NC-VDRS records, adding additional years of NC-VDRS records would be similarly time-intensive. Through fine-tuning the post-linkage filters and assessment of additional linkage variables, it may be possible to identify these valid, high-quality links without a heavy reliance on the manual review of thousands of records, promoting a more sustainable, long-term data linkage process. Next steps for iterating upon the linkage process include the investigation of linkage variable patterns and probabilities for high-quality links, the development of higher-quality mechanism and intent definitions, and varying how current linkage variables are treated within the linkage model.

The results of this feasibility study warrant further research in this area. In order to identify earlier intervention opportunities in the ED setting for individuals who sustain fatal firearm injuries, we recommend the following next steps using the linked dataset:

1. Identification of common ED diagnoses and dispositions for all the ED visits linked to firearm-related NC-VDRS decedents, including their ED visits in the year prior to death.
2. Time-to-event analyses of prior-year ED visits among firearm-related NC-VDRS decedents with two or more visits in the 365 days prior to their date of death.

3. Investigation of NC-VDRS circumstance fields, including exposure to intimate partner violence (perpetration or victimization) among linked firearm-related NC-VDRS decedents.
4. Description of firearm-related NC-VDRS decedents with high-risk for fatal injury such as decedents that presented to the ED with suicidal ideation and/or self-harm prior to death.
5. Qualitative analysis of themes from ED visit data for linked decedents based on chief complaint and triage note free-text fields.

Application of Results

We suggest that key findings and implications of this linkage feasibility study be incorporated into the following dissemination tools:

1. Dashboards –

   Dashboards allow for various audiences to visualize and engage with data alongside meaningful context and storytelling. While a North Carolina-specific firearm dashboard does not yet exist, there has been substantial interest in creating one and these data would be a great asset. Additionally, these results could be included as supplemental data on the existing North Carolina Division of Public Health's Injury and Violence Prevention Branch NC-VDRS dashboard.
2. Blog posts –

   Blogs can increase accessibility of information and engage diverse audiences. Brief narrative blog posts highlighting interesting linkage results could be shared on key partners' social media platforms and websites.
3. Fact sheets and infographics –

   Fact sheets and infographics provide a way to briefly and effectively summarize complex information in an easy-to-understand, visual manner. These materials could be shared on key partners' social media platforms and websites to raise awareness involving key takeaways.
4. Presentations –

   Presentations at state and national conferences can disseminate our experience in NC with others around the country, while allowing us to learn from the experience of other states undertaking similar linkage projects.

6. REFERENCES

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