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A geospatial analysis of naloxone distribution patterns in the Massachusetts Overdose Education and Naloxone Distribution Program (MA OEND)

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Abstract

Introduction: This study describes the distribution and administration of naloxone throughout one state heavily impacted by the opioid overdose crisis. We sought to: 1) assess whether naloxone kits were used in rescue attempts in the same communities where they were distributed, and 2)

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explore how best to define geographical boundaries for comparing naloxone supply to demand, accounting for naloxone mobility patterns to identify areas of surplus or shortage.

Methods: We used data from Massachusetts' Overdose Education and Naloxone Distribution (OEND) programs for 2018–2020, linking participants' residence, overdose rescue attempt, and refill locations at the ZIP code level. We built a Sankey plot describing the distribution and administration of naloxone between OEND program regions based on refill encounters with a reported rescue attempt. We algorithmically derived "naloxone service areas (NSAs)," defined as collections of municipalities that receive naloxone from high-volume naloxone distribution hubs. For each NSA, we calculated a coverage ratio (naloxone kits dispensed per opioid-related overdose death).

Results: From 2018–2020, the MA OEND programs had 88,085 naloxone dispensing encounters among 49,344 people. People reported a prior rescue attempt in 16% of all observed encounters. There was substantial migration between residence and rescue attempt locations, with much naloxone distributed in Boston. The average naloxone dispensing-to-overdose death ratio was 14 kits per death over the three years, ranging from 8 to 32 kits per death across NSAs.

Conclusions: Naloxone kits are often used by people residing in communities other than where kits were distributed, with significant variation in coverage ratios across regions.

1. INTRODUCTION

Since 2000, the US experienced exponential growth of opioid-involved overdose deaths per year,[1] with an estimated 81,083 people dying in 2023.[2,3] Naloxone is a medication that effectively reverses opioid overdose but must be present (and administered) during an overdose.[4] The World Health Organization (WHO) and the US Centers for Disease Control and Prevention recommend that naloxone (and training in the management of opioid overdoses) be made available to people likely to witness an opioid overdose.[5,6]

In response to the overdose crisis, an increasing number of state and local governments, community-based organizations, and harm reduction programs are implementing overdose education and naloxone distribution (OEND) programs.[7] OEND programs provide education and training on opioid overdose prevention, recognition of opioid overdose, and opioid overdose rescue response; they also distribute naloxone kits.[8] Studies have consistently demonstrated OEND effectiveness. A 2013 interrupted time series analysis of the OEND program in Massachusetts (MA) found reductions in opioid overdose death (OOD) rates in communities with greater OEND implementation.[9] A 2017 pre-post comparison of Scotland's prison-release-based OEND program found a significant reduction in the number of opioid-related deaths four weeks following release.[10] A 2021 systematic review found that OEND is effective at reducing opioid overdose mortality.[11]

A fundamental aim of OEND programs is to increase community availability of naloxone, especially for communities with the greatest need (i.e., highest OOD rates). One way to measure the balance between availability and need, often termed "naloxone saturation,"[12,13] is through a naloxone "coverage ratio" - a metric that divides total naloxone kits distributed by total OODs for a certain population (defined by geography and/or demographics and over a certain time period). A 2015 study from Scotland suggested that programs should

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annually distribute 20 times or more the number of naloxone doses as the number of OODs in the previous year (20:1).[14] Several studies have measured naloxone saturation to evaluate the effectiveness of OEND programs. Irvine et al., 2022 proposed a 'saturation target' of naloxone use in 80% of witnessed overdoses, and they found that using 2017 data, only 1 of the 12 states modeled had sufficient naloxone distribution to meet this target.[15] Zang et al., 2021 study used MA and Rhode Island OEND programmatic data to compute a county-level ratio of naloxone kits distributed through OEND programs per OOD.[16] Nolen et al. used these same data and coverage ratio to examine whether naloxone was distributed equitably to cities and towns based on racial/ethnic composition, finding no evidence of municipal-level racial/ethnic inequalities.[17] However, in a follow-up study using individual-level race/ethnicity data, by comparing race/ethnicity-specific coverage ratios, researchers found that African American/Black (non-Hispanic) and Hispanic racial/ethnic groups had lower rates of naloxone receipt per opioid-related overdose death than white (non-Hispanic) residents.[18]

How an OEND program defines the boundaries of its community determines the relevance of the coverage ratio to program performance measurement. The most common method is to use administrative geographic boundaries; for example, the town or county in which the OEND program is located and therefore distributing the medication. Previous work, however, suggests substantial movement and important mobility patterns related to drug use, service access, and overdose risk. A 2020 study by Nesoff and colleagues examining Cook County, IL (Chicago) found that 30% of those who died from an overdose traveled far from their home to the location of the fatal overdose, tending to travel to more resources-deprived neighborhoods.[19] Literature from MA, conversely, found that half of OODs occur at the decedent's residence, but there was heterogeneity in overdose location by residence location.[20]

This study aims to answer two related questions: 1) are communities in which naloxone kits are used during rescue attempts the same communities to which those kits were distributed (in other words, what are the travel patterns of OEND participants)?, and; 2) is there a data-driven method to define the service area of an OEND program, which incorporates potential travel patterns, to more accurately identify shortage and surplus areas of naloxone access? Using operations data from MA's OEND program and geographic information regarding rescue attempts, we provide initial answers and propose tools other OEND programs might use to optimize their naloxone distribution efforts.

2. MATERIAL AND METHODS

2.1 Data

We obtained MA OEND program operations data from the Massachusetts Department of Public Health (MDPH) for 2018–2020. MDPH uses these data for day-to-day administration of the OEND program and regular oversight, and they have been successfully leveraged in previous research.[9,16,18,21]

During the study period, the MA OEND program had two participant-level data collection forms: 1) a registration form on first visit and 2) a refill form at subsequent visits. The

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registration form collects self-reported demographic characteristics, residence location, drug use behaviors, and past-year addiction treatment, incarceration, and homelessness experiences. The refill form collected information about overdose rescue attempts. Program sites also reported information on these forms, including site address, number of naloxone kits distributed, and date of services. Data were linkable across each form by a unique participant ID. Blank versions of these forms are provided in the Appendix.

Rescue data included the following event-level information: date of overdose; rescue attempt location (5-digit ZIP code or city if ZIP code was unknown); relationship to the person who overdosed; setting of overdose (public or private); whether someone present sought help (i.e., emergency medical services, fire, police were called or present); whether the rescue attempt was successful (the person lived), and; whether the form filer obtained the naloxone used in the rescue attempt from the OEND program.

This analysis used three pieces of participant- and program-reported geographic information, each at the ZIP code level: location of 1) residence (participant-reported), 2) rescue attempt (regardless of outcome, participant-reported), and 3) naloxone kit fill/refill (program-reported). MDPH de-identified the data used in this analysis and provided it at the encounter (naloxone dispensing)-level. The “residence” ZIP code for individuals experiencing homelessness was typically recorded based on where they slept or assigned as 99999 if they were transient. Each individual in the dataset had a unique client code, and that code applies to any encounters the individual had with the OEND program. The number of encounters per individual reflects the number of times that an individual visited any OEND program and obtained naloxone. All encounters in the data indicate naloxone dispensation. Because the number of naloxone kits distributed was missing for 69% of encounters, we assumed that one kit with two naloxone doses was distributed per encounter (see Appendix). We obtained all data in April 2021. MDPH granted permission to use these de-identified data, and the MDPH and Boston University Medical Center Institutional Review Boards deemed this work to be non-human subjects research.

To contextualize naloxone distribution patterns, we also collected community-level risk data describing opioid-related overdose deaths in MA for concurrent years (2018–2020). These data come from annual reports generated by MDPH and made available to the MA Legislature and the public. MA is divided into 39 cities and 312 towns (“municipalities”) across 14 counties; OODs are reported at the municipality level.

We collected publicly available geographic information systems (GIS) data from MA to generate our maps.[22] These data included the latest catalog of 5-digit ZIP code locations in the state for 2015. We included all observed encounters for naloxone distribution in the MA OEND data for 2018–2020. We also identified a sub-sample of encounters reporting an overdose rescue attempt at fill/refill with non-missing ZIP code-level geographic data for 1) residence, 2) rescue attempt, and 3) fill/refill.

2.2 Statistical Analysis

We described the nature of MA’s OEND program and community naloxone network in four ways: 1) a table of descriptive statistics of program participants; 2) a Sankey

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plot depicting distribution and administration of naloxone kits; 3) algorithmically derived "naloxone service areas" (NSAs), defined as hubs of high-volume naloxone distribution and the municipalities which received most (>50%) of their naloxone from these locations, and; 4) the ratio of naloxone dispensing kits (assuming one kit per encounter) to OODs in these NSAs.[23]

We aggregated encounter-level data to the individual level and stratified the total sample into two groups: those who did report an overdose rescue attempt upon refill and those who did not. For each group and by each level of our categorical variables, we calculated the average number of visits to the OEND program. We conducted Pearson's χ^2 tests to assess differences in the distribution of each categorical demographic variable between our two groups. In our main analyses, we generated χ^2 for observations with non-missing demographic data (a more conservative estimate), and we conducted a sensitivity analysis including missing as a level in the categorical variables (see Appendix).

Next, we generated a Sankey plot to track the geographic "flows" of naloxone kits across the state. Specifically, for our sub-sample of refill encounters reporting a rescue attempt (and with complete location data), we traced backward from refill ZIP code (i.e., location in which naloxone was distributed) to rescue ZIP code (i.e., location in which the naloxone was administered) to residence ZIP code (as measured on the OEND enrollment / initial naloxone distribution form) to get a sense of the movement of program participants and naloxone kits throughout the state. We aggregated ZIP codes to the MA Bureau of Substance Addiction Services (BSAS) program regions; these were six mutually exclusive divisions of the municipalities that were programmatically relevant to our MDPH stakeholders. The regions were Boston, Metrowest (i.e., western suburbs of Boston), Northeast MA, Southeast MA, Central MA, and Western MA.

Next, we derived NSAs in two parts: 1) identifying "hubs" using program location data, and 2) labeling service areas using participant residence data. First, we defined a hub as a single (individual-hub) or group (cluster-hub) of high-volume naloxone dispensing municipalities: municipalities that dispensed >1% of the OEND state total naloxone dispensations. For parsimony, we grouped municipalities that were in close proximity into cluster-hubs based on pre-specified rules (see Appendix). Second, we defined a service area (or spokes) as the collection of municipalities whose residents received the plurality of their naloxone from each hub. These service areas are analogous to (and modeled after) hospital service areas from the Dartmouth Atlas.[23] The full algorithm is available in the Appendix.

For each algorithmically identified NSA, over the study period (2018–2020), we calculated a coverage ratio of naloxone distribution encounter at each hub (numerator) to opioid-involved overdose deaths within each service area (denominator). We calculated this ratio for both opioid-involved overdose deaths by residence and opioid-involved overdose deaths by location of occurrence. We used Stata 16.1 for data management and analyses.[24] We used ArcGIS to generate maps[25] and SankeyMatic to generate Sankey plots.[26] The results from this analysis should be considered exploratory.

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3. RESULTS

3.1 Descriptive statistics

From 2018–2020, the MA OEND program had 88,085 naloxone dispensing encounters, representing 49,344 unique individual program participants. Among the 49,344 participants, 14,358 (29.1%) refilled naloxone at an OEND program location at least once. Of this group, 7,675 (15.6%) reported (upon refill) having used a naloxone kit in an overdose rescue attempt, and a subset of this group (4,368 participants [8.9% of overall sample]) also had complete zip code location data (residence, location of overdose response, location of refill). A total of 13,754 rescue attempts were reported (upon refill) during the study period among 7,675 program participants. Among these rescue attempts, 13,361 (97.1%) were reported as successful (i.e., the rescued person lived), 8,064 had complete location data and 7,660 had complete location data within Massachusetts (see Appendix Figure 1).

Table 1 provides detailed information on the demographic characteristics of the sample, overall and stratified by those who did not and those who did report an overdose rescue attempt during the study period. Most of the observed overall sample identified as non-Latino and white. The majority of the observed (non-missing) overall sample were between the ages of 20 and 39 years old;68.4% of the group reporting a rescue attempt was in this age range. Participants who reported an overdose rescue attempt had a significantly higher average number of visits to the OEND program than those who never reported a rescue attempt (2.87 more visits on average, 95% CI [2.73, 3.01], $p < 0.001$). Participants who reported an overdose rescue attempt predominantly identified as male, resided in Boston, engaged in drug-use behaviors, had survived at least one overdose, and had received SUD treatment within the past year. Participants who reported an overdose rescue attempt also more often experienced incarceration and homelessness during the past year compared to those not reporting a rescue attempt. (see Table 1). Notably, the amount of missing demographic data in the total sample, across strata, and across collected demographic variables was substantial. In general, the strata reporting an overdose rescue attempt had more data missing (39.4% - 85.0%) compared to the strata without a rescue attempt (20.0% - 65.3%) and the overall sample (25.0% - 68.4%) (See Appendix for missingness by each specific variable). Therefore, we encourage caution in interpreting the $\chi 2$ values calculated from observed data given the substantial, differential amount of missing data between strata. In sensitivity analyses that included missing data as a row in each variable, the identified differences between the strata also came to the same conclusion of statistically significant differences between the strata for all demographic variables (see Appendix).

3.2 Sankey plot of naloxone distribution and overdose administration

Figure 1 displays the Sankey Plot of naloxone distribution and overdose administration of naloxone between BSAS regions. This analysis drew from the subset of 4,368 program participants reporting a rescue attempt and with complete location data (56.9% of the 7,675 participants reporting a rescue attempt) and with all location data in MA (n = 3,920, 51.1% of rescue reporters) (see Supplemental Figure 1 in Appendix). Among these 3,920 individuals, there were 7,660 refills in which a rescue attempt was reported.

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At the residence stage, 26.7% (n = 2,045) of encounters were among participants residing in Boston, 23.9% (n = 1,829) were among those residing in Southeastern MA, and 49.4% (n = 3,786) were from the remaining regions. Moving from residence location to rescue attempt location: 43.5% of reported rescue attempts occurred in Boston (n=3,784), 19.0% occurred in Southeastern MA (n=1,455), and 37.5% occurred in the remaining regions (n=2,873). The three largest inflows into Boston were from the adjacent Metrowest, Northeast, and Southeast regions (see Appendix for a more detailed analysis). Central and Western MA regions contributed less inflow to Boston, and largely remained self-contained between residence and rescue attempt locations. Refill locations are largely consistent with reported rescue attempt locations for all regions. For example, the number of encounters reporting rescue attempts in Boston is 3,330, while the number of refill encounters at OEND locations in Boston is 3,370.

3.3 Algorithmically derived naloxone service areas

Of the total 88,085 naloxone dispensing encounters in the data, 66,988 (76.5%) had non-missing dispensing location information. Twenty-one municipalities each accounted for at least one percent of these 66,988 observable naloxone dispensing encounters, collectively accounting for 58,434 (87.2%) of the total observable encounters (this samll number of municipalities is consistent with the limited number of OEND sites in the state, see Appendix). After applying our naloxone dispensing clustering algorithm to the MA OEND programmatic data, these 21 municipalities formed 13 hubs. Each hub had a corresponding NSA; the NSAs collectively encompassed 243 municipalities (out of 351 in MA, see Figure 2). The map overlays high-volume naloxone dispensing NSAs onto municipality-level opioid-related overdose data (by residence of the person who died in the overdose). The NSAs are listed in order of volume of naloxone dispensing encounters and are given corresponding colors from red to violet; hubs of high rates of naloxone dispensing are highlighted with a white dotted outline. OODs (by residence) are represented by the size of black dots. To aid with interpretation, specific aspects of the map to consider are i) municipalities that reported overdose deaths yet are not in an NSA, which may indicate naloxone shortage areas, and ii) the size of each NSA, which gives a sense of the distance traveled for naloxone dispensing encounters.

3.4 Ratio of naloxone dispensing encounters to overdose deaths in NSAs, administrative regions, and the state

Table 2 lists information on naloxone dispensing encounters per hub, opioid-related overdose events per NSA, and a calculated ratio relating the two. We organized the table by increasing geographic level (NSA, region, state) and column-wise by the municipality of residence of the person who died and the municipality of overdose death occurrence. From 2018–2020, the state experienced 6,109 confirmed OODs, and the MA OEND program observed 85,085 naloxone dispensing encounters, giving a state-wide dispensing to opioid-related overdose death ratio of 13.9 kits-per-death. Among the NSAs, this ratio ranged from 7.8 kits-per-death in the Lowell-Lawrence-Tewksbury NSA to 32.2 kits-per-death in the North Adams NSA, by municipality of residence of the decedent. For context, a commonly referenced target coverage ratio is 20 naloxone kits per death.[14]

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4. DISCUSSION

From 2018–2020, the MA OEND program reported 13,361 successful rescue attempts using naloxone obtained from the state's program. Two important findings relevant for OEND decision-makers are: 1) who receives naloxone, and; 2) where it will ultimately be used. While most people reporting a rescue attempt reside in the community where the rescue occurred and refill in that community, people reporting rescues in Boston represent a net "inflow" of residents from all other regions. The net inflow of residents to Boston to rescue and report a refill drew mainly from Metro-West, Northeast, and Southeast regions surrounding Boston. In contrast, movement in or out of Central and Western regions was limited.

One explanation for observed patterns is a "commuting" hypothesis: people live in one town, travel to another to obtain naloxone, return to their residence, use naloxone, and then return to the program location where they obtained naloxone to refill. However, Figure 1 offers evidence for a different mechanism: participants refill naloxone near where they use it in a rescue attempt, which tends to occur in the major population center of the region (what we are terming the "rescue-centric" hypothesis). Figure 2 supports this finding; the Boston-Cambridge-Quincy NSA includes the top 4 contributing BSAS regions for Boston-located rescue attempts. In the Appendix, we provide a map displaying the residence towns of those reporting an overdose rescue attempt in Boston, which aligns with the commuter rail network and metro-region population centers, giving further credence to the rescue-centric hypothesis. A previous study (Nessoff et al., 2020) found that fatal opioid overdoses in Cook County, IL often occurred in ZIP codes far from the decedent's last known residence, indicating substantial travel between place of residence and neighborhoods were drugs are used and naloxone is administered in many circumstances. This demonstrates the importance of surveillance in determining where use and rescue attempts are taking place in addition to where participants live, and suggests that prioritizing these areas for naloxone distribution, education, and health care engagement may be particularly important for preventing fatal overdose. Future research should further characterize and validate these pathways through both qualitative interviews with people who carry naloxone and quantitative trajectory analysis.

Whether and how far someone travels to obtain and use naloxone is likely a function of several variables, including but not limited to where unregulated drugs are supplied and purchased, what the dominant opioid/drug is in the area, where this drug use is taking place, where opioid overdoses are taking place, the location of harm reduction and other programs providing naloxone, public and private transportation options, and individual characteristics of the naloxone recipient. Future mixed-methods studies conducted in partnership with people who use drugs (PWUD) and OEND programs could further examine the relationships among these variables and whether and how far individuals travel to obtain naloxone.

If coverage ratios of naloxone distribution—often defined using a single, administratively defined geographic unit—are to become the recommended benchmark with which to monitor equitable naloxone access and promote harmonization of methods across jurisdictions,[11,27] then a critical step is to select an appropriate level of geographic

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aggregation. While other factors may refine coverage ratio adequacy for a given area, such as dominant opioid or program features,[28, 29] these are secondary to choice of geographic aggregation. Ratios must account for the observed movement of program participants across administrative borders that we observe in this study, as should analytic models of naloxone distribution. We used a data-driven process to aggregate information from ZIP codes to municipalities and then to collections ('hubs') of municipalities. This made sense in MA, where municipalities are relatively small in area and may not fully encompass travel patterns. Other jurisdictions may have other needs relating to their geographic scale and aggregation choice.

4.1 Limitations

Our paper has several limitations. First, we could not track exact travel paths of naloxone kits; we could only observe reported residence, refill, and administration locations of people who receive kits from known distribution locations. Additionally, we measured the approximated travel path retrospectively (i.e., from refills to rescue attempts and ending with the municipality of residence). Second, our coverage ratios were likely conservative given that we: i) assumed distribution of only one kit per encounter (which could result in undercounting, particularly during 2020 when programs were encouraged to distribute more kits per encounter during the early phase of the COVID-19 pandemic), and ii) did not account for in- and out-flows of kits to NSAs from other hubs." This makes our results less comparable to previous studies, which used kits, whereas our coverage ratios compare encounters to OODs.[16,18] However, we applied our method consistently across all of our NSAs, so valid comparisons across NSAs can be made. Also, the standard distribution policies of the OEND program were to distribute one kit containing two doses (as packaged by retailer). Third, we have a high degree of missing data, making it difficult to ascertain the validity and generalizability of our findings. This likely reflects the tradeoff between complete data collection and speedy care provision in harm reduction settings; of course, care provision should be of primary importance. We also lack specific data about the opioid type mix (prevalence of synthetic opioids for example) in each specific area, though the proportion of opioid deaths that involved fentanyl was greater than 85% statewide during this time period. Additionally, data collection requirements were relaxed at the onset of the COVID-19 pandemic to allow organizations to respond to the pandemic conditions without being overburdened by data collection requirements. Fourth, our data were limited to naloxone distributed through MDPH-sponsored OEND programs and does not account for harm reduction programs who received their naloxone from other sources and pharmacy naloxone distribution, undercounting total coverage ratios by not showing the complete amount of naloxone in each geographic area. Fifth, OEND participation in some municipalities is quite low, contributing "noise" to the NSA algorithm and the borders of certain NSAs.

Despite these limitations, this dataset is unlike any other OEND program's data in the country, and it provides rich understanding about where and to whom naloxone is distributed in MA. Without the detailed location data collected by MA OEND programs, we would not be able to draw conclusions on naloxone kit flows and travel patterns. NSAs are a useful and convenient method for monitoring naloxone saturation in that they state the likely

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geographic reach of a particular OEND program location. Fortunately, the derivation of our NSAs only requires program location and participant residence location data to generate, which are straightforward to collect; similar data are likely accessible to other OEND programs seeking to make data-informed decisions regarding naloxone distribution and shortage and surplus areas. By comparing NSAs to OODs, decision-makers may compute coverage ratios that reflect the likely reach of the OEND programs. By comparing NSAs to travel times, decision-makers may consider planning additional OEND program locations.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- From 2018–2020, at least 49,344 people received naloxone through Massachusetts OEND programs.
- There was substantial migration between residence and rescue attempt locations.
- Analysis of naloxone service areas reveal relatively underserved regions for naloxone distribution services.

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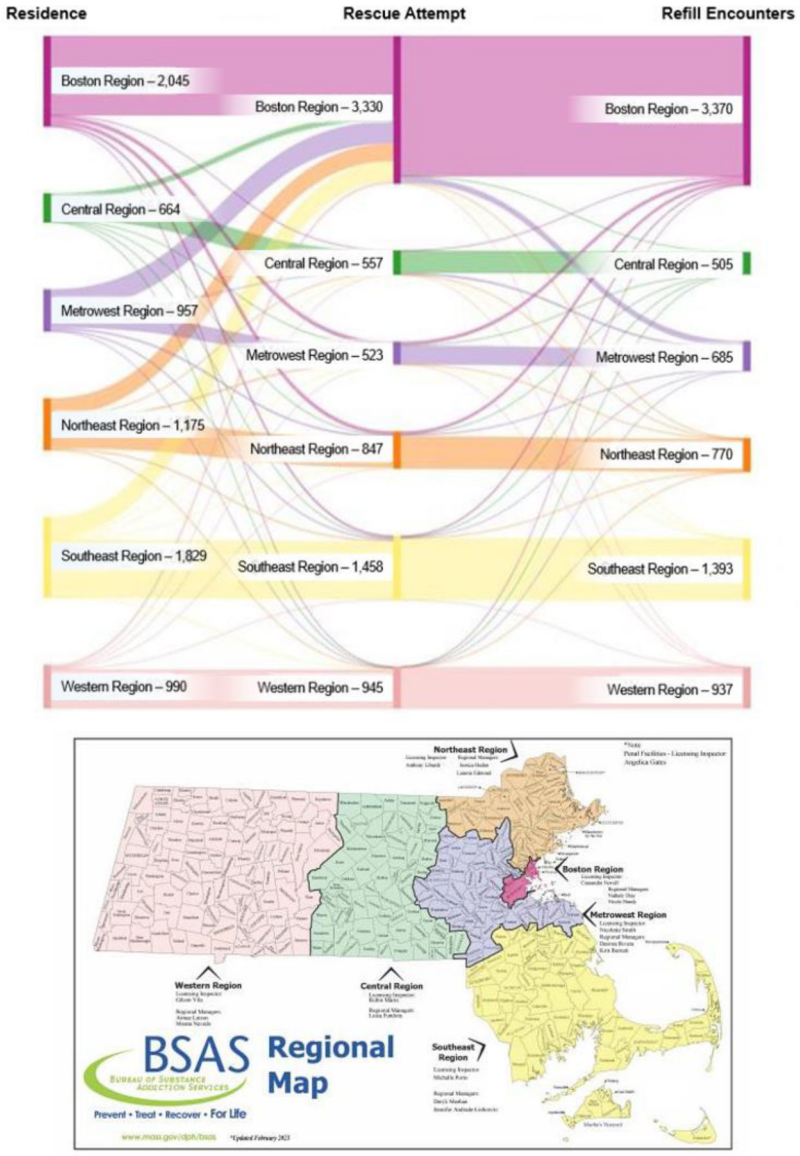


Figure 1. Sankey Plot – Flows of naloxone kits throughout the state among individuals reporting a rescue attempt in Massachusetts (2018–2020)

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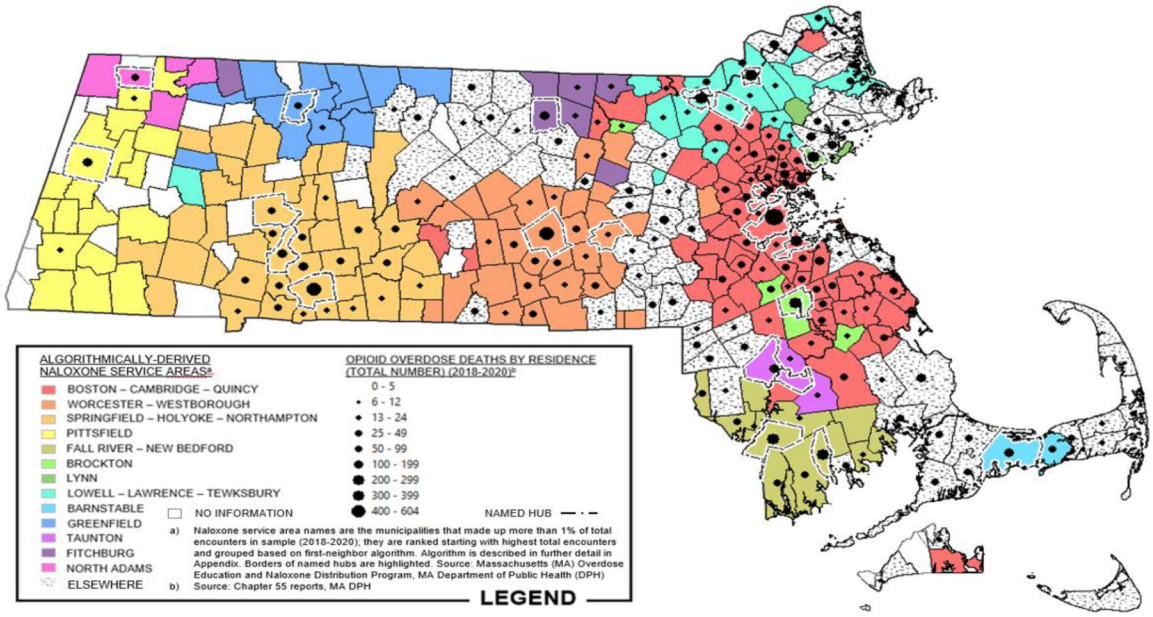


Figure 2. Naloxone service areas (NSAs) and overdose deaths (by residence) in Massachusetts (2018–2020)

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Table 1. Demographic characteristics of Massachusetts Overdose Education and Naloxone Distribution (MA OEND) program participants (2018–2020)

	Total Sample of individual participants (100% of total)			Never report an overdose rescue attempt (84.4% of total)			Report an overdose rescue attempt upon naloxone refill (15.6% of total)			χ^{2C}
	n	(missing) % of observed[a]	Average number of visits[b]	n	(missing) % of observed[a]	Average number of visits[b]	N	(missing) % of observed[a]	Average number of visits[b]	
Overall	49,344	100	1.74	41,669	100	1.30	7,675	100	4.17	
Ethnicity		(25.0)			(22.3)			(39.4)		4.7 p=0.03
Latino	5,394	14.6	1.82	4,765	14.7	1.32	629	13.5	5.65	
Non-Latino	31,641	85.4	1.83	27,616	85.3	1.31	4,025	86.5	5.37	
Race		(26.1)			(23.7)			(39.4)		122.8 p<0.001
American Indian	305	0.8	1.83	263	0.8	1.27	42	0.9	5.33	
Asian	346	1.0	1.28	336	1.0	1.14	10	0.2	6.00	
African-American / Black	3,707	10.1	1.68	3,334	10.5	1.26	373	8.0	5.42	
Hawaiian / Pacific Islander	63	0.2	2.38	52	0.2	1.40	11	0.3	7.00	
White	29,242	80.2	1.86	25,361	79.7	1.32	3,881	83.4	5.38	
Other Race	1,936	5.3	2.01	1,642	5.2	1.40	294	6.3	5.39	
Multi-Racial	862	2.4	1.36	821	2.6	1.14	41	0.9	5.76	
Age Group		(22.9)			(20.0)			(38.6)		478.0 p<0.001
19 years or younger	674	1.8	1.85	593	1.8	1.30	81	1.7	5.86	
20–29 years old	10,432	27.4	2.09	8,829	26.5	1.39	1,603	34.0	5.94	
30–39 years old	11,116	29.2	2.00	9,498	28.5	1.37	1,618	34.4	5.69	
40–49 years old	6,957	18.3	1.74	6,088	18.3	1.28	869	18.5	5.00	
50–59 years old	5,854	15.4	1.38	5,429	16.2	1.22	425	9.0	3.52	
60 years or older	3,002	7.9	1.23	2,887	8.7	1.13	115	2.4	3.63	
Gender		(22.9)			(20.0)			(38.5)		99.0 p<0.001
Female	18,558	48.8	1.75	16,463	49.4	1.28	2,095	44.4	5.43	
Male	18,741	49.2	1.89	16,155	48.4	1.34	2,586	54.8	5.35	
Other	159	0.4	1.91	147	0.4	1.55	12	0.3	6.33	
Unknown/ refused	613	1.6	1.42	589	1.8	1.97	24	0.5	6.79	
BSAS[d] region of residence		(25.6)			(22.9)			(40.2)		307.4 p<0.001
Boston	6,358	17.3	2.21	5,251	16.4	1.32	1,107	24.1	6.47	
Central	5,065	13.8	1.60	4,566	14.2	1.27	499	10.9	4.66	
Metrowest	4,060	11.1	1.92	3,528	11.0	1.30	532	11.6	6.10	
Northeast	5,174	14.1	1.82	4,465	13.9	1.29	709	15.4	5.18	
Southeast	8,228	22.4	1.73	7,135	22.3	1.28	1,093	23.8	4.67	

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	Total Sample of individual participants (100% of total)			Never report an overdose rescue attempt (84.4% of total)			Report an overdose rescue attempt upon naloxone refill (15.6% of total)			χ^{2C}
	n	(missing) % of observed[a]	Average number of visits[b]	n	(missing) % of observed[a]	Average number of visits[b]	N	(missing) % of observed[a]	Average number of visits[b]	
Western	7,809	21.3	1.74	7,156	22.2	1.40	653	14.2	5.51	
How many overdoses have you survived?		(68.2)			(65.1)			(84.8)		146.0 p<0.001
0	8,762	55.8	1.47	8,296	57.1	1.27	466	40.0	5.20	
1–5	5,696	36.3	1.67	5,151	35.4	1.30	545	46.7	5.20	
6–15	1,016	6.5	2.04	896	6.2	1.37	120	10.3	7.09	
>15	220	1.4	2.26	185	1.3	1.57	35	3.0	5.86	
Person who uses drugs		(22.0)			(19.1)			(38.0)		2406.2 p<0.001
Uses drugs	24,271	49.2	2.12	20,160	48.4	1.42	4,111	53.6	5.55	
Does not use drugs	14,208	28.8	1.32	13,563	32.6	1.16	645	8.4	4.82	
enrollment information	10,865	22.0	1.45	7,946	19.1	1.22	2,919	38.0	2.09	
Any addiction treatment, past year		(68.2)			(65.1)			(84.8)		13.6 p=0.001
Yes	7,593	48.4	1.65	6,993	48.1	1.33	600	51.4	5.40	
No	6,517	41.5	1.55	6,033	41.5	1.25	484	41.5	5.26	
Unable to collect information	1,516	10.1	1.49	1,503	10.4	1.21	83	7.1	6.48	
Released from jail/prison, past year		(68.2)			(65.1)			(84.8)		22.7 p<0.001
Yes	3,055	19.5	1.73	2,780	19.1	1.32	275	23.6	5.95	
No	11,000	70.1	1.57	10,196	70.2	1.29	804	69.0	5.11	
Unable to collect information	1,641	10.4	1.50	1,555	10.7	1.22	44	7.4	6.62	
Experienced homelessness, past year		(68.4)			(65.3)			(85.0)		83.6 p<0.001
Yes	5,240	33.6	1.47	4,715	32.6	1.36	525	48.3	4.61	
No	8,841	56.7	1.83	8,283	57.3	1.26	558	45.5	6.05	
Declined / unable to collect	1,523	9.7	1.49	1,451	10.1	1.22	72	6.2	6.90	

a) This column describes the percentage of the total sample that is missing and the percentage of the observed data attributable to each level of the categorical demographic variables. The amount of observed data is 100% minus the missing percentage of data. The column percentages listed below the missing data value sum to 100% of the observed data, not 100% of the total sample in each stratum. For example, 75.0% of the total sample has observed ethnicity data (100–25% = 75%). Of this 75% of the data, 14.6% is Latino, while 86.4% is Non-Latino.

b) The data extracted for this study is at the encounter/visit level. Individual participants may visit the MA OEND program multiple times during the study period. When aggregating to the individual level, we counted the number of visits per person. We then took a simple average of the number of visits for each level of the demographic group per strata

[c] Pearson's χ^2 compares the observable distribution of participants in each categorical level of each demographic variable across the two strata (never report an overdose rescue attempt vs. report an overdose rescue attempt upon naloxone refill). These were also calculated, including missing data as a row, with the same conclusions (larger χ^2 values).

[d] Massachusetts Bureau of Substance Abuse Services-defined operating regions (see Figure 1 for map)

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Table 2. Ratios of naloxone dispensing encounters to opioid overdose deaths (2018–2020) by geographic areas.

Geographic areas		Total naloxone dispensing encounters	Opioid-related overdose deaths by municipality of residence	
			Total	Ratio to naloxone dispensing encounters (x : 1)[a]
Top naloxone dispensing NSAs[b]				
1	Boston – Cambridge – Quincy	24,491	1,812	13.5
2	Springfield – Holyoke – Northampton	8,086	737	11.0
3	Fall River – New Bedford	4,627	504	9.2
4	Worcester – Westborough	4,541	528	8.6
5	Lowell – Lawrence – Tewksbury	3,914	504	7.8
6	Pittsfield	2,848	106	26.9
7	Brockton	2,329	194	12.0
8	Lynn	2,233	174	12.8
9	Barnstable	1,304	75	17.4
10	Greenfield	1,267	46	27.5
11	Taunton	966	97	10.0
12	Fitchburg	926	85	10.9
13	North Adams	902	28	32.2
BSAS Regions[c]				
1	Boston	21,462	730	29.4
2	Central	5,863	856	6.8
3	Metrowest	5,888	838	7.0
4	Northeast	7,893	1,263	6.2
5	Southeast	11,950	1,457	8.2
6	Western	13,932	944	14.8
TOTAL State[e]		85,085	6,109	13.9

a) Ratio = number of kit distribution encounters in geographic area/overdose deaths by residence in geographic area

b) Naloxone Service Areas (NSAs) are centered around (and named after) hubs. Hubs were algorithmically derived: 1) select and sort by highest volume naloxone distributing municipalities (must account for >1 % of all distributing encounters in state for study period; 21 municipalities); 2) identify first order / nearest neighbors by land border; 3) if one of the nearest neighbors is a municipality lower on the list, subsume it and its first order neighbors (include it in NSA name); 4) if municipality shares 2 first order neighbors with another municipality on the list, combine it and its first order neighbors into one hub (include it in NSA name); 5) once a town in a first order neighbor of a municipality, it cannot be counted as a first order neighbor of a municipality lower on the list; 6) if a town is cut off from all other land neighbors by NSA, include town in cluster.

c) Massachusetts Bureau of Substance Addiction Services-defined operating regions

d) Columns do not sum to total given dispensing encounters occurring outside of clusters, missing location data, and locally suppressed overdose deaths; totals are from MDPH data.