Supplementary Appendix
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Supplementary Appendix

A. Model Description and Analysis

The model explicitly describes differences in opioid overdose and death risk by subpopulation, U.S. state (geographic), and type of epidemic. To fix notation, type of epidemic is indexed by i, sub-population is indexed by j, and geographic state is indexed by k. The population at risk of an overdose N is divided into different categories which impact their risk of overdose. They are,

$$N = (N_{co-presc}, N_{inc}, N_{relapse}, N_{OUD}, N_{RX}, N_{Coke}, N_{other}).$$

Where the sub-populations are: co-prescriptions of benzodiazepines and opioid analgesics (co-presc), incarcerated (or recently incarcerated, inc), relapsing from treatment (relapse), opioid use disorder (OUD), opioid prescription (RX), person who uses cocaine (Coke), and other. The total population at risk is the sum over all sub-populations, $\sum_j \quad N_j$.

The sub-population factor (m_N, j) is similarly defined according to each sub-population,

$$m_N = (m_{N,co-presc}, m_{N,inc}, m_{N,relapse}, m_{N,OUD}, m_{N,RX}, m_{N,Coke}, m_{N,other}).$$

The sub-population factors $m_N$are summed with the sub-population numbers N to produce an effective population at-risk estimate,

$$\widetilde{N} = \sum_j \quad m_j N_j.$$

As the model depends on the rates of opioid overdose events, the effective at-risk population describes the proportional increase in the rate of opioid overdose based on the risk factor associated with that population.

For a given month, each individual has a rate of overdosing at probability o_t. This is dependent on a number of factors. We associate the factors with a probability by transforming a linear combination of them using the inverse-logit transform ($logit^{-1}$). There is a baseline log-odds of an overdose $m_0$for both fentanyl (${o^f}_t$) and non-fentanyl related overdoses (${o^n}_t$). In addition for fentanyl-related overdoses there is an increased risk of overdose (m_{fent}), which is further dependent on a random-walk representing variation in fentanyl in the illicit-drug supply (w_t)

The probability of a non-fentanyl overdose is,

$${o_t}^n = logit^{-1}(m_0).$$

The probability of a fentanyl-related overdose is,

$${o_t}^f = logit^{-1}\left(m_0 + m_{fent} w_t\right).$$

Finally the probability of an overdose is approximately the sum of the probability of a fentanyl and the probability of a non-fentanyl overdose,

$$o_t = {o^f}_t + {o^n}_t.$$

The probability of a non-intervened opioid overdose death μ is similarly defined dependent on a number of factors and transformed into a probability using an inverse-logit transformation according to,

$$\mu = logit^{-1}(l_0).$$

The probability of death following a non-intervened opioid overdose is dependent on the a constant log odds ratio only (l_0). Note that the probability of death following an opioid overdose has no dependency on the at-risk population (j).

The probability of an observed opioid overdose is given as the probability of an opioid overdose o_t, multiplied by the probability of the opioid overdose being witnessed p_w, and the probability that emergency medical services (EMS) is called for a witnessed opioid overdose, p_{EMS}. This probability is multiplied by the effective population at-risk to give the rate of EMS-attended opioid overdoses,

$${r_t}^{EMS} = \widetilde{N} o_t p_w p_{EMS}$$

For prescription opioid-related overdoses, a factor is applied ${\kappa_W}^{RX}$ to the probability that an opioid overdose is witnessed to give the probability of an prescription opioid-related overdose witnessed ${p_W}^{RX}$.

The probability that given an opioid overdose occurs a community-based naloxone kit (abbreviated in the formulas as NLX) is used from either a pharmacy-initiated or community-based program, p_t^N is dependent on the number of kits distributed by the community-based program D_t^{NLX}, as well as the number of kits distributed through provider prescription D_t^{RX} and the number of kits distributed through pharmacy-initiation (abbreviated as SO to represent individual-provider standing orders, state-provider standing orders, collaborative pharmacy practice agreements, prescriptive authority, or prescriptive protocol) ${D_t}^{SO}$. In order to provide flexibility in the relationship of number of kits distributed to probability of use, a parameter for initial program efficiency is introduced: m_{NLX}, which controls the initial increase in probability for kits distributed per capita at risk. As the probability of use is dependent on the number of kits distributed within a given population, the number of kits distributed are normalized using the estimated number of people with opioid use disorder (OUD), $\widetilde{D}_t = \frac{D_t}{N_{OUD}}$. The probability of community-based naloxone use is,

$$p_t^{NLX} = \left(1 - exp\left(-m_{NLX}\widetilde{D}_t^{NLX}\right)\right).$$

Similarly, the probability of provider prescribed naloxone can be modelled using its own efficiency parameter m_{RX},

$$p_t^{RX} = \left(1 - exp\left(-m_{RX}\widetilde{D}_t^{RX}\right)\right).$$

Finally, the probability of a pharmacy-initiated kit used can be similarly defined,

$$p_t^{SO} = \left(1 - exp\left(-m_{SO}\widetilde{D}_t^{SO}\right)\right).$$

As data on the use of provider-prescribed naloxone kits is not available, we assume a constant decrease in the efficiency of provider prescription by κ_{RX}, producing $m_{RX} = \kappa_{RX} m_{NLX}$. In addition it is assumed that pharmacy-initiated kits have the same efficacy as community naloxone program kits $m_{SO} = m_{NLX}$. This total probability of naloxone use p_t^N is given as,

$$p_t^N = \left(1 - exp\left(-m_{NLX}\widetilde{D}_t^{NLX} - m_{RX}\widetilde{D}_t^{RX} - m_{SO}\widetilde{D}_t^{SO}\right)\right).$$

The actual experienced probability of a death following an opioid overdose is dependent on the presence of naloxone (p_t^N), whether an opioid overdose is witnessed, and whether emergency medical services (EMS) is called or other intervention takes place that leads to an individual surviving an overdose other than through the use of naloxone (p^w). The rate of overdose related deaths ${r^d}_t$ is the sum of the rate of unwitnessed opioid overdoses and witnessed but no EMS call-out or naloxone administration,

$${r^d}_t = \widetilde{N} o_t p_w (1 - p_{EMS})(1 - p_{NX})\mu + \widetilde{N} o_t (1 - p_w)\mu.$$

The rate of fentanyl-related overdose deaths is similarly defined replacing the total probability of opioid overdose o_t with the probability of a fentanyl-related overdose ${o_t}^f$,

$${r^f}_t = \widetilde{N} {o_t}^f p_w (1 - p_{EMS})(1 - p_{NX})\mu + \widetilde{N} {o_t}^f (1 - p_w)\mu.$$

The probability of a prescription opioid-related death is modified by the prescription opioid-related probability of an overdose being witnessed and is given by,

$${r^{RX,d}}_t = \widetilde{N} o_t {p_w}^{RX} (1 - p_{EMS})(1 - p_{NX})\mu + \widetilde{N} o_t (1 - {p^{RX}}_w)\mu.$$

The rate of reported naloxone kit use for a community-based program is a product of the number of overdoses intervened upon using naloxone from a community-based program, the probability the naloxone kit used is reported p^{NLXR} and the number of kits used per overdose κ^{kits} and is given by,

$${r_t}^{NLX} = \widetilde{N} o_t p_w p^{NLX} p^{NLXR} \kappa^{kits}.$$

Likelihood

The model likelihood is constructed from independent and identically distributed random variables for: EMS-attended overdoses (O_t), any opioid-related overdose deaths (D_t), prescription-opioid-related overdose deaths (${D_t}^{RX}$), fentanyl-related overdose deaths (${D_t}^f$), and reported number of community-based program naloxone kits used (K_t).

The full model likelihood is then,

$$\prod_{t=1}^{T} \frac{(r_t^{EMS})^{O_t} e^{-(r_t^{EMS})}}{O_t!} \prod_{t=1}^{T} \frac{(r_t^{f})^{D_t^{f}} e^{-(r_t^{f})}}{D_t^{f}!} \prod_{t=1}^{T} \frac{(r_t^{d})^{D_t} e^{-(r_t^{d})}}{D_t!} \times$$

$$\prod_{t=1}^{T} \frac{(r_t^{RX,d})^{D_t^{RX}} e^{-(r_t^{RX,d})}}{D_t^{RX}!} \prod_{t=1}^{T} \frac{(r_t^{NLX})^{K_t} e^{-(r_t^{NLX})}}{K_t!}.$$

The full model diagram is given in Figure S1.

Figure S1. Model priors are shown as orange boxes, latent (hidden state) parameters are shown as white boxes, observed rates are shown as green boxes, and fixed data input are shown as blue boxes. Conditional dependence is indicated using arrows.

B. Sensitivity Analysis

Sensitivity analysis was performed by examining the sensitivity of the model outcomes to the choice of prior distributions. Each prior mean was varied from 50% - 150% of its original value individually and each new model was sampled using the MA dataset. The estimated deaths averted due to combined naloxone were used to determine the robustness of the model to prior specification (Fig. S2). The probability of calling EMS (p_{EMS}) resulted in a reduction in the deaths averted from 537 (95% CrI: 250 - 880) to 113 (95% CrI: -73 - 476) at 150% mean prior, and 674 (95% CrI: 376 - 1031) at 50% mean prior. A 50% reduction in the prior mean for kits reported (p^{NLXR}) resulted in 867 (95% CrI: 445 - 1388) estimated deaths averted and . A 50% increase in the prior mean for kits reported resulted in 353 deaths averted (95% CrI: 136 - 623). A 50% increase in kits used per overdose (κ^{kits}) resulted in 374 (95% CrI: 163 - 619) estimated deaths averted, and a 50% decrease resulted in 1072 (95% CrI: 618 - 1638) estimated deaths averted. Other parameters impacted the estimated deaths averted less and were more comparable to the main model (Figure S2).

Figure S2. Posterior predictive distributions of deaths averted (a) and probability of naloxone use (b).

C. Supplemental for Data collection

Prescription Data

State prescription drug monitoring programs (PMDPs) were used to characterize the prescribed populations that are at risk for an opioid overdose. Our analysis included two distinct, but potentially overlapping prescription receiving populations. First, patients with high daily morphine milligram equivalents (MME) have been shown to have an increased risk of an opioid overdose (link to some source).[1] High daily MME was defined as an average daily dose $\geq$90 MME. Buprenorphine products that are exclusively indicated for the treatment of OUD (i.e. Suboxone®) were excluded from MME calculations. MME conversions were made using standard CDC conversion factors.[2] The second prescription receiving population characterized were patients who received an opioid and benzodiazepine prescription within 30 days of one

another. Every opioid and benzodiazepine fill was given a 30-day lookback window to assess potential overlap. This 30-day lookback window required PDMP data from December 2016 to be analyzed for patients receiving either an opioid or benzodiazepine in January 2017. Data were collected as a yearly point estimate for the number of patients that fall into either of the definitions. There is expected to be a significant overlap between the two populations. For both measures, there were no requirements for the length of therapy. For example, a patient prescribed an opioid and benzodiazepine for 1 week is equivalent to a patient on the combination for the entire study period. Several states were not able to provide data from their PDMP for the above metrics. See Figure S3 for details on how those populations were estimated from current literature.

Figure S3. Hernandez I, He M, Brooks MM, Zhang Y. Exposure-Response Association Between Concurrent Opioid and Benzodiazepine Use and Risk of Opioid-Related Overdose in Medicare Part D Beneficiaries. *JAMA Netw Open.* 2018;1(2):e180919. doi:https://doi.org/10.1001/jamanetworkopen.2018.0919

Emergency Medical Services (suspected opioid overdose) Data

Overdose data were extrapolated from emergency medical services (EMS) data for suspected opioid overdoses. EMS data were collected per state from each respective EMS department. Due to the lack of standardization across the country in 2017, we prepared definitions for a suspected opioid overdose using National Emergency Medical Services Information System (NEMSIS) v3.4.0 and NEMSIS 2.2.1 coding. Data were collected per month for the year 2017. Oklahoma was unable to provide data due to ongoing state-led opioid litigation so data were extrapolated from a publicly available dashboard.[3] Arizona was unable to release data due to a state statute so data were extrapolated for the entire year from publicly available data reported from January to May 2017.[4]

Opioid Overdose Case Definition

Broadly defined, an EMS runs is considered to be opioid overdose-related if it meets one of the following criteria (based on available NEMSIS coding):

NEMSIS v3.4.0 Field Codes

1. A primary or secondary impression is overdose-related (eSituation.11 / eSituation.12 /eInjury.01 includes any of the following ICD10 Codes: F11, T40.0-T40.4, T40.6) AND naloxone is in the medication-given dropdown (eMedications.03 includes “Naloxone” or “Narcan”);
2. A primary or secondary impression is overdose-related (eSituation.11 / eSituation.12 /eInjury.01) AND terms for “Naloxone” / “Narcan” AND “Unresponsive” are in narrative;
3. Naloxone is in the medication-given dropdown (eMedications.03 includes “Naloxone” or “Narcan”) AND medication response is improved (eMedications.07 includes “Improved”); OR

4. Terms “Naloxone” or “Narcan” AND “Unresponsive” are in the narrative AND medication response is undocumented

NEMSIS v2.2.1 Field Codes

1. Primary or secondary impression is overdose-related (E09_15 / E09_16 / E10_01 includes any of the following ICD10 Codes: F11, T40.0-T40.4, T40.6) AND naloxone is in the medication-given dropdown (E18_03 includes “Naloxone” or “Narcan”);
2. Primary or secondary impression is overdose-related (E09_15 / E09_16 / E10_01) AND terms for “Naloxone” / “Narcan” AND “Unresponsive” are in narrative;
3. Naloxone is in the medication-given dropdown (E18_03 includes “Naloxone” or “Narcan”) AND medication response is improved (E18_07 includes “Improved”); OR
4. Terms “Naloxone” or “Narcan” AND “Unresponsive” are in the narrative AND medication response is undocumented

Naloxone Data

Naloxone data were separated into three distinct, non-overlapping groups based on where and how the naloxone was distributed. Naloxone was defined as either originating from a community-based program, provider-prescribed, or pharmacy-initiated. With the help of topic experts we identified the main community naloxone distribution data for each model state for the year 2017. Each community organization was contacted to provide data on naloxone that was distributed and in some cases the naloxone that was reported to have been used. Provider-prescribed and pharmacy-initiated naloxone data were collected using Symphony Health. Using known National Provider Identifier (NPI) numbers of documented naloxone providers in the year 2017, we were able to calculate the number of naloxone kits that were dispensed by pharmacy-initiation, thereby differentiating pharmacy-initiated from provider prescribed naloxone.[5]

Death Data

Opioid overdose death data were requested on a per state basis for all model states. Data were requested to separate overdose deaths into potentially overlapping categories of any opioid, fentanyl, heroin, and prescription opioid. By definition, a death could be classified in more than one category. For example, if an autopsy toxicology showed oxycodone and fentanyl, then the death would be counted within the any opioid, fentanyl, and prescription death categories. Opioid overdose death data were obtained per month during the year of 2017. Arizona was unable to provide opioid overdose death data so values were estimated using CDC WONDER.[6]

Parameters

Table S1. Identified model parameters, prior estimate and data sources.

Method for non-model state counterfactual analysis

Non-model state counterfactuals were developed in a similar way to model state counterfactuals. First, the model state's posterior was sampled and the population sizes were adjusted to correspond to each individual non-model state. Each non-model state counterfactual altered a parameter posterior derived from the model state and/or the input data that corresponded to a given intervention. This procedure was repeated for each model state in an opioid epidemic type and the results were sampled and averaged to produce a similar credible interval described in the above section. This procedure was repeated for each non-model state to account for differences in population sizes that were estimated from the literature or collected from published data.

D. Non-model States Counterfactual Results

Table S2: Deaths averted and probability of naloxone use by naloxone access point at 100 kits per 100,000 population

*Negative values in confidence intervals indicate no effect.

Table S3: Deaths averted and probability of naloxone use by naloxone access point at 500 kits per 100,000 population

*Negative values in confidence intervals indicate no effect.

Table S4: Deaths averted and probability of naloxone use by naloxone access point at 1,000 kits per 100,000 population

*Negative values in confidence intervals indicate no effect.

References

1. Dowell D, Haegerich TM, Chou R. CDC Guideline for Prescribing Opioids for Chronic Pain--United States, 2016. JAMA network open. 2016;315(15):1624-45.
2. Centers for Medicare & Medicaid Services. Opioid oral morphine milligram equivalent (MME) conversion factors. https://www.cms.gov/Medicare/Prescription-Drug-Coverage/PrescriptionDrugCovContra/Downloads/Oral-MME-CFs-vFeb-2018.pdf.
3. Oklahoma State Department of Public Health. https://oklahoma.gov/health/prevention-and-preparedness/injury-prevention-service/drug-overdose/data-resources.html.
4. 2016 Arizona Opioid Report. https://www.azdhs.gov/documents/audiences/clinicians/clinical-guidelines-recommendations/prescribing-guidelines/arizona-opioid-report.pdf. 2017.
5. Green TC, Davis C, Xuan Z, Walley AY, Bratberg J. Laws Mandating Coprescription of Naloxone and Their Impact on Naloxone Prescription in Five US States, 2014-2018. American journal of public health. 2020;110(6):881-7.
6. CDC WONDER. https://wonder.cdc.gov/. Accessed August 3, 2021.

Parameters	Parameter Definition	Prior distribution	Data Source	Parameter/Parameter Calculation
POPULATIONS AT RISK				
Parameter	Definition	Prior distribution	Data Source	Estimate Source
Nco-presc	2017 total patient count co-prescribed at least 1 benzodiazepines and opioids prescription within 30 days of each other	Gamma	States' PDMP unless mentioned otherwise	Arizona, Idaho, Iowa, Oklahoma, Oregon used the average of the 9 states studied in Guy, et al. Estimates: Guy GP Jr, Zhang K, Halpin J, Sargent W. An Examination of Concurrent Opioid and Benzodiazepine Prescribing in 9 States, 2015. Am J Prev Med. 2019;57(5):629-636. doi:10.1016/j.amepre.2019.06.007
Ninc	Person with diagnosed OUD and recently released from incarceration in 2017	Gamma	"TABLE 7. Admissions and releases of sentenced prisoners under jurisdiction of state or federal correctional authorities, 2016 and 2017" ; http://www.bjs.gov/index.cfm?ty=pbdetail&iid=6546	Number of inmates released in 2017 multiplied by 18.9% (heroin/opiate use in prison pop) (estimate from the Prisoners in 2017 report) "TABLE 5. State prisoners and sentenced jail inmates who had ever used or regularly used drugs, by drug type, 2002, 2004, and 2007–2009" Heroin/opiates in 2007-2009 18.9% ; https://www.bjs.gov/index.cfm?ty=pbdetail&iid=5966
Nrelapse	Return to use from treatment population prior	Gamma	N/A	Table 8.1 (# discharged - # transferred) multiplied by 65% Table 9.1 (# discharged - # transferred) multiplied by 65% Table 11.1 (# discharged - # transferred) multiplied by 65% Table 12.1 (# discharged - # transferred) Table 13.1 (# discharged - # transferred) "Treatment Episode Data Set (TEDS): 2017 Admissions to and Discharges from Publicly-Funded

				Substance Use Treatment" (Tables 8.1 Short-term residential treatment, 9.1 Long-term residential treatment, 11.1 Detoxification, 12.1 Outpatient medication-assisted opioid therapy, 13.1 Medication-assisted opioid detoxification)
NOUD	Opioid use disorder population prior	Gamma	N/A	Number of 19-64 year olds multiplied by 4.6% (OUD pop in state in 2015) KFF "Population Distribution by Age" 19-64 year olds CY 2017 ; https://www.kff.org/other/state-indicator/distribution-by-age/ Barocas, J., White, L., Wang, J., Walley, A., Larochelle, M., Bernson, D., . . . Linas, B. (2018). Estimated Prevalence of Opioid Use Disorder in Massachusetts, 2011-2015: A Capture-Recapture Analysis. American Journal of Public Health, 108(12), 1675-1681. Barocas JA, White LF, Wang J, et al. Estimated Prevalence of Opioid Use Disorder in Massachusetts, 2011-2015: A Capture-Recapture Analysis. Am J Public Health. 2018;108(12):1675-1681.
NRx	2017 total patient count prescribed high dose (>90 MME) opioids population prior per CDC MME conversion tables. Concurrent opioid prescriptions were totaled to get an average daily MME.	Gamma	States' PDMP unless mentioned otherwise	Estimated: Arizona, California, Idaho, Iowa, Oklahoma, Oregon Ratio calculated with full high dose rx datasets (monthly pts prescribed & yearly total pt count) from Massachusett, Rhode Island, South Carolina, Washington Estimates: 2018 ANNUAL SURVEILLANCE REPORT OF DRUG-RELATED RISKS AND OUTCOMES: Table 1C to estimate the number of high dose rx prescriptions (https://www.cdc.gov/drugoverdo

				se/pdf/pubs/2018-cdc-drug-surveillance-report.pdf)
NCoke	Cocaine users unaware of fentanyl exposure	Gamma	N/A	2017 admissions data used to estimate cocaine use in population. Number of cocaine admissions multiplied by 18.5% for cocaine users exposed/unaware of fentanyl-contamination "Treatment Episode Data Set (TEDS): 2017 Admissions to and Discharges from Publicly-Funded Substance Use Treatment"; Table 14.4a. Primary cocaine admissions aged 12 years and older, by Census region, Census division, and state or jurisdiction: Number, 2007–2017 Hughto, J.M.W., Stopka, T.J., Case, P., Palacios, W.R., Tapper, A., & Green, T.C. (2021) Understanding opioid overdose risk and response preparedness among people who use cocaine and other drugs: mixed-methods findings from a large, multi-city study. Substance Abuse. *Georgia (2014 TEDS) and Oregon (Medicaid data requested)
ASSOCIATE RISK PER POPULATION				
Prior Name	**Definition**	**Prior distribution**	**Data Source**	**Prior Value**
mco-presc	OD risk for sub population	Gamma	Sun, E., Dixit, A., Humphreys, K., Darnall, B., Baker, L., & Mackey, S. (2017). Association between concurrent use of prescription opioids and benzodiazepines and overdose: Retrospective analysis. BMJ (Clinical Research Ed.), 356, J760.	AOR: 2.14, (95%CI 2.05 to 2.24) ; non-fatal, compared to all opioid users
minc	OD risk for sub population	Gamma	"An Assessment of Fatal and Nonfatal Opioid Overdoses in Massachusetts (2011 – 2015)" Bar Graph on page 50: "Opioid Death Rate 120 Times Higher for Individuals	120 RR ; fatal, compared to general population

			with Histories of Incarceration" ; https://www.mass.gov/files/documents/2017/08/31/legislative-report-chapter-55-aug-2017.pdf	
mrelapse	OD risk for sub population	Gamma	MA DPH "Data Brief: Stimulants, health disparities, and the impact of the opioid epidemic on maternal health and high risk populations" March 2019 ; https://www.mass.gov/files/documents/2019/03/13/PHD-1.0-Combined-Data-Brief.pdf (table 15)	2.4 RR
mOUD	OD risk for sub population	Gamma	Evans, E., Li, L., Min, J., Huang, D., Urada, D., Liu, L., . . . Nosyk, B. (2015). Mortality among individuals accessing pharmacological treatment for opioid dependence in California, 2006–10. Addiction, 110(6), 996-1005.	SMR: 4.5 (95% CI: 4.2, 4.8) ; fatal, compared to general population
mRX	OD risk for sub population	Gamma	Bohnert, A., Valenstein, M., Bair, M., Ganoczy, D., Mccarthy, J., Ilgen, M., & Blow, F. (2011). Association between opioid prescribing patterns and opioid overdose-related deaths. JAMA, 305(13), 1315-21.	AHR: 4.54 (95% CI: 2.46-8.37) ; fatal, patients with substance use disorder on greater than 100 MME/d compared to patients on 1-20 MME/d
mCoke	OD risk for sub population	Gamma	An Assessment of Fatal and Nonfatal Opioid Overdoses in Massachusetts (2011 – 2015) Bar Graph on page 50: "Opioid Death Rate 120 Times Higher for Individuals with Histories of Incarceration" ; https://www.mass.gov/files/documents/2017/08/31/legislative-report-chapter-55-aug-2017.pdf **Justification**: cocaine users who are exposed to fentanyl contamination do not have any tolerance to an opioid-	120 RR ; fatal, compared to general population

			similar to those leaving incarceration and return to use having no tolerance since being incarcerated	
MODEL PARAMETERS				
Prior Name	Definition	Prior distribution	Data Source	Prior Value
pNt	Probability of naloxone being present and used	Derived variable	Naloxone distribution data from community programs and pharmacy claims datasets.	Inferred from distribution data per state. norm_nlx_distributed = d['kits_distributed_community']/NOUD prob_nlx_used = 0.99*(1- np.exp(-mNLX*norm_nlx_distributed))
pW	Probability of overdose being witnessed (percent)	Beta	Hughto, J.M.W., Stopka, T.J., Case, P., Palacios, W.R., Tapper, A., & Green, T.C. (2021) Understanding opioid overdose risk and response preparedness among people who use cocaine and other drugs: mixed-methods findings from a large, multi-city study. Substance Abuse. Green T, Boggis J, Plotke R. High Geographic Variation and Dynamic Change in the U.S. Opioid Epidemic: Results from a Delphi Panel. American Public Health Association; November 3, 2019; Philadelphia, PA 2019. Wagner KD, Valente TW, Casanova M, Partovi SM, Mendenhall BM, Hundley JH, Gonzalez M, Unger JB. (2010). Evaluation of an overdose prevention and response training programme for injection drug users in the Skid Row area of Los Angeles, CA. International Journal of Drug Policy, 21(3), 186-193. Ogeil, Dwyer, Bugeja, Heilbronn, Lubman, & Lloyd. (2018). Pharmaceutical	Epidemic dependent: Fentanyl: .62 (.10); Rx/F: .45 (.19); Prescription/Heroin: .45 (.19); Fentanyl/Heroin: .61 (.08); Rx: .29 (.09) Prescription only: .38 (.23); [Delphi] Heroin only: .60; [Delphi]

			opioid overdose deaths and the presence of witnesses. International Journal of Drug Policy, 55, 8-13. and Levy, Spelke, Paulozzi, Bell, Nolte, Lathrop, . . . Landen. (2016). Recognition and response to opioid overdose deaths—New Mexico, 2012. Drug and Alcohol Dependence, 167, 29-35.	
p_EMS	Probability of calling EMS (percent)	Beta	Hughto, J.M.W., Stopka, T.J., Case, P., Palacios, W.R., Tapper, A., & Green, T.C. (In Press) Understanding opioid overdose risk and response preparedness among people who use cocaine and other drugs: mixed-methods findings from a large, multi-city study. Substance Abuse. Lim JK, Forman LS, Ruiz S, Xuan Z, Callis BP, Cranston K, Walley AY. Factors associated with help seeking by community responders trained in overdose prevention and naloxone administration in Massachusetts. Drug Alcohol Depend. 2019 Nov 1;204:107531. doi: 10.1016/j.drugalcdep.2019.06.033. Epub 2019 Aug 30. PMID: 31526959. Wagner, Valente, Casanova, Partovi, Mendenhall, Hundley, . . . Unger. (2010). Evaluation of an overdose prevention and response training programme for injection drug users in the Skid Row area of Los Angeles, CA. International Journal of Drug Policy, 21(3), 186-193.	0.60 (.11)

m0	Baseline OD rate	Normal	Irvine MA, Buxton JA, Otterstatter M, Balshaw R, Gustafson R, Tyndall M, et al. Distribution of take-home opioid antagonist kits during a synthetic opioid epidemic in British Columbia, Canada: a modelling study. The Lancet Public health. 2018;3(5):e218-e25.	0.00913 annual rate
p	Probability of coming into contact with fentanyl	logit Normal	Randomly assigned to a small probability and the posterior will be inferred using a random walk fitted to the model.	0.1 (logit space)
m_fentanyl	Impact of fentanyl on overdoses (logit space)	Gamma	Irvine MA, Buxton JA, Otterstatter M, Balshaw R, Gustafson R, Tyndall M, et al. Distribution of take-home opioid antagonist kits during a synthetic opioid epidemic in British Columbia, Canada: a modelling study. The Lancet Public health. 2018;3(5):e218-e25.	'm':2.15 , 'sd':0.2
l0	Baseline probability of death following an OD (no intervention)	Normal	Green T, Boggis J, Plotke R. High Geographic Variation and Dynamic Change in the U.S. Opioid Epidemic: Results from a Delphi Panel. American Public Health Association; November 3, 2019; Philadelphia, PA 2019.	'm': 1.4, 'sd': 0.2 (in logit space)
kit	Mean number of kits used in a reversal	Gamma	Mahonski SG, Leonard JB, Gatz JD, Seung H, Haas EE, Kim HK. Prepacked naloxone administration for suspected opioid overdose in the era of illicitly manufactured fentanyl: a retrospective study of regional poison center data. Clin Toxicol (Phila). 2020;58(2):117-123.	.95 (.48)

Table S2: **Deaths averted per 100 000 population and probability of naloxone use by naloxone access point at 100 kits per 100,000 population**

Non-Model States Counterfactuals (mean for 100 kits per 100,000 population)						
State	**Deaths averted by community program naloxone**	**Deaths averted by provider prescribed naloxone**	**Deaths averted by pharmacy-initiated naloxone**	**Probability of naloxone use from a community program**	**Probability of naloxone use from a provider prescription**	**Probability of naloxone use from pharmacy-initiation**
Alaska	0.7 (-12.6-15.5)	0.1 (-13.2-13.0)	0.5 (-11.9-14.0)	20.8 (15.9-26.3)	4.6 (3.4-6.1)	20.8 (15.9-26.3)
Alabama	2.4 (-0.7-4.8)	0.3 (-2.1-2.5)	1.3 (-1.4-3.4)	26.9 (14.2-38.8)	6.1 (3.0-9.5)	26.9 (14.2-38.8)
Arkansas	0.6 (-2.2-4.8)	0.1 (-3.0-3.4)	0.6 (-2.1-4.2)	21.7 (16.7-27.4)	4.8 (3.5-6.3)	21.7 (16.7-27.4)
Colorado	7.0 (0.5-11.9)	0.6 (-0.8-2.3)	1.6 (-0.0-5.6)	49.2 (21.1-76.4)	12.8 (4.6-25.7)	49.2 (21.1-76.4)
Connecticut	2.7 (-1.4-5.7)	0.3 (-2.8-3.3)	1.5 (-2.1-4.2)	26.2 (13.8-37.8)	5.9 (2.9-9.2)	26.2 (13.8-37.8)
Delaware	3.5 (-10.4-14.5)	0.3 (-11.3-11.6)	1.8 (-10.3-12.4)	27.2 (14.4-39.1)	6.2 (3.0-9.6)	27.2 (14.4-39.1)
Florida	1.2 (0.5-2.4)	0.2 (-0.3-0.7)	0.6 (0.1-1.6)	27.4 (14.5-39.4)	6.2 (3.1-9.7)	27.4 (14.5-39.4)
Georgia	1.5 (-0.2-2.5)	0.5 (-0.8-1.2)	1.4 (-0.4-2.3)	19.7 (10.8-48.9)	4.3 (2.2-12.7)	19.7 (10.8-48.9)
Hawaii	0.6 (-6.0-8.7)	0.1 (-6.6-6.9)	0.6 (-5.8-7.5)	21.9 (16.8-27.6)	4.9 (3.6-6.4)	21.9 (16.8-27.6)
Indiana	2.2 (-0.2-4.0)	0.3 (-1.4-1.9)	1.1 (-0.7-2.7)	27.0 (14.3-38.8)	6.1 (3.0-9.5)	27.0 (14.3-38.8)
Kansas	0.6 (-2.4-4.8)	0.1 (-3.1-3.4)	0.6 (-2.3-4.3)	21.6 (16.6-27.3)	4.8 (3.5-6.3)	21.6 (16.6-27.3)
Kentucky	2.5 (-0.9-5.0)	0.3 (-2.2-2.7)	1.3 (-1.5-3.6)	26.9 (14.2-38.8)	6.1 (3.0-9.5)	26.9 (14.2-38.8)
Louisiana	0.6 (-1.1-3.6)	0.1 (-1.9-2.3)	0.6 (-1.1-3.1)	21.1 (16.2-26.7)	4.6 (3.4-6.1)	21.1 (16.2-26.7)
Maryland	2.2 (-0.3-4.2)	0.3 (-1.6-2.1)	1.2 (-0.9-2.9)	26.0 (13.7-37.6)	5.8 (2.9-9.1)	26.0 (13.7-37.6)
Maine	3.4 (-6.9-11.0)	0.4 (-7.8-8.4)	1.8 (-7.2-9.4)	26.7 (14.1-38.5)	6.0 (3.0-9.4)	26.7 (14.1-38.5)
Michigan	1.8 (0.3-3.3)	0.3 (-0.9-1.3)	0.9 (-0.3-2.2)	26.6 (14.0-38.3)	6.0 (2.9-9.3)	26.6 (14.0-38.3)
Minnesota	1.9 (-1.0-3.6)	0.5 (-1.6-1.9)	1.8 (-1.1-3.2)	19.6 (10.8-48.7)	4.3 (2.2-12.7)	19.6 (10.8-48.7)
Missouri	2.2 (-0.3-4.2)	0.3 (-1.6-2.0)	1.2 (-0.8-3.0)	27.0 (14.3-38.9)	6.1 (3.0-9.5)	27.0 (14.3-38.9)
Mississippi	0.6 (-2.1-4.7)	0.1 (-2.9-3.4)	0.6 (-2.3-4.2)	21.7 (16.7-27.4)	4.8 (3.5-6.3)	21.7 (16.7-27.4)
Montana	0.7 (-8.5-11.4)	0.1 (-8.8-9.4)	0.7 (-7.8-10.3)	21.5 (16.5-27.1)	4.8 (3.5-6.3)	21.5 (16.5-27.1)
North Dakota	0.7 (-12.0-15.0)	0.3 (-12.8-12.9)	0.7 (-12.1-13.4)	21.1 (16.2-26.7)	4.7 (3.5-6.2)	21.1 (16.2-26.7)
Nebraska	0.6 (-4.0-6.7)	0.2 (-4.7-5.1)	0.6 (-4.0-5.9)	21.6 (16.6-27.3)	4.8 (3.5-6.3)	21.6 (16.6-27.3)
New Hampshire	3.3 (-6.8-10.8)	0.3 (-7.7-8.3)	1.7 (-7.1-9.1)	26.3 (13.9-37.9)	5.9 (2.9-9.3)	26.3 (13.9-37.9)
New Jersey	1.9 (0.2-3.5)	0.3 (-1.0-1.4)	1.0 (-0.4-2.4)	25.9 (13.6-37.4)	5.8 (2.9-9.1)	25.9 (13.6-37.4)
New Mexico	7.9 (-0.5-17.8)	0.6 (-3.0-4.4)	2.3 (-1.6-8.0)	51.1 (22.2-78.2)	13.5 (4.9-26.9)	51.1 (22.2-78.2)
New York	1.2 (0.51-2.5)	0.3 (-.4-0.8)	0.6 (0.1-1.6)	25.6 (13.5-37.0)	5.7 (2.8-8.9)	25.6 (13.5-37.0)

Nevada	0.6 (-2.2-4.8)	0.1 (-2.9-3.3)	0.6 (-2.1-4.2)	20.9 (16.0-26.4)	4.6 (3.4-6.0)	20.9 (16.0-26.4)
Ohio	1.6 (0.4-3.1)	0.3 (-0.7-1.2)	0.9 (-0.1-2.0)	26.8 (14.2-38.6)	6.0 (3.0-9.4)	26.8 (14.2-38.6)
Pennsylvania	1.6 (0.5-3.0)	0.3 (-0.6-1.1)	0.8 (-0.1-2.0)	26.8 (14.1-38.6)	6.0 (3.0-9.4)	26.8 (14.1-38.6)
South Dakota	0.7 (-10.4-13.0)	0.2 (-10.5-10.9)	0.6 (-10.1-11.9)	22.2 (17.0-27.9)	4.9 (3.6-6.5)	22.2 (17.0-27.9)
Tennessee	1.8 (-0.7-3.2)	0.5 (-1.3-1.6)	1.7 (-0.9-2.9)	19.8 (10.9-49.0)	4.3 (2.2-12.8)	19.8 (10.9-49.0)
Texas	2.7 (0.4-3.7)	0.3 (0.0-1.2)	0.6 (0.1-2.4)	50.3 (21.7-77.5)	13.1 (4.8-26.4)	50.3 (21.7-77.5)
Utah	0.6 (-2.0-4.5)	0.1 (-2.7-3.2)	0.6 (-2.1-4.1)	22.0 (16.9-27.8)	4.9 (3.6-6.4)	22.0 (16.9-27.8)
Virginia	1.9 (0.2-3.5)	0.3 (-1.1-1.5)	1.0 (-0.4-2.4)	26.7 (14.1-38.5)	6.0 (3.0-9.4)	26.7 (14.1-38.5)
Vermont	3.7 (-16.8-20.6)	0.3 (-17.2-17.4)	1.9 (-16.3-19.0)	26.7 (14.1-38.4)	6.1 (3.0-9.5)	26.7 (14.1-38.4)
West Virginia	3.2 (-4.6-8.9)	0.4 (-5.8-6.2)	1.7 (-4.9-7.2)	27.1 (14.3-39.0)	6.1 (3.0-9.6)	27.1 (14.3-39.0)
Wisconsin	1.9 (-1.0-3.5)	0.5 (-1.5-1.8)	1.8 (-1.2-3.2)	19.7 (10.8-48.8)	4.3 (2.2-12.8)	19.7 (10.8-48.8)
Wyoming	0.7 (-16.6-19.6)	0.2 (-16.6-17.0)	0.5 (-15.6-18.0)	21.4 (16.4-27.0)	4.8 (3.5-6.3)	21.4 (16.4-27.0)

*Negative values in confidence intervals indicate no effect.

Table S3: Deaths averted per 100 000 population and probability of naloxone use by naloxone access point at 500 kits per 100,000 population

Non-Model States Counterfactuals (mean for 500 kits per 100,000 population)						
State	Deaths averted by community program naloxone	Deaths averted by provider prescribed naloxone	Deaths averted by pharmacy-initiated naloxone	Probability of naloxone use from a community program	Probability of naloxone use from a provider prescription	Probability of naloxone use from pharmacy-initiation
Alaska	2.3 (-9.5-19.1)	0.5 (-12.2-13.6)	2.3 (-9.1-17.1)	68.8 (58.0-78.2)	20.8 (15.8-26.6)	68.8 (58.0-78.2)
Alabama	3.7 (0.2-8.7)	0.8 (-1.5-3.0)	1.8 (-0.3-5.9)	79.2 (53.6-91.4)	26.9 (14.1-39.2)	79.2 (53.6-91.4)
Arkansas	1.7 (-0.3-8.6)	0.5 (-2.4-4.0)	1.6 (-0.4-7.2)	70.6 (59.8-79.9)	21.7 (16.5-27.8)	70.6 (59.8-79.9)
Colorado	4.1 (1.3-10.4)	1.3 (-0.3-4.8)	1.9 (-0.5-6.8)	96.6 (69.5-99.9)	49.5 (21.1-77.3)	96.6 (69.5-99.9)
Connecticut	4.1 (0.7-10.2)	1.0 (-2.2-3.9)	2.0 (-0.5-6.9)	78.1 (52.5-90.7)	26.1 (13.7-38.2)	78.1 (52.5-90.7)
Delaware	8.9 (-5.3-20.4)	1.2 (-10.4-12.3)	4.7 (-7.7-15.7)	79.5 (53.9-91.6)	27.1 (14.2-39.5)	79.5 (53.9-91.6)
Florida	0.9 (-0.1-2.6)	0.4 (-0.1-1.2)	0.4 (-0.2-1.9)	79.9 (54.4-91.9)	27.4 (14.4-39.9)	79.9 (54.4-91.9)
Georgia	1.7 (0.1-4.0)	1.0 (-0.5-1.9)	1.4 (0.1-3.1)	66.7 (43.7-96.5)	19.7 (10.7-49.4)	66.7 (43.7-96.5)
Hawaii	2.0 (-2.7-12.7)	0.5 (-6.1-7.9)	2.0 (-3.0-10.6)	70.9 (60.1-80.1)	21.9 (16.6-28.0)	70.9 (60.1-80.1)
Indiana	3.2 (-0.0-7.2)	0.7 (-0.9-2.4)	1.6 (-0.3-4.9)	79.2 (53.6-91.4)	26.9 (14.1-39.2)	79.2 (53.6-91.4)
Kansas	1.7 (-0.4-8.7)	0.5 (-2.5-4.0)	1.6 (-0.4-7.3)	70.4 (59.6-79.6)	21.6 (16.4-27.6)	70.4 (59.6-79.6)
Kentucky	3.8 (0.4-9.0)	0.9 (-1.7-3.3)	1.8 (-0.3-6.2)	79.2 (53.6-91.4)	26.8 (14.1-39.2)	79.2 (53.6-91.4)
Louisiana	1.4 (-0.2-7.4)	0.4 (-1.3-2.9)	1.4 (-0.2-6.1)	69.5 (58.7-78.9)	21.1 (16.0-27.0)	69.5 (58.7-78.9)

Maryland	3.4 (0.0-7.6)	0.7 (-1.1-2.7)	1.6 (-0.3-5.1)	77.8 (52.2-90.5)	25.9 (13.6-38.0)	77.8 (52.2-90.5)
Maine	7.5 (-2.2-16.7)	1.2 (-7.4-9.3)	4.0 (-4.7-12.6)	78.8 (53.3-91.2)	26.7 (14.0-38.9)	78.8 (53.3-91.2)
Michigan	2.4 (-0.2-5.5)	0.6 (-0.4-1.9)	1.2 (-0.3-3.8)	78.6 (53.0-91.0)	26.5 (13.9-38.7)	78.6 (53.0-91.0)
Minnesota	2.3 (0.6-5.5)	1.4 (-1.3-2.6)	1.8 (0.1-5.2)	66.5 (43.5-96.4)	19.6 (10.6-49.2)	66.5 (43.5-96.4)
Missouri	3.4 (0.0-7.6)	0.8 (-1.1-2.6)	1.6 (-0.3-5.1)	79.3 (53.7-91.5)	26.9 (14.1-39.3)	79.3 (53.7-91.5)
Mississippi	1.7 (-0.4-8.6)	0.5 (-2.4-4.0)	1.6 (-0.4-7.3)	70.6 (59.8-79.8)	21.7 (16.5-27.7)	70.6 (59.8-79.8)
Montana	2.2 (-5.3-15.2)	0.5 (-8.2-9.6)	2.1 (-5.0-13.2)	70.1 (59.3-79.4)	21.5 (16.3-27.4)	70.1 (59.3-79.4)
North Dakota	2.2 (-8.8-19.1)	0.5 (-11.8-13.8)	2.2 (-8.4-16.8)	69.4 (58.6-78.8)	21.1 (16.0-27.0)	69.4 (58.6-78.8)
Nebraska	1.9 (-1.2-10.5)	0.5 (-4.0-5.9)	1.8 (-1.4-9.0)	70.4 (59.6-79.7)	21.6 (16.4-27.6)	70.4 (59.6-79.7)
New Hampshire	7.4 (-2.4-16.5)	1.3 (-7.2-9.0)	3.9 (-4.4-12.4)	78.2 (52.6-90.8)	26.2 (13.7-38.4)	78.2 (52.6-90.8)
New Jersey	2.6 (-0.2-5.9)	0.6 (-0.5-2.0)	1.3 (-0.3-4.1)	77.6 (51.9-90.4)	25.8 (13.5-37.8)	77.6 (51.9-90.4)
New Mexico	18.4 (2.0-25.7)	2.0 (-1.9-7.3)	4.3 (-0.4-16.2)	97.2 (71.4-100.0)	51.3 (22.1-79.1)	97.2 (71.4-100.0)
New York	2.3 (0.7-5.0)	0.6 (0.1-1.5)	1.1 (0.3-3.4)	77.1 (51.5-90.1)	25.5 (13.3-37.4)	77.2 (51.5-90.1)
Nevada	1.7 (-0.4-8.5)	0.5 (-2.3-4.0)	1.5 (-0.4-7.3)	69.1 (58.2-78.4)	20.9 (15.8-26.7)	69.1 (58.2-78.4)
Ohio	2.0 (-0.2-4.8)	0.5 (-0.3-1.7)	1.0 (-0.2-3.4)	79.0 (53.4-91.3)	26.7 (14.0-39.0)	79.0 (53.4-91.3)
Pennsylvania	1.9 (-0.2-4.5)	0.5 (-0.2-1.6)	0.9 (-0.2-3.2)	78.9 (53.3-91.2)	26.7 (14.0-39.0)	78.9 (53.3-91.2)
South Dakota	2.3 (-6.9-16.8)	0.6 (-10.1-11.7)	2.2 (-6.8-15.1)	71.4 (60.6-80.5)	22.2 (16.8-28.3)	71.4 (60.6-80.5)
Tennessee	2.2 (0.5-4.9)	1.3 (-1.0-2.3)	1.7 (0.2-4.5)	66.8 (43.8-96.5)	19.8 (10.7-49.5)	66.8 (43.8-96.5)

Texas	0.1 (-0.2-0.4)	0.4 (-0.1-1.5)	0.1 (-0.2-0.3)	97.0 (70.7-99.9)	50.5 (21.7-78.3)	97.0 (70.7-99.9)
Utah	1.6 (-0.3-8.3)	0.4 (-2.2-3.8)	1.6 (-0.4-7.1)	71.1 (60.3-80.3)	22.0 (16.7-28.1)	71.1 (60.3-80.3)
Virginia	2.7 (-0.1-6.1)	0.6 (-0.6-2.1)	1.3 (-0.3-4.2)	78.8 (53.2-91.2)	26.6 (14.0-38.9)	78.8 (53.2-91.2)
Vermont	10.7 (-11.7-27.5)	1.3 (-16.6-18.4)	5.6 (-13.6-21.9)	78.7 (53.1-91.1)	26.6 (14.0-38.9)	78.7 (53.1-91.1)
West Virginia	6.2 (-0.6-14.3)	1.2 (-5.0-7.0)	3.2 (-2.7-10.2)	79.4 (53.8-91.5)	27.0 (14.2-39.4)	79.4 (53.8-91.5)
Wisconsin	2.3 (0.6-5.5)	1.3 (-1.2-2.6)	1.8 (0.2-5.1)	66.7 (43.6-96.5)	19.7 (10.7-49.4)	66.7 (43.6-96.5)
Wyoming	2.4 (-12.6-22.8)	0.5 (-15.9-17.0)	2.3 (-12.3-20.8)	69.9 (59.1-79.2)	21.4 (16.2-27.3)	69.9 (59.1-79.2)

*Negative values in confidence intervals indicate no effect.

Table S4: Deaths averted per 100 000 population and probability of naloxone use by naloxone access point at 1,000 kits per 100,000 population

Non-Model States Counterfactuals (mean for 1,000 kits per 100,000 population)						
State	Deaths averted by community program naloxone	Deaths averted by provider prescribed naloxone	Deaths averted by pharmacy-initiated naloxone	Probability of naloxone use from a community program	Probability of naloxone use from a provider prescription	Probability of naloxone use from pharmacy-initiation
Alaska	4.7 (-4.3-26.3)	1.1 (-10.9-14.8)	4.5 (-4.6-22.2)	90.3 (82.3-95.3)	37.3 (29.0-46.1)	90.3 (82.3-95.3)
Alabama	6.2 (0.3-13.3)	1.4 (-0.7-4.1)	3.1 (-0.2-9.1)	95.7 (78.5-99.3)	46.5 (26.2-63.1)	95.7 (78.5-99.3)
Arkansas	2.9 (-0.1-15.2)	1.0 (-1.5-5.2)	2.9 (-0.1-12.3)	91.4 (83.9-96.0)	38.7 (30.2-47.8)	91.4 (83.9-96.0)
Colorado	4.3 (1.7-11.8)	1.9 (0.1-7.9)	2.3 (-0.5-7.8)	99.9 (90.7-100.0)	74.5 (37.7-94.8)	99.9 (90.7-100.0)
Connecticut	7.6 (0.9-16.2)	1.7 (-1.4-5.0)	3.7 (-0.1-10.8)	95.2 (77.4-99.1)	45.4 (25.5-61.9)	95.2 (77.4-99.1)
Delaware	14.8 (1.3-30.5)	2.6 (-9.8-13.5)	7.7 (-3.4-20.8)	95.8 (78.8-99.3)	46.8 (26.4-63.4)	95.8 (78.8-99.3)
Florida	0.9 (-0.1-3.0)	0.7 (-0.0-1.8)	0.4 (-0.2-2.2)	96.0 (79.2-99.3)	47.2 (26.7-63.8)	96.0 (79.2-99.3)
Georgia	2.3 (0.1-6.7)	1.3 (-0.0-3.0)	2.0 (0.1-4.7)	88.9 (68.3-99.9)	35.6 (20.2-74.4)	88.9 (68.3-99.9)
Hawaii	4.2 (-0.4-19.1)	1.1 (-5.0-8.8)	3.9 (-0.6-16.3)	91.6 (84.1-96.1)	39.0 (30.5-48.1)	91.6 (84.1-96.1)
Indiana	4.8 (-0.0-10.6)	1.2 (-0.3-3.4)	2.3 (-0.2-7.4)	95.7 (78.5-99.3)	46.5 (26.2-63.1)	95.7 (78.5-99.3)
Kansas	3.0 (-0.1-15.4)	1.0 (-1.6-5.1)	3.0 (-0.1-12.6)	91.2 (83.7-95.9)	38.5 (30.1-47.6)	91.2 (83.7-95.9)
Kentucky	6.6 (0.4-14.1)	1.5 (-0.9-4.3)	3.3 (-0.2-9.7)	95.7 (78.5-99.3)	46.5 (26.2-63.0)	95.7 (78.5-99.3)
Louisiana	2.0 (-0.1-13.8)	0.9 (-0.5-3.9)	2.0 (-0.1-11.1)	90.7 (82.9-95.5)	37.8 (29.5-46.7)	90.7 (82.9-95.5)

Maryland	5.2 (0.0-11.5)	1.2 (-0.4-3.6)	2.5 (-0.2-7.9)	95.1 (77.1-99.1)	45.2 (25.3-61.6)	95.1 (77.1-99.1)
Maine	12.0 (3.3-26.4)	2.4 (-6.4-10.4)	6.2 (-1.4-17.6)	95.5 (78.1-99.2)	46.2 (26.0-62.7)	95.5 (78.1-99.2)
Michigan	3.1 (-0.2-7.5)	0.9 (-0.0-2.8)	1.4 (-0.3-5.3)	95.4 (77.9-99.2)	45.9 (25.8-62.4)	95.4 (77.9-99.2)
Minnesota	4.0 (0.9-8.9)	2.2 (-0.7-4.0)	3.3 (0.7-7.4)	88.8 (68.0-99.9)	35.4 (20.1-74.2)	88.8 (68.0-99.9)
Missouri	5.2 (0.0-11.3)	1.2 (-0.3-3.6)	2.5 (-0.2-7.9)	95.7 (78.6-99.3)	46.6 (26.3-63.2)	95.7 (78.6-99.3)
Mississippi	2.9 (-0.1-15.4)	0.9 (-1.5-5.1)	2.9 (-0.1-12.4)	91.3 (83.8-95.9)	38.7 (30.2-47.7)	91.3 (83.8-95.9)
Montana	4.4 (-1.2-21.4)	1.1 (-7.1-10.7)	4.1 (-1.5-18.1)	91.1 (83.4-95.8)	38.3 (29.9-47.3)	91.1 (83.4-95.8)
North Dakota	4.7 (-3.9-25.9)	1.2 (-10.8-14.9)	4.5 (-4.1-21.4)	90.7 (82.9-95.5)	37.8 (29.4-46.7)	90.7 (82.9-95.5)
Nebraska	3.7 (-0.2-17.2)	1.0 (-3.1-6.8)	3.6 (-0.2-14.3)	91.3 (83.7-95.9)	38.6 (30.1-47.6)	91.3 (83.7-95.9)
New Hampshire	11.9 (3.2-26.0)	2.4 (-6.3-10.2)	6.2 (-1.3-17.6)	95.3 (77.5-99.1)	45.5 (25.6-62.0)	95.3 (77.5-99.1)
New Jersey	3.5 (-0.2-8.3)	1.0 (-0.1-2.9)	1.6 (-0.3-5.8)	95.0 (76.9-99.1)	44.9 (25.2-61.3)	95.0 (76.9-99.1)
New Mexico	23.4 (4.2-36.6)	3.4 (-0.8-12.3)	6.3 (0.0-23.9)	99.9 (91.8-100.0)	76.3 (39.3-95.6)	99.9 (91.8-100.0)
New York	2.4 (0.7-5.4)	0.9 (0.2-2.2)	1.2 (0.3-3.8)	94.8 (76.4-99.0)	44.5 (24.9-60.8)	94.8 (76.4-99.0)
Nevada	2.9 (-0.1-15.4)	1.0 (-1.5-4.9)	2.9 (-0.1-12.5)	90.4 (82.5-95.3)	37.4 (29.1-46.3)	90.4 (82.5-95.3)
Ohio	2.5 (-0.2-6.3)	0.9 (0.0-2.5)	1.1 (-0.2-4.5)	95.6 (78.3-99.2)	46.3 (26.1-62.8)	95.6 (78.3-99.2)
Pennsylvania	2.2 (-0.2-5.7)	0.9 (-0.0-2.4)	1.0 (-0.2-4.1)	95.6 (78.2-99.2)	46.2 (26.0-62.8)	95.6 (78.2-99.2)
South Dakota	4.5 (-2.6-23.5)	1.1 (-8.7-12.7)	4.3 (-3.1-20.2)	91.8 (84.5-96.2)	39.4 (30.8-48.5)	91.8 (84.5-96.2)
Tennessee	3.5 (0.6-8.3)	1.9 (-0.5-3.7)	3.0 (0.5-6.3)	89.0 (68.4-99.9)	35.7 (20.3-74.5)	89.0 (68.4-99.9)

Texas	0.1 (-0.2-0.4)	0.5 (-0.1-1.7)	0.1 (-0.2-0.3)	99.9 (91.4-100.0)	75.5 (38.6-95.3)	99.9 (91.4-100.0)
Utah	2.8 (-0.1-15.1)	0.9 (-1.2-5.0)	2.8 (-0.1-12.3)	91.7 (84.3-96.1)	39.2 (30.6-48.3)	91.7 (84.3-96.1)
Virginia	3.7 (-0.2-8.6)	1.0 (-0.1-3.0)	1.7 (-0.2-6.0)	95.5 (78.1-99.2)	46.1 (26.0-62.6)	95.5 (78.1-99.2)
Vermont	18.8 (-3.8-37.5)	2.7 (-15.5-19.2)	9.7 (-9.3-27.3)	95.5 (78.0-99.2)	46.1 (25.9-62.6)	95.5 (78.0-99.2)
West Virginia	10.0 (3.1-23.0)	2.2 (-4.3-8.1)	5.1 (-0.3-15.2)	95.7 (78.7-99.3)	46.7 (26.3-63.3)	95.7 (78.7-99.3)
Wisconsin	3.9 (0.8-8.8)	2.2 (-0.7-3.9)	3.2 (0.7-7.1)	88.9 (68.2-99.9)	35.5 (20.2-74.4)	88.9 (68.2-99.9)
Wyoming	4.8 (-7.4-29.1)	1.0 (-14.7-18.3)	4.7 (-8.0-26.1)	90.9 (83.3-95.7)	38.2 (29.7-47.1)	90.9 (83.3-95.7)

*Negative values in confidence intervals indicate no effect.

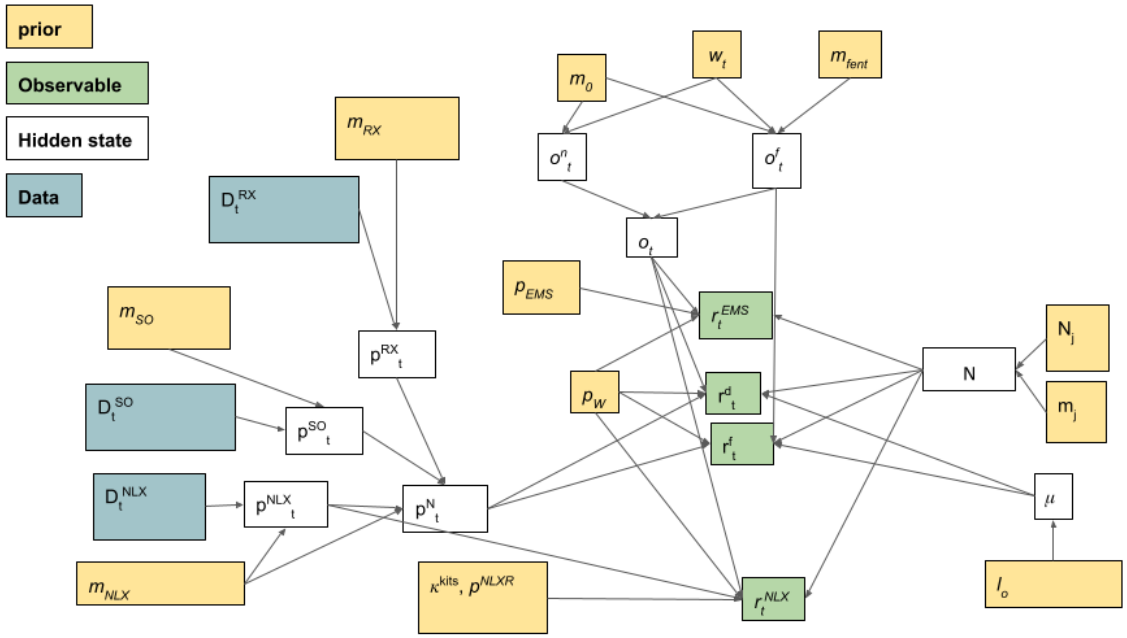


Figure S1. Model priors are shown as orange boxes, latent (hidden state) parameters are shown as white boxes, observed rates are shown as green boxes, and fixed data input are shown as blue boxes. Conditional dependence is indicated using arrows.

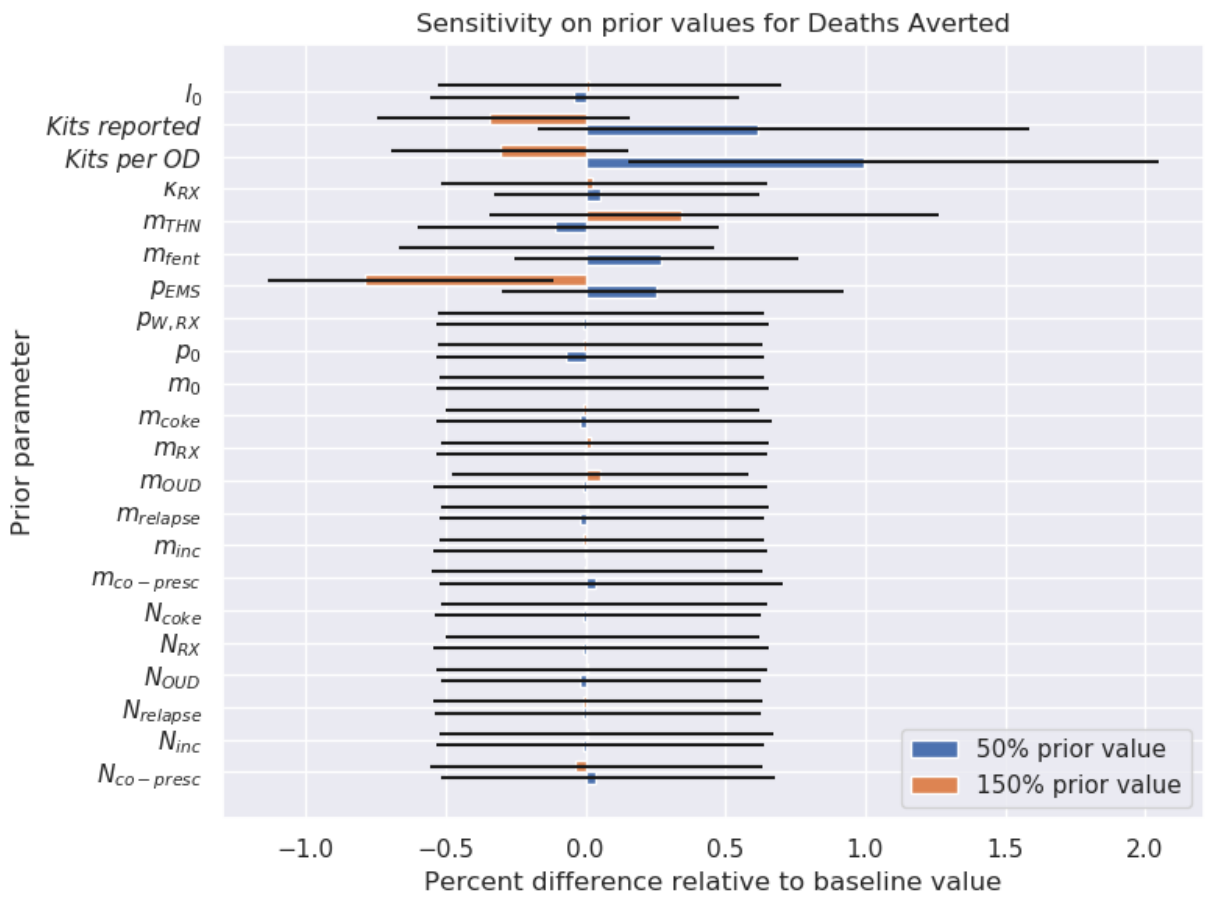
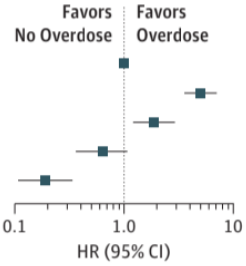


Figure S2. Posterior predictive distributions of deaths averted (a) and probability of naloxone use (b).

A Adjusting for No. of opioid and benzodiazepine prescribers

Treatment Group	No. at Risk	Adjusted HR of Opioid-Related Overdose (95% CI)
Opioid use and no benzodiazepine use	50 583	1 [Reference]
1-90 d with concurrent opioid and benzodiazepine use	3603	5.05 (3.68-6.93)
91-180 d with concurrent opioid and benzodiazepine use	2930	1.87 (1.25-2.80)
181-270 d with concurrent opioid and benzodiazepine use	4082	0.63 (0.37-1.05)
≥271 d with concurrent opioid and benzodiazepine use	10 050	0.19 (0.11-0.33)



B Not adjusting for No. of opioid and benzodiazepine prescribers

Treatment Group	No. at Risk	Adjusted HR of Opioid-Related Overdose (95% CI)
Opioid use and no benzodiazepine use	181 244	1 [Reference]
1-90 d with concurrent opioid and benzodiazepine use	3603	6.21 (4.58-8.40)
91-180 d with concurrent opioid and benzodiazepine use	2930	2.39 (1.62-3.50)
181-270 d with concurrent opioid and benzodiazepine use	4082	0.86 (0.53-1.39)
≥271 d with concurrent opioid and benzodiazepine use	10 050	0.22 (0.13-0.39)

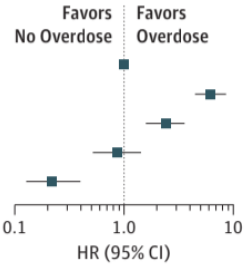


Figure S3. Hernandez I, He M, Brooks MM, Zhang Y. Exposure-Response Association Between Concurrent Opioid and Benzodiazepine Use and Risk of Opioid-Related Overdose in Medicare Part D Beneficiaries. JAMA Netw Open. 2018;1(2):e180919. doi:https://doi.org/10.1001/jamanetworkopen.2018.0919