Drug Overdoses in Pennsylvania

Measuring, Tracking, and Forecasting the Epidemic

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Among the many challenges for public officials in controlling the opioid epidemic, one major problem is how to accurately measure, track, and forecast the epidemic's course, and how to reliably assess the effectiveness—and cost-effectiveness—of epidemic control measures. In this review we summarize available epidemiological data on substance use disorders and their complications that can be useful to measure and track the epidemic in Pennsylvania. We examine the data through the lens of a systems approach, with the goal of using epidemiological data to create and parameterize dynamic models of the epidemic. We suggest that by integrating a variety of datasets into systems models, it should be possible to forecast and predict the future trajectory of the epidemic and make appropriate decisions on how to mitigate the epidemic. In addition, we identify several potentially valuable data sources that are currently underused for public health decision making.

Deaths attributable to drug overdoses are increasing, rapidly and inexorably, in the Commonwealth of Pennsylvania as well as across the entire United States. Among the many challenges for public officials in controlling this epidemic, one major problem is how to accurately measure, track, and forecast the epidemic's course, and how to reliably assess the effectiveness—and cost-effectiveness—of epidemic control measures

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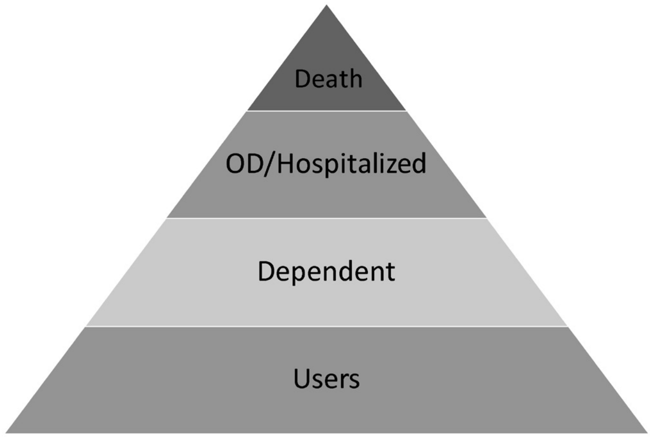

Figure 1. Pyramid. (*Source: Created by authors.*)

(Figure 1). The count of reported deaths due to overdoses per year is one key metric of the epidemic. Another is the count of instances of medical complications attributable to substance use, including nonfatal overdoses and hospitalizations. Yet the epidemic extends well beyond these relatively easily identifiable encounters with the health system, to include persons who use drugs, and those who are dependent on drugs. Additional methods such as surveys are necessary to determine the number of users in a given jurisdiction, to provide an estimate of the entire size of the epidemic, and to generate forecasts of the number of persons at risk for hospitalizations and deaths in the future. Figure 1 represents hospitalizations, overdoses, and deaths as the tip of the iceberg of the drug use epidemic.

In this review we summarize available epidemiological data on substance use disorders and their complications that can be useful to measure and track the epidemic in Pennsylvania. We examine the data through the lens of a systems approach, with the goal of using epidemiological data to create and parameterize dynamic models of the epidemic. We also suggest that by integrating a variety of datasets into systems models, it should be possible to forecast and predict the future trajectory of the epidemic and make appropriate decisions on how to mitigate the epidemic.

We also identify several potentially valuable data sources that are currently underused for public health decision making, including urine drug testing screens, law enforcement drug seizure information, and prescribing and payer claims. We suggest that by integrating these currently underused datasets with existing epidemiological datasets, it should be possible to develop improved descriptive and predictive analytic models.

Death Records

Overdose mortality as calculated from official death records is the most important epidemic metric. Individual deaths in the United States are coded and classified according to the World Health Organization's *International Classification of Diseases* (ICD) (Figure 2), and states submit exact text from the death certificate to the National Center for Health Statistics (NCHS) to be coded into the underlying cause of death and contributory cause(s) of death by a computer algorithm. The map of death rates for the entire United States is shown for the year 2015 (the most currently available data). Pennsylvania lies in a cluster of states with high death rates that spans Appalachia and includes Western Pennsylvania, Ohio, Kentucky, West Virginia, and Tennessee. Other clusters of states with high death rates are in New England and in the Southwestern United States. The epidemic has become increasingly severe in Pennsylvania, such that overdoses are now the leading cause of death among adult Pennsylvanians between the ages of 25 and 44 years.

More than one half million overdose deaths have occurred in the United States from 1979 through 2015 (n = 541,059). The 9th ICD revision was in effect from 1979 to 1998, after which the 10th revision came into effect.

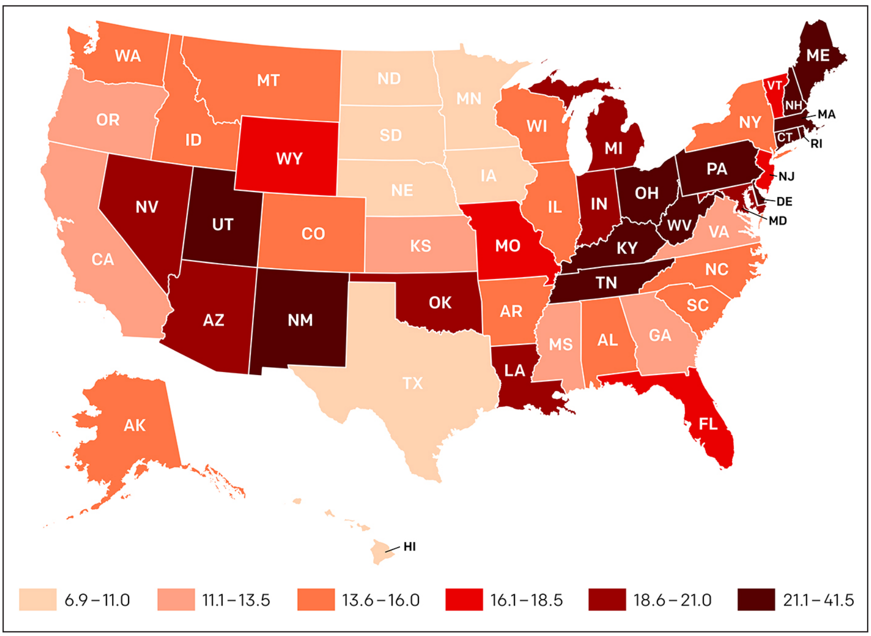

Figure 2. 2015 Drug Overdose Mortality Rate per 100,000. (*Source: Centers for Disease Control and Prevention. 2017. Drug Overdose Death Data. Available at https://www.cdc.gov/drugoverdose/data/statedeaths.html. Accessed February 7, 2018.*)

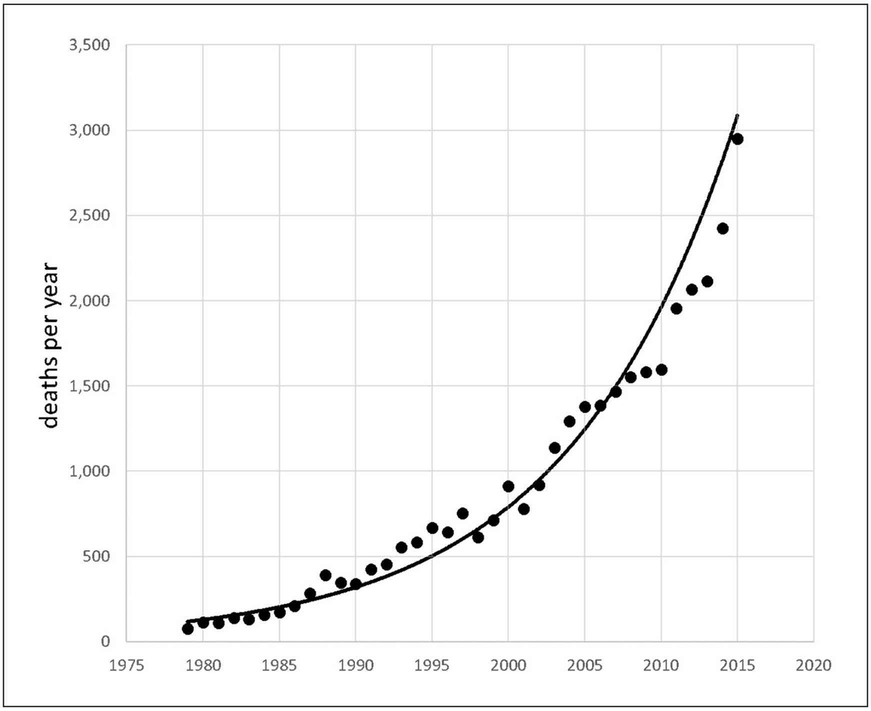

Figure 3. Exponential Growth of Overdose Deaths in Pennsylvania. (*Source: Created by authors.*)

Unintentional drug poisoning, or overdose, deaths were assigned specific codes (E850–E858 in the ICD-9 system and X40–X44 in the ICD-10 system) (Figure 3). The ICD-9 and ICD-10 systems are sufficiently similar so that causes of death can be tracked seamlessly from 1979 through the ICD-9 to ICD-10 transition in 1999 to the present. When deaths per year are plotted, total overdose death counts per year in the United States from 1979 to 2015 have increased on a nearly perfect exponential curve (R^2 = 0.99). The mean percent increase in the number of overdose deaths in the United States since 1979 has been 9% per year, which results in an approximately eight-year doubling time. The graphical plot of overdose deaths in the Commonwealth of Pennsylvania during this same time interval also reveals a near perfect exponential pattern of growth (R^2 = 0.97). Preliminary data on drug overdoses released by the Drug Enforcement Agency show that last year the epidemic in the Commonwealth of Pennsylvania continued to grow at a rate that exceeded the historical average exponential rate of growth (3,642 drug-related overdose deaths, an increase of 37% from 2015). Based on nearly four decades

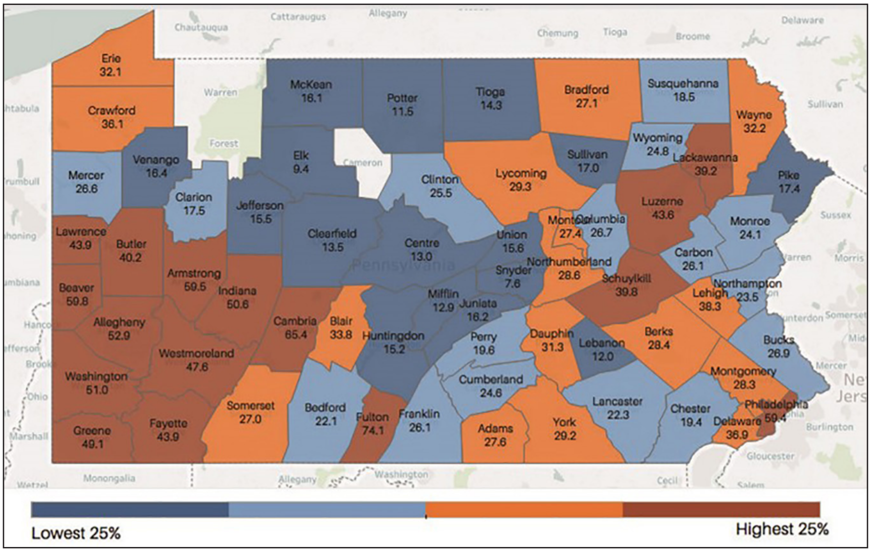

Figure 4. Pennsylvania Overdose Rate by County. (*Source: L. C. Balmert, et al. 2016. "Patterns and Trends in Accidental Poisoning Deaths: Pennsylvania's Experience 1979–2014."* PLOS ONE *11 [3]: e0151655.*)

of inexorably increasing overdose deaths, it is reasonable to forecast that the current exponential growth will continue into the near future, unless extraordinary new efforts to control the epidemic are implemented.

Analyses of U.S. accidental poisoning deaths have found higher rates in certain areas and states, including Pennsylvania (Buchanich et al. 2016; Warner et al. 2014; Warner et al. 2011) (Figure 4). Pennsylvania was one of 20 states with a statistically significantly higher rate compared to the U.S. average. Rates for accidental poisoning mortality in Pennsylvania have increased more than 14-fold since 1979 (Balmert et al. 2016). The largest rate increases were among 35–44-year-olds, females, and white adults. The highest accidental poisoning mortality rates were found in the counties of Southwestern Pennsylvania, those surrounding Philadelphia, and those in Northeast Pennsylvania near Scranton (Balmert et al. 2016).

When the ICD 10th revision was implemented in 1999, it became more straightforward to differentiate which specific drugs were involved in overdose deaths. Drug-specific overdose deaths are identified based on the contributory causes of death, or the "T" codes. The T codes are assigned as the contributory causes based on the specific drugs recorded by the coroner or medical examiner completing the death certificate. Codes exist for nonopioid drugs (such as cocaine and benzodiazepines) and several classes of opioid drugs (opium; heroin; natural and semisynthetic opioids commonly called opioid pain relievers; methadone; other synthetic opioids, including fentanyl) and unspecified narcotics.

Opioid pain relievers (OPR) have been reported in 75% of overdose deaths involving a pharmaceutical (Jones, Mack, and Paulozzi 2013). However, the increase in overdose deaths is not attributable only to opioid pain relievers. Twenty-eight states have reported that heroin deaths doubled between 2010 and 2012 (Rudd et al. 2014), while deaths from OPR during this same time period decreased 6.6%. A recent examination of patterns of death by drug type across the United States found that, from 2013 to 2014, OPR death rates increased 9%, heroin death rates increased 26%, and synthetic narcotic death rates increased 80% (Rudd et al. 2016a). More recent data from 2015 and 2016 suggest that rates continue to rise (Hedegaard, Warner, and Miniño 2017). Data recently released by the Drug Enforcement Agency show that in 2016 fentanyl and related synthetic opioids were identified in 52% of overdose deaths, and heroin was identified in 45% of deaths.

Hospitalizations

Hospitalization data can be used to track nonfatal health impacts of the epidemic. On a regional level (using census divisions that place Pennsylvania in the Northeast region of the United States) from 2012–2014, the estimated hospitalization rates increased for both prescription opioid pain relievers and heroin: a 12% increase in prescription overdose hospitalizations and a 34% increase for heroin overdose hospitalizations (Unick and Ciccarone 2017).

The Pennsylvania Health Care Cost Containment Council (PHC4) is an independent state agency that is mandated to collect inpatient hospitalization data across the Commonwealth. According to PHC4 data, Pennsylvania has a rate of prescription drug overdose hospitalizations of 31.1 admissions per 100,000 residents, compared with 14.4 per 100,000 residents for heroin overdose admissions (Figure 5). From 2014 to 2016, Pennsylvania has seen a 66% increase in the number of hospital admissions due to heroin. In 2016 alone, hospitalizations resulted in payments of an estimated $14 million for heroin admissions and $13 million for prescription drug admissions. Eighty-four percent of admissions were urban residents, but there were larger annual increases per year in rural areas at 27% compared to urban areas with a 24% increase from 2011–2016 (Pennsylvania Health Care Cost Containment Council 2016a).

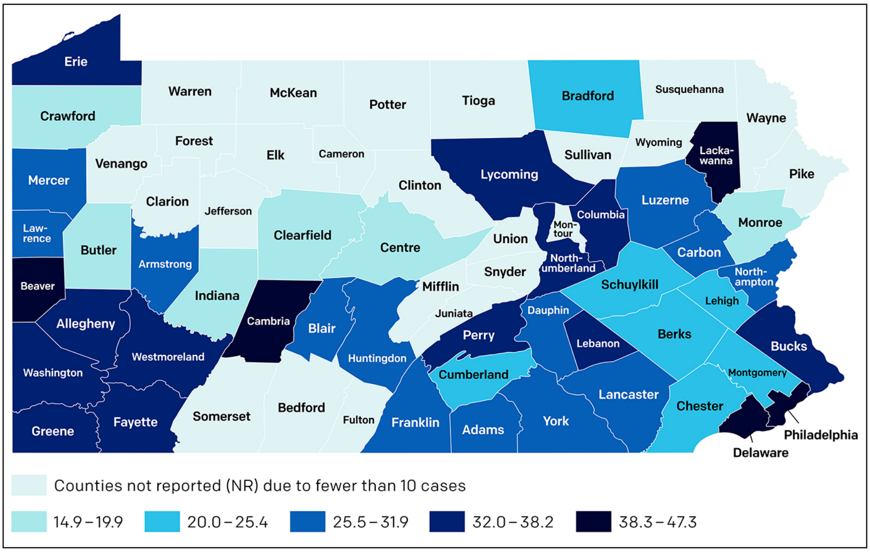

Figure 5. Hospitalization Rate per 100,000. (*Source: Pennsylvania Health Care Cost Containment Council 2016.*)

Rates of drug-related hospitalizations among pregnant women and infants have also risen dramatically. In Pennsylvania, there has been an almost continual increase from 2000–2015 of substance-related neonatal hospital stays, representing a 250% increase (from 5.6 per 1,000 in 2000 to 19.5 per 1,000 in 2015). A similar increase has been observed for maternal stays, with a 510% increase (from 2.8 per 1,000 in 2000 to 16.8 per 1,000 in 2015) (Pennsylvania Health Care Cost Containment Council 2016b).

Prescriptions

Overprescribing of opioids is believed to be an important driver of the overdose epidemic, but the relationship is complicated. Recently, as opioid overdose deaths have continued to increase, prescribing has been decreasing. Opioid prescribing rates peaked in 2011 and have since declined. Nonetheless estimated levels of prescribing in the United States are still three times as high in 2015 as they were in 1999 (Guy et al. 2017). Prescription data can be obtained from various contract research organizations (CRO). CRO provide support services to pharmaceutical companies, often in the form of market analytics. One such type of market analytics data is national prescription drug audit databases (Figure 6), which are typically used for marketing purposes

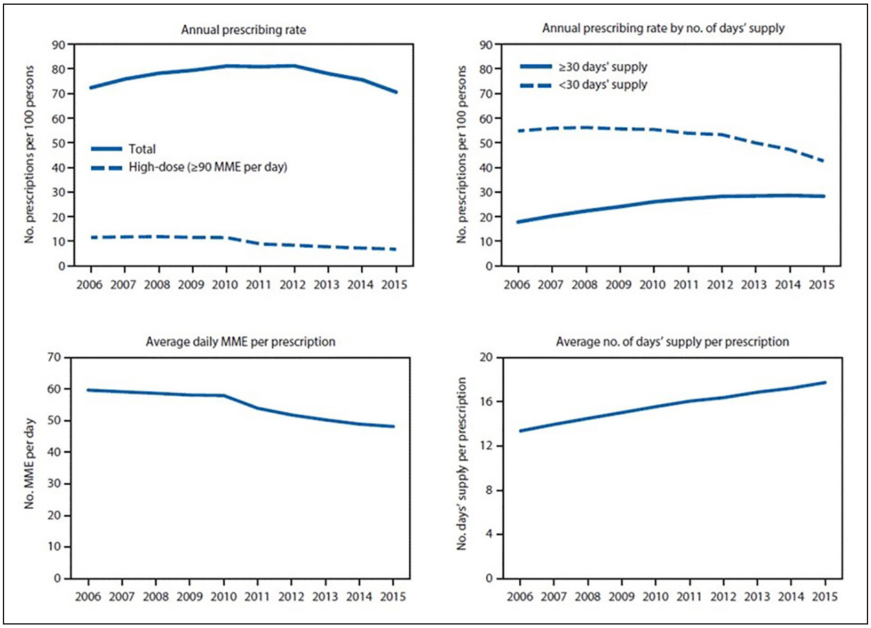

Figure 6. Annual Opioid Prescribing Rates, by Number of Days' Supply, Average Daily Morphine Milligram Equivalent (MME) per Prescription, and Average Number of Days' Supply per Prescription—United States, 2006–2015. (*Source: G. P. Guy Jr., et al. 2017. "Vital Signs: Changes in Opioid Prescribing in the United States, 2006–2015."* Morbidity and Mortality Weekly Report *66 [July 7]: 697–704.*)

by pharmaceutical companies. This is useful to researchers and policymakers alike, as they can provide prescribing rates and counts by drug year over year, and can be used to aid in evaluation of interventions related to prescription drug and public health surveillance. However, access to this database comes at an exorbitant cost and is generally prohibitively expensive for state government agencies, university researchers, and not-for-profits to purchase.

For Pennsylvania, prescribing data are also available via the Prescription Drug Monitoring Program (PDMP). Act 191 of 2014 requires monitoring of controlled substances for Schedule II through Schedule V, and charges the Pennsylvania Department of Health as the responsible state agency to support the operations of the database. The PDMP is a statewide database that houses information regarding dispensing of controlled substances to patients around the Commonwealth. This allows prescribers to access the prior dispensing history of any given patient, and this information can be used to inform clinician prescribing and treatment decisions. The PDMP is also helpful as a mechanism for law enforcement agencies to monitor for fraudulent prescribing and diversion of prescription drugs. By providing access to this database on a de-identified basis, researchers and public officials can develop better analysis and predictive analytics to better understand prescribing patterns, geographic areas in need of additional intervention and training, and appropriate resource deployment as needed. (For more information on PDMPs in Pennsylvania, see Mirigian et al. 2018 in this issue.)

In an effort to curb overprescribing, the Centers for Disease Control and Prevention (CDC) released new guidelines in 2016 for prescribing practices for physicians. These guidelines included recommendations to try to avoid opioid prescribing by: using other nonpharmacologic practices for pain, establishing treatment goals in conjunction with the patient to reduce risks of opioid abuse, identifying and communicating these risks to patients prior to initiating opioid therapies, checking and using an available Prescription Drug Monitoring Program (PDMP), implementing urine drug testing as a component of opioid use therapy, and using medication-assisted treatment (MAT) when appropriate for those with opioid use disorders (Dowell, Haegerich, and Chou 2016). A complicating factor for some of these prescribing patterns may be tied to pharmaceutical industry incentives. Industry payments to opioid prescribers have increased each year since 2013, with an estimated one in twelve physicians receiving payments from the pharmaceutical industry (Hadland, Krieger, and Marshall 2017).

Surveys

The largest and most reliable survey of drug use in the United States is the National Survey on Drug Use and Health (NSDUH) conducted annually by the Substance Abuse and Mental Health Services Administration (SAMHSA). The NSDUH survey involves interviews with approximately 70,000 randomly selected individuals aged 12 and older across the United States. In 2015, 27.1 million people aged 12 or older had used an illicit drug in the past 30 days (10.1%). Most of the illicit drug use was marijuana; there were 22.2 million current marijuana users aged 12 or older (i.e., users in the past 30 days) (Table 1). Regarding opioid use, 3.8 million people aged 12 or older reported current misuse of prescription pain relievers (1.4%), and 600,000 people aged 12 or older reported current misuse of heroin (0.2%). The NSDUH sampling

Table 1. Estimates of opioid epidemic in western Pennsylvania, based on the National Survey of Drug Use and Health

Nonmedical use of pain relievers	160,000
Heroin users	25,000

in any given state within the United States is insufficient to generate reliable state-specific estimates of drug use. However, if the national rates from the NSDUH survey are simply applied to the population of the Commonwealth of Pennsylvania, which has a population of 12.8 million (out of the total U.S. population of 310 million), then the number of persons currently using pain relievers and heroin can be estimated. Given that the overdose death rates are substantially higher in Pennsylvania than the national average, these estimates are probably much too low, by a factor of two or three-fold. Unfortunately, better data are not available.

Underused Data Sources

Records of deaths, hospitalizations, prescriptions, and surveys provide important data to measure and track the course of the opioid epidemic. However, other potentially valuable sources of information about opioids exist that remain relatively inaccessible to public health officials. For example, millions of urine drug tests are administered in the United States each year as required by various federal regulations as well as industry and employer policies. Urine drug testing protocols and labs are certified to conduct testing on specimens. Workplace tests are primarily conducted by just a few lab companies across the United States (Federal Register 2017). Many of these laboratories hold these data as proprietary and restrict access and openness. For others, confusion exists about federal statutes and regulations regarding privacy mandates. Some are reluctant to share these data due to the ambiguity that surrounds the permissibility of sharing data, even in a de-identified manner.

These data could be used for nearly real-time results about not only the prevalence of drug use among employees but also the types of drugs being used. These data could then inform efforts to model and forecast the epidemic and understand patterns not only of substance use, but also its effects and ramifications on the labor force. The Drug Enforcement Agency (DEA) maintains the Automation of Reports and Consolidated Orders System (ARCOS) database to report and track controlled substances transactions and monitors the flow of controlled substances across the continuum of manufacturer, sales, and dispensing, with a goal of monitoring for drug diversion and proper distribution of controlled substances. The monitoring and flow of illicitly manufactured and trafficked drugs via drug seizure data are collected by various law enforcement agencies across multiple levels of oversight; however, these are not readily shared and disseminated in forms that lend themselves to easy analysis. Increased openness of data sharing and usage between law enforcement agencies and other entities for the study and analysis of data could yield better knowledge about the epidemic and more effective policy and intervention decisions. A third source of potentially valuable data is the National EMS Information System database (NEMSIS). It derived from a federal government–led effort to standardize reporting and aggregation of local and state-based EMS data across the country and to report into a national database.

Pennsylvania data could be used to understand emergency medical services' response to the epidemic and to provide a means to analyze the majority of nonhospital Naloxone administrations throughout the Commonwealth. Currently the national level dataset does not provide geographic specificity, and therefore presents a challenge to data analysis in regard to surveillance and forecasting. This level of insight could provide a more rapid reporting and surveillance of overdose hotspots and could aid in evaluating existing interventions, provided that the database is used to its full capacity (Mann et al. 2015).

Lastly, Pennsylvania may benefit from moving closer to establishing an All-Payer Claims Database, which typically houses third-party payers' claims data. These robust cost and claims data would enhance future models and decision making when analyzed on a state and payer level. All-payer claims databases can provide an improved mechanism for state policymakers to factor in health costs in decision making, and public health agencies can use the claims data for surveillance and intervention planning (Freedman, Green, and Landon 2016).

Public health data sharing can be challenging, with a myriad of potential barriers including technical challenges, motivational, economic, political, legal, and ethical concerns and challenges (van Panhuis et al. 2014). Governmental agencies should work to implement greater data sharing, while continuing to protect private and protected health information and meeting regulatory and statutory requirements.

Economic Burden

There have been few studies of the costs of the current overdose epidemic on U.S. society, and no published studies specifically of the impact on the Commonwealth of Pennsylvania. Last year a study from the Centers for Disease Control and Prevention (CDC) was published that reported an estimate for the nationwide economic burden of the epidemic for the year 2013. They estimated the total economic burden to be $78.5 billion. Of that total, one-third was due to increased health care and substance abuse treatment costs ($28.9 billion). They also reported that approximately one-quarter of the total economic burden of the epidemic was borne by the public sector for health care, substance use treatment, and criminal justice. If the national economic burden for the year 2013 from this CDC study is simply proportionally applied to the population of the Commonwealth of Pennsylvania, which has a population of 12.8 million (out of the total U.S. population of 310 million), then the economic burden of the opioid epidemic for the Commonwealth of Pennsylvania in 2013 was $3.2 billion. However, because overdose deaths have increased by at least 70% in Pennsylvania in the four years since 2013, we estimate that the current economic burden in Pennsylvania will likely be closer to $4.7 billion per year. One-quarter of the total, or $1.2 billion per year, is being borne by the public sector in the Commonwealth. Note that because the overdose death rates are substantially higher in Pennsylvania than the national average (as above), these estimates of economic burden are probably much too low. And again, unfortunately, better data are not currently available.

Data-Based Modeling for Decision Support

> All decisions are made on the basis of models. Most models are in our heads. Mental models are not true and accurate images of our surroundings, but are only sets of assumptions and observations gained from experiences. . . . Computer simulation models can compensate for weaknesses in mental models. —Jay Forrester

The opioid epidemic can be conceptualized and diagrammed as a dynamical system, which can be represented in computer code as a computational model. A robust and validated computational representation of the overdose epidemic could provide valuable decision-making support by providing a tool to simulate and evaluate difficult policy options *in silico* before they are implemented at a population level. Furthermore, the mere act of developing a model is often a useful exercise in itself in that it generates discussion and understanding about how the various subsystems interact within the larger complex system

The overdose epidemic involves persons who are nonusers, legal users, illicit users, those with substance use disorders, and those who are in recovery, with transitions between these states. Individuals and the probability that they will transition from one substance use state to another are affected by their community, the prescription drug supply system, the illicit drug supply system, law enforcement, and treatment providers. Figure 7 shows a simplified diagram of some of these interacting components. Indeed, the organization of this special volume of *COMMONWEALTH* reflects the complicated dynamics of the epidemic and its subcomponents, including physicians, prescription

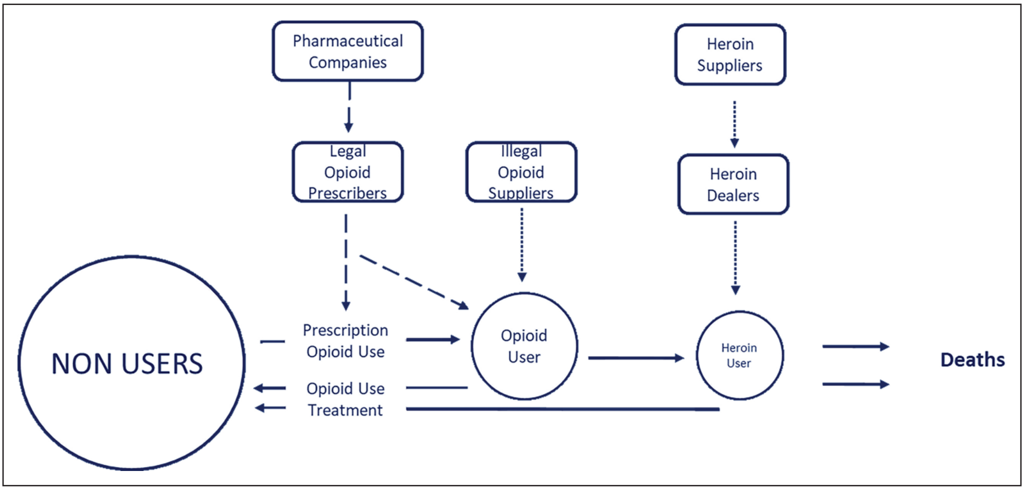

Figure 7. Systematic Continuum. (*Source: Created by authors.*)

monitoring, prevention, treatment and recovery, families and social connections, and the community. Computational models and simulations are widely used for decision support in other complex dynamical public health emergencies, such as epidemics of infectious diseases. We suggest that it should be similarly possible to use the datasets we have discussed here in useful computational models for decision support in the current opioid epidemic (Burke 2016).

Conclusions

Numerous data sources are necessary to obtain a clear and comprehensive picture of the overdose epidemic in Pennsylvania. These data not only include regularly collected reports on deaths and hospitalizations but also prescribing data, survey data, law enforcement data, and several other possible sources of data. Unfortunately, at present these data are not systematically collected and are not routinely made available to the public. One important step in epidemic control would be for the Commonwealth of Pennsylvania to create and curate a comprehensive data system in which granular (i.e., detailed) data from all these disparate sources are systematically collected and stored in such a way that the data are accessible. New standards should be developed and implemented for opioid epidemiological data in the Commonwealth that are consistent with the "FAIR" (Findable, Accessible, Interoperable, Reproducible) principles for sharing of public health emergency data. These various data sources can then be integrated into system-wide models for improved epidemic decision making, including policy analysis and cost-effectiveness studies.

NOTE

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