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Michigan system for opioid overdose surveillance

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Abstract

Community rapid response may reduce opioid overdose harms, but is hindered by the lack of timely data. To address this need, we created and evaluated the Michigan system for opioid overdose surveillance (SOS). SOS integrates suspected fatal overdose data from Medical Examiners (MEs), and suspected non-fatal overdoses (proxied by naloxone administration) from the Michigan Emergency Medical Services (EMS) into a web-based dashboard that was developed with stakeholder feedback. Authorised stakeholders can view approximate incident locations and automated spatiotemporal data summaries, while the general public can view county-level summaries. Following Centers for Disease Control and Prevention (CDC) surveillance system evaluation guidelines, we assessed simplicity, flexibility, data quality, acceptability, sensitivity, positive value positive (PVP), representativeness, timeliness and stability of SOS. Data are usually integrated into SOS 1-day postincident, and the interface is updated weekly for debugging and new feature addition, suggesting high timeliness, stability and flexibility. Regarding

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Contributors JG was responsible for the overall direction of the SOS project as Co-PI, led the evaluation of the surveillance system, and led the drafting of the manuscript. AB runs the SOS project as the project manager, conducted the data analyses required for the evaluation, directs the data abstraction conducted by SOS staff for the system, and critically reviewed and revised the manuscript. CF directs the computational team that oversaw the creation of the SOS data system and web-based dashboard, and critically reviewed and revised the manuscript. JR collaborated on all aspects of the SOS project as Managing Director of the U-M Injury Prevention Center—most notably creation and analysis of materials for the stakeholder engagement projects in Washtenaw, Wayne, and Genesee County—and critically reviewed and revised the manuscript. CS aided with the development of the ME data abstraction protocol, and has provided help throughout in ascertainment of suspected overdoses, and also critically reviewed and revised the manuscript. RMC was responsible for the overall direction of the SOS project as Co-PI from its inception and contributed to all aspects of the project; she also critically reviewed and revised the manuscript.

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representativeness, SOS data cover 100% of EMS-based naloxone adminstrations in Michigan, and receives suspected fatal overdoses from MEs covering 79.1% of Michigan's population, but misses those receiving naloxone from non-EMS. PVP of the suspected fatal overdose indicator is nearly 80% across MEs. Because SOS uses pre-existing data, added burden on MEs/EMS is minimal, leading to high acceptability; there are over 300 authorised SOS stakeholders (~6 new registrations/week) as of this writing, suggesting high user acceptability. Using a collaborative, cross-sector approach we created a timely opioid overdose surveillance system that is flexible, acceptable, and is reasonably accurate and complete. Lessons learnt can aid other jurisdictions in creating analogous systems.

INTRODUCTION

Opioid overdose mortality rate has increased nearly fivefold over the last decade.[1] Michigan saw analogous increases, with the death rate increasing from 6.2 to 21.1 per 100 000 residents from 2008 to 2018.[2] In Michigan, as with many states, current decisions on overdose-related resource allocation are based on year-end reports, with no rigorous empirical basis for resource allocation over shorter time frames. We sought to construct a near real-time system for monitoring overdoses in Michigan that can be used by public health stakeholders to guide data-driven, community-level responses.

While most states have some form of overdose surveillance programme,[3] we are unaware of any that have daily data updates—both fatal and non-fatal—with subcounty-level data available to authorised stakeholders. Some more sophisticated and timely state-level systems include Indiana[4] and Arizona,[5] but both primarily focus on county-level (or larger area) data, although Indiana does show subcounty-level data for naloxone administrations.[6] The Overdose Mapping Application Program (ODMap)[7] is a national system with pointlevel data in many areas, but often partially relies on active data entry for time liness, which is not required in passive surveillance systems. With expanded funding for state-wide opioid surveillance (eg, through the Enhanced State Opioid Overdose Surveillance (ESOOS)[8] program) a roadmap for scalable, near-real time surveillance is critical. Such efforts would complement those of the National Syndromic Surveillance Program (NSSP),[9] which covers 69.3% of US emergency departments, with incidents not involving hospital interaction.

Resource allocation can be determined using year-end reports, or large area (eg, county) summaries, but the process could be optimised by more spatiotemporally proximate data. Such short-term responses are analogous to those used for disease outbreaks, natural disasters and terrorist attacks, where protocols aim to contain damage and accelerate resource access. Timely data would help direct the distribution of resources that are known to reduce overdose death, including peer recovery coaches,[10] safe disposal sites,[11] naloxone kits[12] and fentanyl test strips.[13] Optimising that opportunity requires ensuring the data provision and presentation is tailored to the needs of a variety of overdose prevention stakeholders, underscoring the broadly recognised importance of a collaborative, cross-sector approach to overdose prevention.[14 15] In addition, the feasibility of system construction is enhanced by leveraging existing infrastructure and data.

In this manuscript, we describe how we created and evaluated the system for opioid overdose surveillance (SOS), incorporating input from a broad cross-section of community stakeholders, and using existing data and infrastructure where possible. SOS is near-real time a fatal and non-fatal overdose surveillance system for the state of Michigan that cleans and organises the data and displays it on an interactive web dashboard that generates interactive spatial and temporal data summaries. SOS data is uploaded several times weekly and approximate incident point locations are visible to authorised stakeholders. Intended as a roadmap for other jurisdictions, we conclude our description and evaluation with lessons learnt during the process of creating SOS.

METHODS

Data sources and case definitions

Data for SOS come from mortality records and from emergency medical services (EMS) encounters (figure 1). EMS encounters are abstracted from the Michigan EMS Information System (MI-EMSIS) and are collected daily through the Michigan Department of Health and Human Services (MDHHS); all Michigan counties use NEMSIS V3. Leveraging pre-existing relationships between the University of Michigan Injury Prevention Center and MDHHS, we forged a data use agreement that allowed SOS access to MI-EMSIS data under the conditions that: (1) patient identifiers will be destroyed after 6 months; (2) all identifiable data are stored behind a firewall competent to manage patient data and (3) point locations are randomly displaced within a 500 m radius. Suspected overdoses cases are are ascertained from naloxone administration (EMSIS field eMedication.03). Michigan EMS protocols indicate naloxone for altered mental status cases where respiratory depression/suspected opioid overdose is present.[16] Most EMS agencies upload their data in real time, but are required to upload by the 15th of each month.

Mortality records are obtained from medical examiners (MEs). In Michigan, MEs are decentralised and operate at the county level; some MEs oversee multiple counties, with 51 total MEs across the 83 Michigan counties. Given there is no centralised public data system, we used a for-profit electronic death database available to MEs (the Medicolegal Death Investigation Portal (MDILog)) in Michigan to simplify data entry and storage; currently, MEs covering 45 Michigan counties use this system. For a fee, we obtain daily records for cases declared suspected overdoses by the handling ME, which is our case definition for all counties using this electronic death database. Data collection from MEs not using that system was done by soliciting their voluntary participation in SOS; we have thus far secured participation of 4 counties (Wayne, Oakland, Genesee, Monroe) who do not use the electronic database. For those counties we receive suspected overdose cases either directly from the ME office, or SOS staff abstracts suspected overdose cases from ME reports according to the algorithm described in online supplemental appendix 1. In all counties, toxicology reports confirming overdose are received 3–12 weeks later, with the time lag depending on the individual ME. Data attributes transmitted for all data sources are shown in table 1. SOS data coverage for EMS and ME data, by county, is shown in online supplemental appendix figure 1.

SOS data system and interface

MI-EMSIS data and MDILog data are automatically transferred daily through open data feeds; non-MDILog ME data are uploaded by SOS staff with frequency shown in table 1. Uploaded data are checked for duplicates, geocoded using the Google API,[17] and organised into the proper data source (EMS/ME) and jurisdiction (county/city). Duplicates are primarily ascertained from identical incident identifying information and time/location combinations. Incomplete addresses are assigned to nearby locations (eg, if missing the number, the street centroid is assigned); unmappable incidents whose city/county are known are included in total counts but not displayed on maps. Incident locations are randomly displaced within a 500 m radius; the displaced locations and other data elements, are stored in a relational database (the 'analytical database'). Identifiers (name, address, date of birth) are deleted from this database after at most 6 months, per our data use agreements. Data used for mapping and data visualisations are sent to a separate web database, which is separate from the original analytical database. Thus, identifiable information is stored on secure Health Insurance Portability and Accountability Act (HIPAA) compliant servers, and not the web server. All software for analysis/processing and visualisation was written in Python.

Components of the current SOS dashboard are shown in figure 2. The authorised stakeholder view contains comprehensive spatiotemporal data summaries. Logged-in stakeholders can fully customise the time, spatial zoom window (see figure 3) and demographic subpopulations (age group, sex, race), which will then update all timeplots, total counts and map characteristics. Stakeholder access, with username/password, is only granted to those with verifiable status as working in overdose prevention/response (see online supplemental appendix for terms of service). The public view only shows a map of aggregate county-level counts, state-level time plots and rates-per-100k population for year-to-date suspected overdoses.

Data dissemination

Surveillance data have been disseminated to stakeholders—public health officials, law enforcement, community treatment providers and community outreach organisations—across the state since January 2019. Initially, data were disseminated through county-level reports summarising past 2-week EMS and ME incidents. These reports contained maps displaying approximate incident locations in the stakeholder's county, timeplots of incident counts and demographic (age, sex, race) descriptive statistics.

Through three qualitative pilot studies in Detroit, Washtenaw County, and Genesee County, we solicited feedback to optimise content delivery to meet stakeholder needs. Briefly, those studies proceeded with biweekly report dissemination to a stakeholder group (9–12 per study) for 8 weeks; their feedback was gathered through one-on-one semistructured interviews and biweekly surveys. Those studies were bookended with two focus groups. This process resulted in several modifications, including: customised time windows and zoom levels, demographic subsetting for map/timeplot displays and city-level views. Incorporating stakeholder feedback, an interactive dashboard,[18] was launched in November

2019 to replace the reports. Since launch, we added report generation capability to the interface; future updates, including spike alerts, are forthcoming.

Evaluation approach

We used elements of the CDC guidelines for the evaluation of public health surveillance systems[19] to systematically describe the system and some of its key characteristics. Specifically, we described the usefulness of SOS, in addition to nine system characteristics:

- Simplicity—The structure of the system and its ease of use.
- Flexibility—Ability of the system to adapt to changing stakeholder needs.
- Data Quality—Completeness and correctness of data presented.
- Acceptability—Interest and willingness of stakeholders to participate in, and use, the system.
- Sensitivity—The ability of the system to correctly identify cases.
- PVP—The proportion of cases identified by the system that were true positives.
- Representativeness—How accurately the target population is represented.
- Timeliness—How quickly data make it onto SOS.
- Stability—The overall reliability of the system in terms of (1) being available when needed and (2) identifying and correcting data errors

When possible, we will empirically quantify those characteristics.

RESULTS

Surveillance findings

From 1 January 2020 to 11 September 2020, there were 10001 EMS naloxone administrations captured by SOS; from 1 January 2020 to 11 September 2020 there were 1624 suspected opioid overdose deaths captured by SOS. Calhoun (207 cases/100 k population) had the highest crude rates of EMS naloxone administration during this time period; Wayne county, the largest population center in the state, had 175 cases per 100k. Five SOS counties had crude suspected fatal overdose rates of ≥25 per 100 k during this time period—Wayne (39), Ingham (35), Genesee (30), Calhoun (30) and Muskegon (26). There was notable within-jurisdiction temporal variability; for example, in Detroit, the 7-day moving average for EMS naloxone administrations varied between about 3 and 14 incidents per day and the suspected overdose mortality varied between 0.5 and 2.5 incidents per day in 2020. SOS data suggest changes in overdoses during the COVID-19 pandemic,[20] particularly in EMS naloxone administrations. Across counties, the most common substance found on toxicology reports was fentanyl (86%).

Evaluation results

The aforementioned pilot studies revealed that SOS provided stakeholders with a missing empirical basis for placement of naloxone distribution sites, neighbourhoods for community

educational programmes and targeted peer recovery outreach. In addition, SOS data have been used with stakeholder groups to create toolkits for coordinate community overdose response.[21] That, combined with providing a previously unavailable basis for monitoring spatiotemporal suspected overdose trends, establishes usefulness of SOS.

Simplicity—SOS operates using pre-existing data and the systems required to clean and organise those data are programmed into the data interface. The user facing web dashboard gives stakeholders access to data and allows easily modified spatial and temporal windows, and demographic subsetting in an interface that's as easy to use as common navigational websites and weather websites. These facts enhance the simplicity of SOS, both from a sustainability and usability perspective.

Flexibility—The SOS infrastructure was built in such a way to allow for planned expansions—such as adding new data sources (eg, hospital/emergency department data), data overlays (eg, treatment provider locations), data linkage between sources, spike alerts and built-in forecasting—which enhances flexibility. In addition, changing case definitions (eg, if a symptom-based EMS case definition were developed) would be a trivial modification. However, some elements inherent to the data sources are less flexible. For example, the turnaround time for toxicology testing, and the lack of follow-up patient data in the EMS data, are both barriers to timely confirmation of suspected overdoses in the data sets we have now.

Data quality—Because SOS relies on pre-existing data, its quality equals the quality of those data sources. There is no objective data source for comparison, so we are limited examining missingness. The primary data fields used by SOS are incident location, age, race, sex and—for ME records—the drugs present on toxicology testing. Missingness rates for each variable in the MI-EMSIS data, and in the ME data are shown in table 2. Overall, the missingness rate for the most important variable—the incident locations—are generally very low. The most missing data are in patient age and race.

Acceptability—These data are passively collected using existing systems—because MI-EMSIS is a mandated statewide system and we have the proper data permissions, the acceptability with regard to EMS reports is 100%. We currently have ME data covering 79.1% of the state population; further expansion is curtailed by the fact that ME offices do not always have sufficient resources to take on additional reporting burdens. For the four counties MEs, we have onboarded outside of the electronic death database, we offset these additional burdens however possible (eg, having our staff ascertain suspected overdoses). In terms of user acceptability—the dashboard currently has ≥300 registered users. The average is six registrations/week, though more occurred at launch and in recent months (online supplemental appendix figure 2).

Sensitivity—Because the number of unreported overdoses (eg, individuals revived by naloxone not administered by EMS) is not available, the sensitivity of SOS with regard to overdoses, generally, is not calculable. Because the filtering criteria for the MI-EMSIS data we receive is naloxone administration, its sensitivity for naloxone administration is definitionally 100%. The data abstraction algorithm we use for the MEs (online

supplemental appendix 1) is intentionally broad to maximise sensitivity, but exact calculation is not possible.

Predictive value positive—We cannot estimate the PVP for the MI-EMSIS data due to non-availability of subsequent data verifying overdose status, though other sources suggest estimates of ~60%.[22] Table 3 shows the proportion of suspected overdose cases in the ME data that were confirmed to have opioids in their system after toxicology. Overall, the PVP is good, with 77.2% of suspected fatal overdoses confirmed as having opioids in their system on toxicology; the PVP is best in Oakland county, at 86.8%. Full autopsies are not available in most counties, but in the largest county (Wayne), most false positives were not directly attributable to any substance (most often cardiovascular disease); the most common substance found on toxicology among false positives was cocaine (12%).

Representativeness—SOS is representative of EMS encounters involving naloxone in the jurisdictions because it contains all records where naloxone was given by EMS. Similarly, all deaths are certified by an ME, so the data are representative insofar as the suspected overdose indicator is sound. The primary groups missed by SOS are (1) suspected overdoses where the individual was given naloxone in the community and EMS was not summoned; and (2) individuals in counties without ME coverage (~20.9% of the population).

ME data are received daily, and EMS data are received daily. Delays in data reporting (eg, individual agencies reporting to MI-EMSIS) may lengthen that timeframe. Because staff effort is required to place datasets in the proper directories, time between data receipt and entry into the system—while generally <1 day (and 2 days on weekends)—can be slightly prolonged. Regarding stability—the SOS interface is updated weekly to fix any bugs discovered. The SOS interface has no history of unscheduled outages.

DISCUSSION

SOS provides timely overdose data in a geographically broad state of ~10 M residents, and its data shows substantial regional and subannual trends underscoring the importance of spatiotemporally proximate date. The system was developed for—and in collaboration with—state and local overdose prevention stakeholders by leveraging partnerships required to obtain the data, and optimising its delivery. Community stakeholders are currently using SOS data to allocate resources over shorter time-frames than are possible with year-end mortality reports.[21] SOS relies on passive data reporting systems and does not require additional effort from first responders to manually enter overdoses above-and-beyond their pre-existing duties, which enhances scalability and acceptability. The system is tractable to manage, with data acquisition representing the primary ongoing monetary cost.

An important aspect of SOS is its potential for expansion. While now relying on only EMS and ME data, a key avenue for SOS expansion is the onboarding of hospitals to add the missing piece of passively available data on non-fatal overdoses. A corollary expansion is the incorporation of linkage between sources. If hospital data, in addition to data linkage, can be accomplished, this would provide a basis for surveilling patients' paths

from EMS through to the hospital or ME in near-real time, all within a secure computing environment. This would allow, for example, rigorous, statewide evaluations of naloxone save rates, indicating geographical areas for improvement. A third avenue for expansion is the incorporation of forecasting into SOS. The idea of forecasting incident locations to inform coordinated response is well-established in criminal justice,[23] and has shown potential at reducing crime.[24] Similar logic may be mobilised to reduce overdose mortality by prospectively knowing where to focus, though care must be taken to avoid potential harmful profiling of communities and the people in them.

There are five key limitations to the SOS system. First, because EMS does not encounter all non-fatal overdoses, there are cases missed by SOS. Specifically, individuals administered naloxone from civilians or who arrive at the hospital without EMS transportation, would not get into SOS. Second, the EMS case definition—having received naloxone—is not a perfect proxy for opioid overdose. While there is no evidence its association with opioid overdose is spatially/temporally confounded (making it a potential basis for ascertaining trends, but not absolute counts), more rigorous, symptom-based case definitions are needed. Third, wait time for toxicology testing limits the final determination of overdose cause for all surveillance systems. While some rapid-testing technologies may shorten this time, the reality is that rapid response strategies likely cannot reliably identify all of a broad spectrum of possible intoxicants. Fourth, MEs practices vary across counties, including how drug deaths are certified.[25] This would be an inherent limitation to any such system. Fifth, while the system is useful currently, sustainability requires ongoing funding. Long-term sustainability ultimately necessitates a productive public/state partnership, but creating the system is the first step.

Notwithstanding those limitations, there are several lessons that can be gleaned for other states looking to build analogous systems. First, stakeholder engagement is essential throughout the process, as the optimal presentation of surveillance data is context-dependent, and requires feedback from a diverse group to ensure the system works for a variety of stakeholders. Second, onboarding data providers in a decentralised system (MEs in Michigan) requires shifting as much of the burden as possible, as many departments are under-resourced. Third, building a proposed infrastructure around a HIPAA-compliant computing system alleviates patient privacy concerns of data sharers. Similarly, jittering points ameliorates provider concerns about data reidentifiability. Fourth, a multidisciplinary project team with representation from law enforcement, public health, MEs and academia ensures the development of a broadly useful system.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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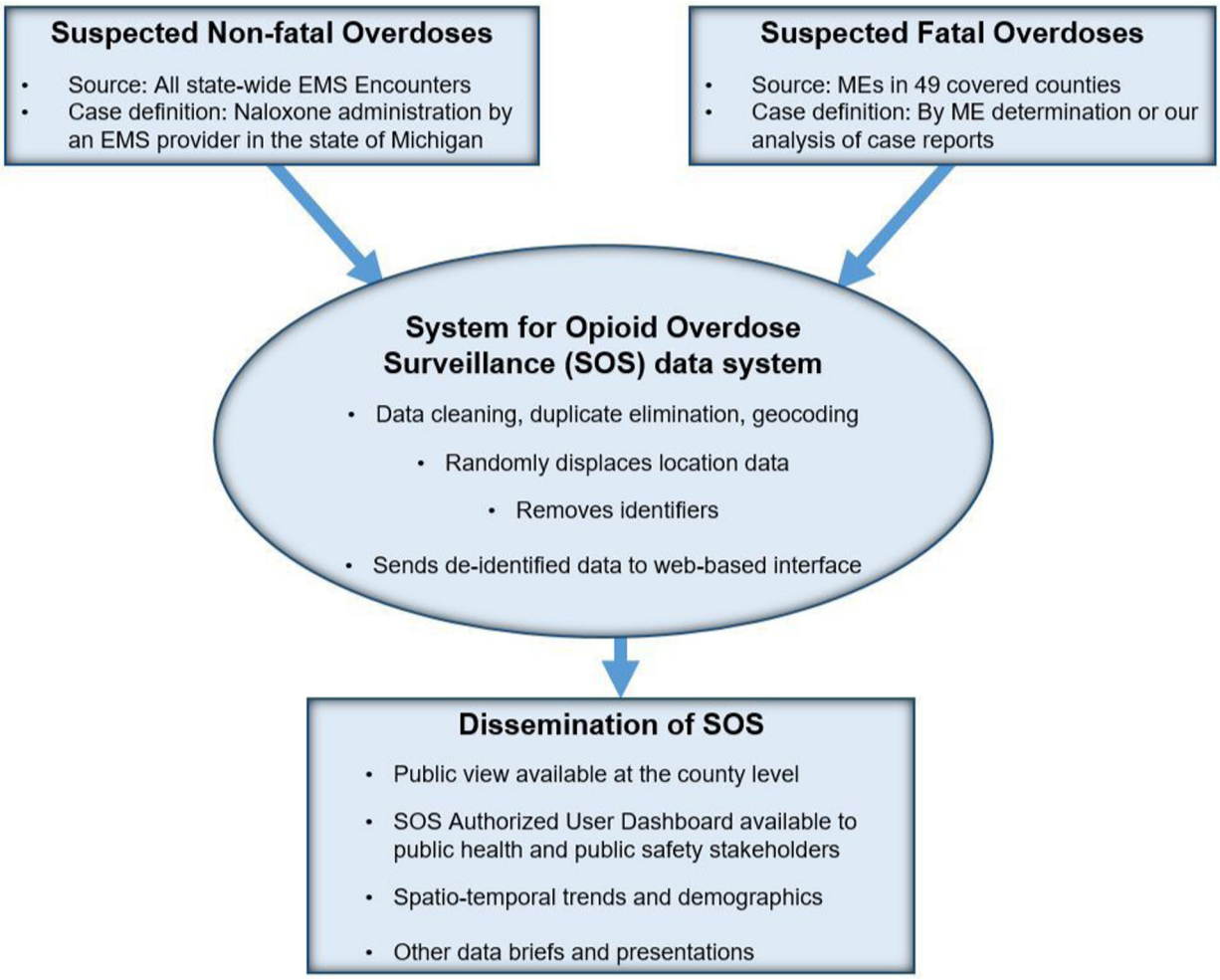

Figure 1.

Conceptual model of the system for opioid overdose surveillance. EMS, Emergency Medical Services.

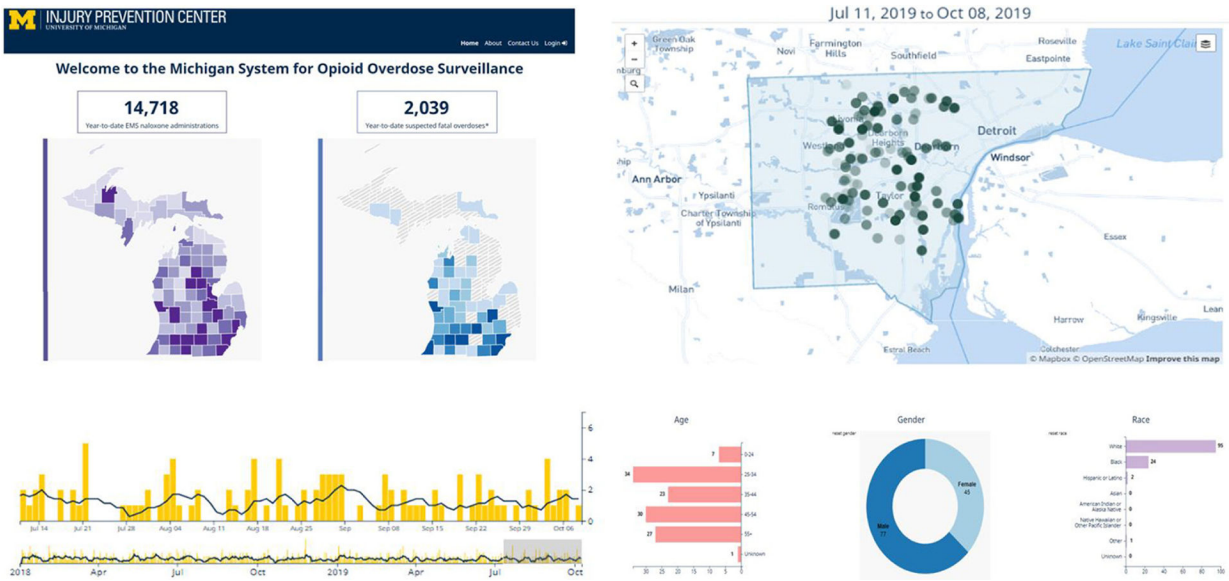

Figure 2.

System for opioid overdose surveillance (SOS) Screenshots figure. *Top left panel displays the public user homepage, top right panel displays a sample map from the authorised user interface, bottom left panel displays the daily frequency of suspected overdose events in the selected jurisdiction in the authorised user interface, and bottom right panel displays age, race and gender demographic visualisations in the authorised user interface.*All data shown in the authorised user interface here are simulated data.

Figure 3.

Zoom capabilities available to authorised users within the system for opioid overdose surveillance (SOS).

Table 1

Sources of data on suspected opioid overdoses, system for opioid overdose surveillance

	Data sources				
Variable	**MI-EMSIS**	**Electronic ME database**	**Wayne/Monroe ME**	**Oakland ME**	**Genesee ME**
Date of incident	X	X	X	X	X
Full name	X	X	X		X
Date of birth	X	X	X		X
Race	X	X	X	X	X
Age	X	X	X	X	X
Sex	X	X	X	X	X
Incident location	X	X	X	X	X
Incident county	X	X	X	X	X
Resident location	X	X	X		X
Resident county		X			
Provider impression	X		X	X	
Toxicology results		X	X	X	X
Data frequency	Daily	Daily	Daily [*]	Monthly [†]	3X/week [‡]
Case definition	Naloxone administration	Death investigator judgement	Suspected overdose algorithm [§]	Death investigator judgement	Suspected overdose algorithm [§]
Population covered	9 995 915	4 493 216	1 753 893	1 259 201	406 892

[*] Subject to staff availability. On a typical week reports were received daily.

[†] Subject to staff availability. Typically received reports monthly.

[‡] Subject to data abstractor schedule. On a typical week reports were received three times.

[§] See online supplemental appendix for suspected fatal overdose definition.

EMS, Emergency Medical Services; ME, medical examiner; MI-EMSIS, Michigan EMS Information System.

Table 2

Missingness rates in each variable per data source

Data source	Incident location (%)	Age (%)	Race (%)	Sex (%)	Tox. results (%)
MI-EMSIS	0.1	24.1	10.2	0.2	n/a
Electronic ME database	12.4	1.2	1.4	0.1	18.3
Wayne/Monroe ME	5.5	3.4	0.6	0.0	0.0
Oakland ME	1.4	0.0	0.0	0.0	3.6
Genesee ME	0.1	0.0	0.1	0.0	0.0

ME, Medical Examiner; MI-EMSIS, Michigan EMS Information System; n/a, not avilable.

Table 3

Proportion of suspected fatal opioid overdose cases confirmed to have opioids in their system after toxicology testing

	Electronic ME database	Wayne/Monroe	Oakland	Genesee	Total
No of suspected cases	1651	1415	393	238	3697
No of confirmed cases	1356	964	341	193	2854
Percentage of suspected cases confirmed	82.1	68.1	86.8	81.1	77.2
Date range	1 January 2018–11 September 2020	24 January 2019–30 June 2020	01 January 2019–30 August 2020	1 January 2019–14 July 20	

Note: Cases with missing toxicology results were not included in suspected cases.