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Regional and Temporal Variation in Methamphetamine-Related Incidents: Applications of Spatial and Temporal Scan Statistics

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Abstract

Introduction—This investigation utilized spatial scan statistics, geographic information systems and multiple data sources to assess spatial clustering of statewide methamphetamine-related incidents. Temporal and spatial associations with regulatory interventions to reduce access to precursor chemicals (pseudoephedrine) were also explored.

Methods—Four statewide data sources were utilized including regional poison control center statistics, fatality incidents, methamphetamine laboratory seizures, and hazardous substance releases involving methamphetamine laboratories. Spatial clustering of methamphetamine incidents was assessed using SaTScan™. SaTScan™ was also utilized to assess space-time clustering of methamphetamine laboratory incidents, in relation to the enactment of regulations to reduce access to pseudoephedrine.

Results—Five counties with a significantly higher relative risk of methamphetamine-related incidents were identified. The county identified as the most likely cluster had a significantly elevated relative risk of methamphetamine laboratories (RR=11.5), hazardous substance releases (RR=8.3), and fatalities relating to methamphetamine (RR=1.4). A significant increase in relative risk of methamphetamine laboratory incidents was apparent in this same geographic area (RR=20.7) during the time period when regulations were enacted in 2004 and 2005, restricting access to pseudoephedrine. Subsequent to the enactment of these regulations, a significantly lower rate of incidents (RR 0.111, $p=0.0001$) was observed over a large geographic area of the state, including regions that previously had significantly higher rates.

Conclusions—Spatial and temporal scan statistics can be effectively applied to multiple data sources to assess regional variation in methamphetamine-related incidents, and explore the impact of preventive regulatory interventions.

Introduction

Methamphetamine is a highly addictive stimulant that causes both acute and chronic effects on brain function [1]. The abuse and illicit production of methamphetamine is a widespread public health problem in United States and throughout the world [2,3]. Federal and international regulations have been implemented to tighten control of precursor chemicals (ephedrine and pseudoephedrine) that can be diverted towards the illicit synthesis of methamphetamine [2, 4-5]. Many states have also enacted regulations that restricted over-the-counter consumer access to pseudoephedrine. In 2005, Oregon was the first state in the country to enact regulations requiring a physician's prescription to obtain pseudoephedrine [6]. The effectiveness of such interventions on the number of methamphetamine laboratories has not been extensively studied.

The utility of data relating to methamphetamine synthesis and abuse may be enhanced through the application of geographic information systems (GIS) and spatial statistics. Geographic information systems (GIS) are automated processes for the capture, analysis, and display of spatial data [7]. Geographic information systems and spatial scan statistics have been utilized in public health research to assess regional variation in the prevalence of substance abuse, and to investigate the impact of preventive interventions [8,9].

The purpose of the current study was to utilize several relevant sources of spatial and temporal data to assess geographic variation associated with the synthesis and abuse of methamphetamine in Oregon. Spatial scan statistics were utilized to test the hypothesis of whether methamphetamine-related incidents were more frequently observed in specific geographic regions of the state, as opposed to being simply a function of population size. In addition, space-time scan statistics were used to explore geographic and temporal clusters in association with regulatory interventions to mitigate risks from methamphetamine laboratories.

Methods

Four databases of relevance to methamphetamine abuse and production were utilized in this investigation, including:

1. methamphetamine-related incidents reported to the Oregon Poison Control Center (OPC) during 2001 to 2005,
2. illicit methamphetamine laboratories, dump sites, and partial lab remnants reported by the Oregon Narcotics Enforcement Association (ONEA) during 2003 to August, 2007,
3. methamphetamine-related deaths reported by the Oregon State Police (Medical Examiner Division) during 2001 to 2005, and
4. methamphetamine-related hazardous substance release incidents reported to the Hazardous Substance Emergency Events Surveillance System (HSEES) of the Oregon Public Health Division during 1998 to 2005.

Spatial (at the county level) and temporal data were available in each of these databases, and are summarized in Table 1. For the ONEA data, spatial identifiers were not available for the time period from January-December, 2003.

Clustering of methamphetamine-related incidents (illicit production and abuse) was assessed using SaTScan™ (Version 7.0), a software program that uses spatial scan statistics to detect clusters in a temporal, spatial or space-time setting [10]. This is done by scanning a window across time and/or space, and counting the number of observed and expected observations inside the window at each location. The scanning window is either an interval (in time), or a circle (in space). Multiple different window sizes are used by SaTScan™. The program will scan for clusters of geographic size ranging from zero to an upper limit of 50% of the population at risk, thereby covering wide geographic areas. A p-value is assigned to the identified cluster (s), and the window with the maximum likelihood is reported as the most likely cluster (least likely to be due to chance).

SaTScan™ was used to generate a multivariate scan statistic from the four data sets compiled in this investigation, to search for spatial clusters indicating high rates of incidents relating to methamphetamine synthesis and abuse in more than one data set. A Poisson-based model was used in this analysis, under the null hypothesis that the expected number of cases in each area was proportional to its population size. SaTScan™ was also utilized to analyze the ONEA data set (January, 2004- August, 2007) for space-time clustering of high and low rates of illicit methamphetamine laboratories, dump sites, and partial lab remnants involving

methamphetamine production. For statistical inference 9999 Monte Carlo replications were conducted in all of these analyses, and a p-value less than 0.05 was considered statistically significant. The research protocol was reviewed and approved by the Institutional Review Board of Oregon State University.

Results

The four data sets included 2,570 incidents relating to methamphetamine. Analysis of these data sets with a multivariate scan statistic resulted in the identification of five counties where significant clustering of methamphetamine-related incidents was observed in more than one dataset. The most likely spatial cluster (least likely to be due to chance) was observed in Umatilla County. Secondary clusters were identified in Multnomah, Marion, Linn, and Lincoln Counties. The locations where clustering was observed included counties with higher populations (Multnomah, Marion) as well as rural areas (Umatilla, Linn, and Lincoln). Figure 1 shows the location of these spatial clusters.

In Umatilla County, where the most likely spatial cluster was observed, the relative risk of ONEA incidents (methamphetamine laboratories, dump sites, and partial lab remnants) was 11.5. This means that ONEA incidents were 11.5 times as likely to have been reported in Umatilla County in comparison to the state as a whole. The relative risk of HSEES (hazardous substance release) incidents involving methamphetamine in Umatilla County was 8.3. Umatilla also had a higher relative risk of methamphetamine-related fatalities (RR=1.4). Table 2 summarizes the data for counties where spatial clustering of methamphetamine-related incidents was observed.

Analysis of the ONEA data set resulted in the detection of significant space-time clustering of incidents during the time period leading up to the enactment of regulations to reduce access to pseudoephedrine in 2004 and 2005. The relative risk of methamphetamine laboratories reported by ONEA was 20.7 ($p=0.0001$) during the time period from January, 2004 to August, 2005. This cluster included Umatilla and two neighboring rural counties located along a major interstate highway that has been recognized as a drug trafficking route for methamphetamine [11]. Subsequent to the enactment of these regulations, a significantly lower rate of incidents (relative risk=0.111, $p=0.0001$) was observed over a large geographic area of the state, including regions that previously had significantly higher rates. These results are summarized in Figure 2.

Figure 3 displays the number of statewide methamphetamine labs that were reported by ONEA during the study period, as well as the dates corresponding to the implementation of regulatory initiatives to reduce access to pseudoephedrine. A decline in the number of methamphetamine laboratories is apparent during the study period.

Discussion

The results of these analyses revealed geographic clustering of methamphetamine-related incidents in certain rural and urban counties. An assessment of other sources of regional data relating to illicit production and abuse of methamphetamine provides some validation of the spatial clusters observed in this investigation. Three of the five counties identified in this study as having significant clusters of methamphetamine-related incidents (Umatilla, Multnomah, and Marion) are classified as High Intensity Drug Trafficking Areas (HIDTA) by the National Drug Intelligence Center [11]. In the county identified as the most likely cluster in the current study (Umatilla County), methamphetamine is the primary drug of abuse reported in substance abuse treatment admissions [11].

In the current investigation, it was necessary to aggregate data at the county level because of the manner in which the data were originally collected and reported. Although poison control center data may frequently include more specific geographic identifiers on the location of callers, the protection of privacy must be ensured when databases are used that contain personal health information. This is a limitation and challenge in the application of GIS and spatial statistics to toxicsurveillance activities. The analysis of aggregate data in spatial epidemiology is also vulnerable to the ecological fallacy, a form of bias that arises that can occur when aggregation of data conceals meaningful variation that may exist within the defined population at a smaller geographical scale [8].

For some counties that were identified as having significant spatial clustering of methamphetamine-related incidents, an increase in risk was not apparent across all four data sets. For example, the most likely cluster in Umatilla County had an increased relative risk in each of the data sets with the exception of the poison control center database. One potential explanation for this observation is that rural counties with lower population densities have been reported to have lower utilization rates of poison control center services [12]. Another potential explanation is that health care providers do not always consult poison control centers for common poisonings [13]. While these and other potential limitations to poison control center data are acknowledged [14], the widespread access to toll-free poison control center services is an important strength of these data. In contrast to other sources of drug abuse surveillance data, such as the Drug Abuse Warning Network which reports information from major municipalities [15], poison control centers capture data (including spatial information) from a larger segment of the general population.

The decline in number of statewide methamphetamine laboratories observed during the study period suggests that the regulatory initiatives to reduce access to pseudoephedrine have been effective, a finding that is supported by another recent report [11]. The space-time analysis conducted in this investigation provides additional information localizing regions of the state where significantly higher and lower rates of methamphetamine labs were observed during the study period. Space-time analysis and GIS can be effectively utilized to display and summarize these data, including the population size within observed clusters.

The results of this investigation support the usage of multiple informational sources in the assessment of community trends relating to drug abuse [16]. Moreover, the inclusion of temporal and spatial analyses may enhance the utility of such data by helping public health and policy officials target and assess the impact of preventive interventions in high-risk communities. Federal drug control policy officials have recognized the potential utility of multiple data sets, GIS, and spatial scan statistics in the control of drugs of abuse in major cities [17]. These same tools can also be utilized in the assessment of drug abuse in rural communities and broader segments of the general population.

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Figure 1.

Counties identified as spatial clusters for methamphetamine-related incidents are bordered in white.

Figure 2.
Space-Time Clustering of High and Low Rates of Methamphetamine Lab Incidents (ONEA data)

Figure 3. Methamphetamine illicit laboratories, dump sites, and partial lab remnants reported by the Oregon Narcotics Enforcement Association (ONEA), January 2003-August 2007

Table 1

Datasets Utilized in This Investigation

Dataset	Type of Data	Time Period	Temporal Units	Number of Incidents
OPC	Methamphetamine-related incidents reported to the Oregon Poison Control Center (OPC)	2001–2005	Date	746
ONEA	Illicit laboratories, dump sites, and partial lab remnants reported by the Oregon Narcotics Enforcement Association (ONEA)	2003–Aug, 2007	Month	1178
Fatalities	Methamphetamine-related deaths reported by the Oregon State Police (Medical Examiner Division)	2001–2005	Year	358
HSEES	Methamphetamine-related hazardous substance release events reported to the Hazardous Substance Emergency Events Surveillance System (HSEES) of the Oregon Public Health Division	1998–2005	Year	288

Table 2
Relative Risks for Counties with Spatial Clustering Of Methamphetamine-Related Incidents

County	Relative Risk				p-value
	OPC	ONEA	Fatalities	HSEES	
Umatilla (most likely cluster)	0.8	11.5	1.4	8.3	0.0001
Multnomah (secondary cluster)	1.6	1.4	2.1	1.8	0.0001
Linn (secondary cluster)	0.9	2.1	1.2	4.0	0.0001
Marion (secondary cluster)	1.9	0.3	1.0	0.4	0.0003
Lincoln (secondary cluster)	0.6	1.2	2.6	3.0	0.0277