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Temporal Clustering of Heroin Overdoses in Washington, DC

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ABSTRACT: During the 5-day period from 28 Feb. 1985 through 4 March 1985, 24 heroin overdoses occurred in the District of Columbia. Statistical tests for clustering of fatal and nonfatal overdoses during this interval identified 7 heroin-related deaths that occurred on March 1 to 2 as a statistically significant cluster ($p = 0.007$). An extension of the analysis for clustering to a 15-month period identified 2 additional clusters, 1 of fatal overdoses and 1 of nonfatal ones. When all victims of fatal overdose in cluster intervals were combined and compared with all other heroin-related deaths, no significant differences were noted for levels of morphine or ethanol in blood. However, bile morphine concentrations of cluster decedents were significantly lower than those of noncluster decedents ($p = 0.033$), suggesting that these decedents were less tolerant to the effects of narcotics than the comparison group. Heroin concentrations in street-level heroin samples collected during clusters did not differ from those collected during comparison intervals. These data conflict with the traditional explanation of overdose clusters, which attributes these events to unusually potent street-level heroin.

KEYWORDS: forensic science, heroin, statistical analysis

From 28 Feb. through 4 March 1985, 24 heroin-related overdoses, 8 of which were fatal, occurred in the District of Columbia. These overdoses were perceived as a substantial increase over usual morbidity and mortality rates and attracted a great deal of public attention. Many media reports cited unusually pure heroin as the cause of overdose clustering during this period. In our study, we demonstrate statistical methods that can be used to identify and study overdose clusters. We also examine forensic science data to test the hypothesis that clusters of heroin-related overdoses are due to the availability of unusually pure heroin.

The largest epidemic of heroin-related deaths (HRDs) in the District of Columbia began in mid-1979 and has continued through 1988 [*1*]. The HRDs that have occurred in this epidemic were distributed fairly evenly over time. Occasionally, however, brief periods of perceived increases in morbidity and mortality attracted the attention of the news media as well as health and law enforcement officials. Such apparent clusters, in the District of Columbia

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as well as in many other cities, have rarely been verified as significant increases over baseline morbidity or mortality rates. Furthermore, they have often been attributed to the distribution of unusually pure heroin [2]. In many instances, public health and law enforcement agencies have responded to these perceived clusters by warning narcotics users of the availability of particularly strong heroin, even though they had no data to support this belief.

Clusters of heroin overdoses have been studied only rarely. One occurred in Atlanta when the average content of heroin in street drug samples increased. This cluster ended abruptly, even though the heroin content of street packages decreased gradually [2]. Zimney and Luke [3] reported individual HRDs known to be associated with unusually pure heroin, but these deaths occurred in the midst of many other HRDs not linked to strong heroin. They also identified over two dozen instances in which several persons injected the same preparation of heroin, and in each case only one person died. These reports suggest that factors other than heroin purity affected these deaths.

Methods

We reviewed the autopsy reports of all narcotics-related fatalities investigated by the Office of the Chief Medical Examiner, District of Columbia, from January 1984 through March 1985. A death was considered heroin-related when no natural or traumatic cause was identified and when there was toxicologic evidence that heroin contributed to the fatality. We abstracted demographic, pathologic, and toxicologic data from autopsy records of HRDs, and recorded measurements of morphine (the principal metabolite of heroin) in blood, urine, and bile and ethanol, phencyclidine (PCP), and cocaine in blood [1,4]. We also abstracted from police death reports the date of lethal injection and the victim's employment status.

Seven hospitals within the District reported emergency treatment for heroin overdoses during our study period. We reviewed emergency admissions of five of these hospitals for the period 1 Jan. 1985 through 15 March 1985. Two hospitals could not provide records for review. A nonfatal overdose (NFO) was defined as a drug overdose, clinically attributed to heroin use, that did not cause death. Data for NFOs were abstracted from hospital records.

The temporal occurrence of HRDs from 1 Jan. 1984, through 31 March 1985, and NFOs from 1 Jan. through 15 March 1985, was evaluated to select all time intervals with large numbers of overdoses. We compared HRDs, NFOs, and total overdoses (HRDs plus NFOs) in these intervals with background daily-overdose rates for selected time periods, using scan [5] and Poisson [6] tests for clustering. A cluster was defined as a statistically significant ($p < 0.05$) increase over the expected number of overdoses for an interval of equal duration. The expected number of NFOs and HRDs was determined by multiplying the background rate by the number of days in each interval.

The scan statistic was developed to evaluate clustering for a single time interval. Because we wanted to investigate all instances of clustering, we selected several intervals for study. As a result of the effect of multiple comparisons, the true p values computed for the number of overdoses in each cluster interval would be expected to be slightly greater than indicated.

We also compared HRDs from each cluster detected by the above methods with HRDs that occurred during periods before and after the clusters (termed noncluster HRDs). Toxicologic, pathologic, and demographic variables were evaluated in these comparisons. Since hospital emergency services did not collect toxicology and drug use data for NFOs, we did not make detailed comparisons between cluster and noncluster NFOs.

To test for the influence of a change in the purity of street-level heroin over the course of our study period (and a consequent change in autopsy blood morphine levels), we compared HRDs from clusters in 1985 with noncluster HRDs from 1985 only, as well as with noncluster HRDs from the entire study period. Data for all HRD clusters were also combined and com-

pared with data for all noncluster HRDs. Wilcoxon rank-sum and Student's t-tests were used to analyze continuous data. Chi-square and Fisher's exact tests were used for discrete data. Except for the Poisson test, all statistical tests were two-tailed.

To facilitate arrests, the District of Columbia Metropolitan Police Department regularly purchases and seizes heroin. Concentrations of pure heroin (percent dry weight of pure heroin) are determined for all samples. Samples weighing between 50 and 2000 mg with a heroin concentration of under 20% were considered to represent street-level samples. For each cluster interval, the concentrations of heroin in street samples obtained during this period were compared with those for a contiguous period that excluded the cluster samples.

We also compared heroin concentrations of samples collected during the three days immediately before and after clusters with those of samples collected during background periods. This was done to account for possible differences between the time of collection of samples and the time of the overdoses associated with these samples.

Linear regression models were constructed to test the relationship between the heroin concentration of street samples grouped in intervals of three days and the frequency of heroin overdoses that occurred in each of these intervals. We also used regression analysis to study the relationship between the frequency of HRDs and the heroin concentrations during the three-day periods before and after the HRDs occurred.

Results

From 1 Jan. 1984, through 31 March 1985, there were 178 HRDs in the District of Columbia (Fig. 1). Forty-four percent occurred on a Friday or Saturday ($X_6^2 = 20.28, p < 0.001$), when we expected twenty-nine percent to occur by chance alone. Thirty-eight percent of HRDs occurred between 6 p.m. and midnight ($X_3^2 = 30.90, p < 0.001$), when we expected twenty-five percent of all HRDs to occur in each interval.

From 1 Jan. 1985 through 15 March 1985, 84 NFOs were treated at the 5 participating hospitals (Fig. 2). Forty-six percent occurred on a Friday or Saturday ($X_6^2 = 13.13, p < 0.001$), and forty-six percent occurred between noon and 6 p.m. ($X_3^2 = 44.57, p < 0.001$). During this period, many overdose victims refused to be taken to a hospital after receiving emergency treatment from the District of Columbia Fire Department. No data could be obtained for these persons.

Table 1 lists the intervals tested for clustering and identifies a number of clusters of HRDs, NFOs, and total overdoses detected with the scan statistic. The background comparison period selected to detect clusters for HRDs in Intervals 1 to 4 was 1 Jan. 1984 through 31 March 1985, during which 178 HRDs occurred. The background comparison period for HRDs in Intervals 5 to 11 was 1 Jan. 1985 through 31 March 1985, during which 40 HRDs occurred. The background comparison period selected to detect clusters for NFOs and total overdoses was 1 Jan. 1985 through 15 March 1985, during which 84 NFOs and a total of 117 overdoses occurred. Comparisons with other background periods and use of the Poisson test produced similar results.

Eleven percent of the HRDs and thirty percent of the NFOs occurred during intervals with clustering of HRDs or NFOs. The intervals and clusters listed in Table 1 are displayed in Figs. 1 and 2. During the period of interest to District of Columbia health officials (Interval 9), only the HRDs of Interval 11 were in significant excess, and this increase was great enough to cause a significant elevation in the total number of overdoses for this period. Several of the clusters, such as those during Intervals 1, 2, and 3, overlapped. The clusters with the widest temporal windows occurred during Intervals 2 and 11 for HRDs and during Interval 8 for NFOs. Data from these clusters were used in comparisons of autopsy and demographic data for HRDs and NFOs.

Table 2 compares autopsy results for decedents in intervals with clustering of HRDs with

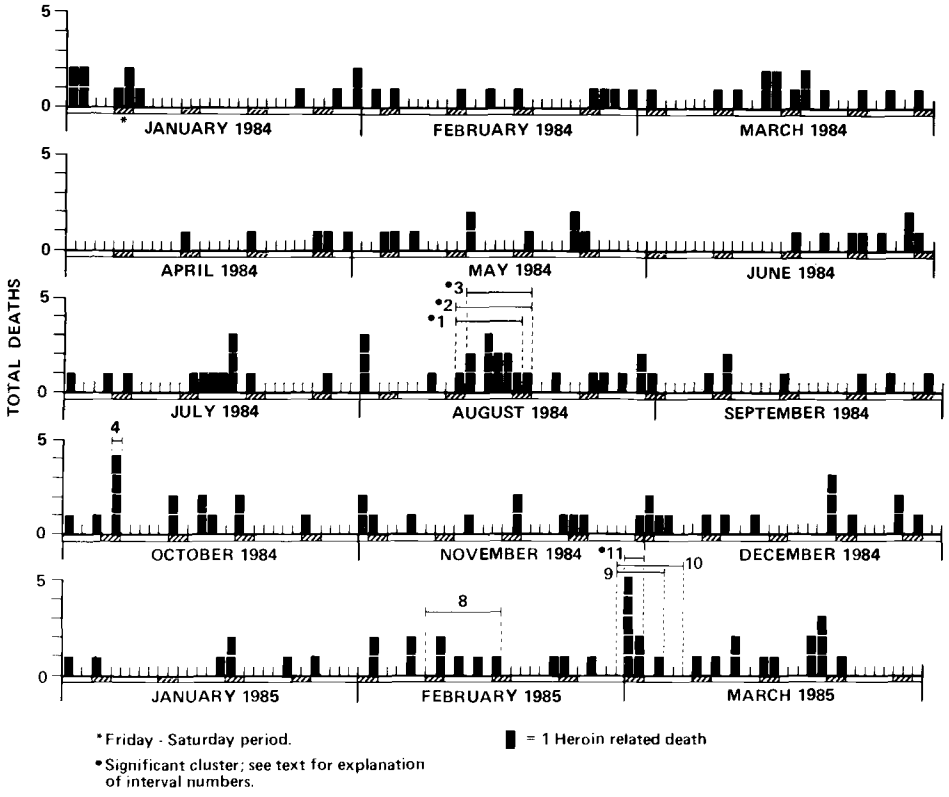

FIG. 1—*Heroin-related deaths in Washington, DC, 1 Jan. 1984 through 31 March 1985.*

those in periods with no clustering. Interval 2 HRDs were significantly different from noncluster HRDs with regard to residence outside the District of Columbia. Bile morphine concentrations of HRDs in Intervals 2 and 11 were lower than those of noncluster HRDs, but the differences for each separate interval were not statistically significant. When bile morphine concentrations for HRDs in Intervals 2 and 11 were combined ($n = 17$, median = 0.20) they were significantly lower ($p = 0.0326$) than those of noncluster HRDs ($n = 95$, median = 0.80). Between 43 and 70% of cluster decedents had multiple needle track areas, suggesting they were addicted to narcotics sometime in the past.

Table 3 shows that concentrations of street-level heroin samples collected during cluster intervals of HRDs and NFOs were not significantly different from those obtained during comparison periods. These concentrations were not significantly different. This relationship was not altered when the date of heroin sample collection was changed to three days before or after the reported date. Furthermore, when heroin samples of greater than 20% purity were included in analyses, results were similar.

Linear regression models showed no consistent relationship between the number of HRDs that occurred in each three-day interval and the median purity of heroin obtained during these periods (for August 1984, $r = -0.37$, $p = 0.0002$; for February to March 1985, $r = -0.04$, $p = 0.5230$). Altering the date of sample collection by three days before or after the reported date produced similar results in regression models.

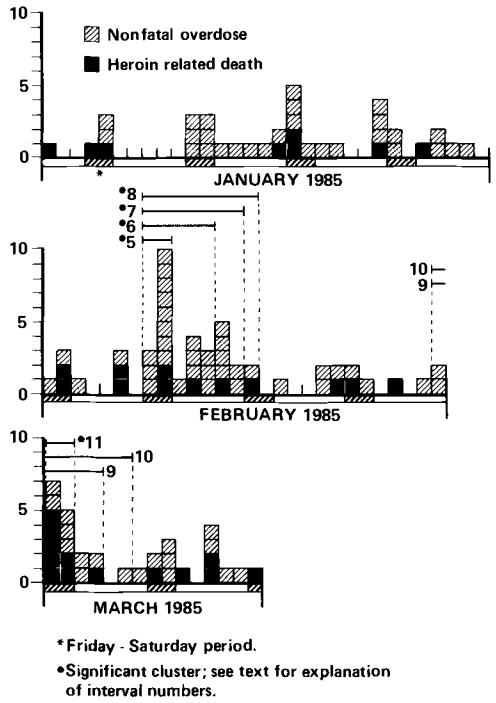

FIG. 2—*Heroin-related overdoses in Washington, DC, 1 Jan. 1985 through 15 March 1985.*

Discussion

If a cluster of HRDs is due to strong heroin, decedents in this period would be expected to have higher blood morphine concentrations than HRDs in noncluster periods. Purity of street-level heroin should also be higher than in noncluster periods. We found no difference between blood morphine concentrations for cluster and noncluster HRDs. Furthermore, our analyses also indicated no relationship between the heroin purity of street samples and the occurrence of HRDs or NFOs. These results contradict the popular belief that unusually pure heroin causes clusters of HRDs.

A previous study in the District of Columbia [5] suggested that reduced tolerance to the effects of heroin, as reflected by comparatively low bile morphine concentrations, was a risk factor for fatal overdose. In our study, bile morphine concentrations for all cluster HRDs were significantly lower than that for all noncluster HRDs. This suggests that the cluster decedents used heroin less intensely in the days before death than did noncluster decedents, and therefore were less tolerant than the noncluster decedents to the effects of narcotics.

In a population with a high prevalence of several risk factors, HRD clusters may result from chance alone or from a transient increase in one or more of the factors, including the purity of street-level heroin. Since our data show no relation between the purity of street-level heroin and the overdose clusters we studied, it is likely that other overdose clusters have also been influenced by factors other than heroin purity. We suggest that the mere detection of a cluster is not sufficient evidence for an increase in the purity of street-level heroin and should not justify warnings of the availability of unusually pure heroin.

The analytic approach described here can be used to identify and study possible overdose clusters in any city for which forensic science data for overdose decedents and hospital ad-

TABLE 1—*Temporal clustering of heroin overdoses, District of Columbia, January 1984 through March 1985.*

Interval Number[a]	Days in Interval	Heroin-Related Overdoses		Nonfatal Overdoses		Total Overdoses	
		Number	*p*	Number	*p*	Number	*p*
1	7	11	0.047				
2	8	12	0.033				
3	7	11	0.047				
4	1	4	NS[b]				
5	2	2	NS	11	0.005	13	0.005[c]
6	5	3	NS	18	0.002	21	0.005
7	7	4	NS	24	<0.001	28	<0.001
8	8	5	NS	25	<0.001	30	<0.001
9	5	8	NS	10	NS	18	0.085[c]
10	7	8	NS	11	NS	19	NS
11	2	7	0.007	5	NS	12	0.022[c]

[a]See Figs. 1 and 2 for interval dates; statistical significance was tested with scan statistic.
[b]$p > 0.10$.
[c]Approximation of p-value.

TABLE 2—*Comparisons[a] between cluster and noncluster heroin-related deaths, District of Columbia, 1 Jan. 1984 through 31 March 1985.*

Variable	Noncluster HRDs	Interval 2[b]	*p*	Interval 11[b]	*p*
Race (% black)	96 (155)	100 (12)	1.0000	100 (7)	1.0000
Sex (% male)	79 (155)	92 (12)	0.4628	71 (7)	0.6499
% Employed	56 (135)	55 (11)	1.0000	57 (7)	1.0000
% Local residents	87 (150)	58 (12)	0.0218	71 (7)	0.2545
% With multiple track areas[c]	55 (139)	70 (10)	0.5131	43 (7)	0.7031
Age	32 (154)	32 (12)	0.2842	32 (7)	0.4752
Weight, kg	74 (158)	70 (12)	0.5735	73 (7)	0.9420
Blood ethanol[d]	100 (143)	40 (11)	0.2724	120 (6)	0.4022
Blood morphine[d]	0.06 (140)	0.08 (11)	0.3484	0.06 (6)	0.6562
Bile morphine[d]	0.80 (95)	0.20 (11)	0.1152	0.15 (6)	0.1106

[a]For continuous variables, medians describe central tendency, and statistical significance is tested with the Wilcoxon rank-sum test; for discrete variables, statistical significance is tested with Fisher's exact test or the chi-square test; ( ) = number of study subjects.

[b]See Figs. 1 and 2 for description of intervals.

[c]Tracks are regions of venous sclerosis indicative of intravenous drug use.

[d]Concentrations expressed as mg/100 mL.

TABLE 3—*Street-level heroin concentrations during cluster and comparison intervals.*[a]

Cluster Interval	Heroin Concentration[b]	Comparison Period	Heroin Concentration[b]	*p*
2	7.4 (12)	August 1984	7.7 (76)	0.7481
8	6.0 (56)	February 1985	6.9 (70)	0.5650
11	9.2 (4)	February 1985 to March 1985	7.0 (216)	0.1226

[a]Data for cluster intervals have been excluded from comparison periods; ( ) = number of heroin samples.

[b]For Intervals 8 and 11, medians describe central tendency, and significance is tested with the Wilcoxon rank-sum test. For Interval 2, the mean describes central tendency, and significance is tested with the Student's *t*-test.

missions are available. We recommend timely examination of such data when there appears to be an unusual increase in heroin overdoses, and before warnings about strong heroin are issued. It may also be imprudent to concentrate public health efforts on overdose clusters to the exclusion of overdoses occurring at other times. During our 15-month study period, only 11% of the HRDs in the District of Columbia occurred in clusters. Control measures aimed at known risk factors for heroin-related death might decrease both the annual incidence of HRDs and the size and frequency of overdose clusters.

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