Annals of Epidemiology 38 (2019) 65–69

Contents lists available at ScienceDirect

Annals of Epidemiology

Brief communication

# Factors associated with incomplete toxicology reporting in drug overdose deaths, 2010–2016

Katherine M. Tote, MPH [a, *], Heather Bradley, PhD [b], Erika G. Martin, PhD [c, d], Recai Yucel, PhD [a], Eli S. Rosenberg, PhD [a, d]

[a] Department of Epidemiology and Biostatistics, University at Albany, SUNY, Albany, NY
[b] Department of Population Health Sciences, Georgia State University School of Public Heath, Atlanta, GA
[c] Department of Public Administration and Policy, University at Albany, SUNY, Albany, NY
[d] Center for Collaborative HIV Research in Practice and Policy, Albany, NY

ARTICLE INFO

*Article history:*
Received 14 May 2019
Accepted 14 August 2019
Available online 20 August 2019

*Keywords:*
Drug overdose
Death certificates
Coroners and medical examiners
United States

ABSTRACT

*Purpose:* Classification of overdose deaths is often geographically and demographically inconsistent. Incomplete surveillance records may distort estimates of drug overdose rates across time and place. We examined incomplete toxicology reporting among drug overdose decedents by demographic and geographic characteristics, measuring changes in missingness rates and their associations with decedent characteristics over time.
*Methods:* We estimated the percentage of overdose deaths reported in the National Vital Statistics System with missing toxicology results from 2010 to 2016, overall and by decedents' demographic and geographic characteristics. Multilevel logistic regression models evaluated prevalence of missingness by decedent characteristics, accounting for geographic clustering.
*Results:* Overall, 20.3% of death certificates did not indicate a specific drug, declining from 24.4% in 2010 to 14.6% in 2016. Deaths were less likely to have missing information if they occurred in counties with medical examiners versus coroners. Female decedents were more likely to have missing information than males, as were non-Hispanic whites compared with Hispanics and non-Hispanic blacks.
*Conclusions:* The percentage of deaths with missing toxicology information declined over time, but demographic and geographic differences in missingness persist. This yields detection biases that skew temporal trends and understanding of groups impacted by the opioid epidemic.


## Introduction

The drug overdose death rate in the United States more than tripled from 1999 to 2017 [1]. In 2017, 70,237 deaths were attributed to drug overdose, 68% of which involved opioids [2]. Monitoring changes in drug classes most frequently involved in overdose deaths is a critical surveillance activity [1–3] and reveals trends such as the 71% annual increase since 2013 in the rate of deaths involving synthetic opioids [2]. However, inconsistencies in investigating and classifying overdose deaths may bias estimates.

Drug overdose deaths are ascertained using a multistep process. Causes of deaths are first recorded on death certificates by physicians, coroners, or medical examiners. The Centers for Disease Control and Prevention (CDC) National Vital Statistics System (NVSS) then classifies them using *International Classification of Diseases, 10th Revision* (*ICD-10*) cause of death codes (X40-X44, X60-X64, Y10-Y14) and toxicology codes (T-codes; T36.0-T50.8) to indicate specific drugs involved [4]. Specific drug information is missing when postmortem toxicology testing does not occur, which may happen in settings with limited death investigation resources or nonstandardized toxicology testing procedures [5]. Missing data may also result from data entry or processing errors and challenges related to reporting mixed-drug toxicity. Missing T-codes lead to the consistent exclusion of >20% of overdose deaths from drug-specific overdose death estimates [6].

Excluding deaths with missing T-code information leads to underreporting of drug-specific overdose rates. Differential

* Corresponding author. Department of Epidemiology and Biostatistics, University at Albany, SUNY, 1 University Pl, Rensselaer, NY 12144. Tel.: +1 3152448968; fax: (518) 402-0380.
*E-mail address:* ktote@albany.edu (K.M. Tote).

https://doi.org/10.1016/j.annepidem.2019.08.006
1047-2797/

missingness by place, demographic characteristics, and time may compromise comparisons that guide public health decision-making [6–8]. Consequently, analyses typically aggregate all overdose deaths, and when specific drugs are analyzed, results are presented with the caveat that there is a high degree of missingness [3]. To address geographic differences in missing data when presenting drug-specific death rates, CDC stratifies presentation by completeness of state reporting [1]. However, deaths are often reported by demographic characteristics irrespective of reporting practices or missing T-code information. We assessed how characteristics of decedents are associated with T-code missingness and how these associations changed from 2010 to 2016.

## Materials and methods

We used the NVSS multiple cause of death microdata file (1999–2016), including records for deaths in 50 states and the District of Columbia ($n$ = 44,071,310) [4]. Drug overdose deaths were classified using *ICD-10* codes X40-X44, X60-X64, and Y10-Y14, indicating drug poisoning of accidental, intentional, and undetermined intent, respectively. The outcome of interest, T-code missingness, is indicated by *ICD-10* T-code 50.9 (drug poisoning by other and unspecified drugs, medicaments, and biological substances) or by a missing T-code value.

Urbanicity was determined using NVSS Federal Information Processing Standard codes and the CDC's standard six-level urban-rural classification scheme [9]. Counties' medicolegal death investigation systems (coroner vs. medical examiner) were classified using the CDC's searchable database of these systems [10] supplemented with an internet search for counties with missing information.

For all intentional, unintentional, and unknown intent drug poisoning deaths occurred during 2010–2016, we first estimated the percentage of overdose deaths with missing T-code information by year, overall, by demographic (sex, race/ethnicity, age group, year of death [nominal]), county (urbanicity, death investigation system), and death circumstances (intent [undetermined, intentional, and unintentional], whether drug overdose was the underlying cause) factors. We used a multilevel generalized logit-link model to estimate the adjusted prevalence of missing T-code information, considering factors and their interactions with year, including random effects for clustering within states and counties within states (PROC GLIMMIX, SAS 9.4; SAS, Cary, NC). Because all covariates and their interactions with year were statistically significant, we estimated adjusted prevalence of T-code missingness for each demographic characteristic, county, and death circumstance by year, controlling for clustering and all other covariates at their marginal distribution. Partial F-tests assess statistical significance of differences in magnitude of missing data by characteristic and year, and likelihood-ratio covariance tests confirm the statistical significance of state/county geographic clustering.

## Results

During 2010–2016, 351,345 deaths met inclusion criteria (Table 1). Three-quarters were deemed unintentional, and drug poisoning was the underlying cause of death for 92.6%. Males accounted for 62.1% of overdose deaths, non-Hispanic whites for 80.4%, and persons aged 25–64 years for 86.5%. Overall, 20.3% of deaths were missing T-code information, declining from 24.4% in 2010 to 14.6% in 2016. Deaths were less likely to have missing T-code information if they occurred in urban areas (from 15.4% for large metro to 24.9% for noncore counties for all years, 2016 adjusted odds ratio [aOR]: 0.31, 95% confidence interval: 0.24, 0.41) and in counties with medical examiners (14.6%) versus coroners (27.8%, 2016 aOR: 0.57 [0.47, 0.69]). Male decedents were less likely to have missing T-code information (females: 24.0%, males: 18.0%, 2016 aOR: 0.73 [0.69, 0.77]). Non-Hispanic whites (21.4%) were more likely to have missing information than non-Hispanic blacks (16.9%, aOR: 1.31 [1.2, 1.4]). The percentage of deaths missing T-code information declined over time, but demographic and geographic differences in missingness persisted.

In adjusted models, the prevalence of T-code missingness declined over time in every demographic and geographic group, and differences across groups also declined. Prevalence estimates of missing T-code information adjusted for demographic, geographic, and descriptors of death circumstances variables are shown in Figure 1A–E. For example, the predicted adjusted prevalence of T-code missingness declined from 15% to 10% among female and male decedents in 2010, respectively, to 7% and 5% in 2016. By 2016, differences in T-code missingness by sex, race/ethnicity, urbanicity, and medicolegal system declined, but meaningful and statistically significant differences remained. Differences in missingness by age and death circumstances remained statistically significant, but their magnitudes were no longer meaningful. Both state- and county-level clustering of variables associated with T-code missingness was detected ($P < 0.01$).

## Discussion

During 2010–2016, one-fifth of overdose deaths had missing T-code information. The prevalence of T-code missingness varied by demographic and geographic characteristics, which declined over time but persisted throughout the period. Statistical analyses that ignore missing values assume an unrealistic assumption of missingness independent of observed characteristics, which may adversely affect the validity of inferences [11]. Understanding how T-code missingness may affect drug-specific overdose death rate estimates, both overall and by demographic and geographic characteristics, is critical as these surveillance data guide resource allocation and overdose prevention programming.

Differential missingness may affect previously reported disparities in drug-specific overdose deaths. For example, a recent CDC report indicated a 2:1 male-to-female ratio in the number of opioid overdose deaths in 2016 among deaths with sufficient T-code information [1]. Our findings suggest that by 2016, female decedents were more likely to have missing T-code information. Assuming the distribution of opioid-related deaths among female decedents with missing T-code information is similar to the distribution among women with sufficient information, the number of opioid-related deaths among females would be underestimated and thus the male-to-female disparity overestimated. This same pattern may apply to persons dying in counties with coroners versus medical examiners, who make up a smaller share of deaths but are more likely to have T-code missingness. Disparities in missingness by decedent's characteristics declined, but comparisons of drug-specific overdose deaths across time and populations are complicated by changing patterns of T-code missingness.

Missing T-code information was more likely among decedents in rural counties and in counties where coroners perform death investigations, which is consistent with previous findings [5,12,13]. This likely reflects geographically disparate resources and training for death investigation and reporting [14] and is particularly problematic given increases in opioid-related overdose deaths in rural areas [1]. Differential T-code missingness by demographic characteristics may be due in part to residual geographic confounding or to demographic differences in circumstances or drug classes involved in overdose deaths.

Much focus has been placed on county and state death investigation systems and their role in monitoring the opioid epidemic.

States have either a coroner system, a medical examiner system, or a combination of the two [10]. Medical examiners are typically physicians trained in pathology, and coroners are elected or appointed officials who may not have clinical training. Our study aligns with other work in the findings that deaths occurring in counties with coroner systems are less likely to have specific-drug toxicology information reported [12,13] and that state variation in death investigation systems can impact apparent geographic disparities in death rates [15].

A recently published study by Boslett et al. reported on disparities in drug overdose reporting from 2014 to 2016 and came to similar conclusions regarding these important inequities, with a particular focus placed on the implications for the field of public health informatics [16]. Similar to our findings, their results provide compelling evidence underscoring the influence of individual and geographic factors on overdose death reporting. Boslett et al. found that counties in lower-income tertiles had higher rates of missingness, which aligns well with and is further explained by our findings regarding adjusted associations with urbanicity and county medicolegal death investigation systems [16].

Critically, our work goes beyond that of Boslett et al. by examining changes over time, since 2010 [16]. While it is promising that missingness is declining, these changes in missingness and disparities in missingness influence our historical understanding of overdose trends. Many recent CDC publications report rapid increases in the last decade in overdoses attributed to synthetic opioids, most notably fentanyl and carfentanil [1,17–19]. This apparent rapid rise could thus be in part explained by surveillance detection bias—as time progresses, fewer decedents were assigned a nonspecific T-code, rendering an apparent increase in deaths attributed to synthetic opioids, including fentanyl, that is faster than truly is the case. Corrections to historical trend data that account for our reported trends in missingness, by key person and place factors, are needed to reduce bias in these estimates.

The improvements in T-code missingness over time are likely a direct result of the focus placed on increasing resources to combat the opioid epidemic, and it is important that we continue to direct surveillance resources toward heavily impacted rural areas. Current processes for death investigation and surveillance are suboptimal for monitoring opioid-related mortality. It is important for public health officials to continue to advocate for improvements to the death investigation system [14]. Current drug overdose mortality

**Table 1**
Distribution of overdose decedents and T-Code missingness, overall and by demographic and geographic characteristics, 2010–2016

| Decedent characteristics | Overall | | 2010 | | 2016 | |
|---|---|---|---|---|---|---|
| | Overdose deaths* | Missing T-code† | Overdose deaths | Missing T-code | Overdose deaths | Missing T-code |
| | N (col%) | N (row%, col%) | N (col%) | N (row%, col%) | N (col%) | N (row%, col%) |
| Total | 351,345 | 71,298 | 41,204 | 10,035 | 67,569 | 9840 |
| Individual factors | | | | | | |
| Age | | | | | | |
| <25 | 27,551 (7.8%) | 4937 (17.9%, 6.9%) | 3462 (8.4%) | 758 (21.9%, 7.6%) | 5362 (7.9%) | 699 (13.0%, 7.1%) |
| 25–44 | 149,954 (42.7%) | 30,256 (20.2%, 42.4%) | 17,026 (41.3%) | 4250 (25.0%, 42.4%) | 30,906 (45.7%) | 4407 (14.3%, 44.8%) |
| 45–64 | 153,886 (43.8%) | 32,661 (21.2%, 45.8%) | 18,555 (45.0%) | 4641 (25.0%, 46.2%) | 27,659 (40.9%) | 4193 (15.2%, 42.6%) |
| 65+ | 19,954 (5.7%) | 3444 (17.3%, 4.8%) | 2161 (5.2%) | 386 (17.9%, 3.8%) | 3642 (5.4%) | 541 (14.9%, 5.5%) |
| Sex | | | | | | |
| Male | 218,306 (62.1%) | 39,357 (18.0%, 55.2%) | 24,867 (60.4%) | 5413 (21.8%, 53.9%) | 44,234 (65.5%) | 5806 (13.1%, 59.0%) |
| Female | 133,039 (37.9%) | 31,941 (24.0%, 44.8%) | 16,337 (39.6%) | 4622 (28.3%, 46.1%) | 23,335 (34.5%) | 4034 (17.3%, 41.0%) |
| Race/ethnicity | | | | | | |
| Hispanic | 26,878 (7.7%) | 4541 (16.9%, 6.4%) | 2810 (6.8%) | 594 (21.1%, 5.9%) | 5597 (8.3%) | 683 (12.2%, 6.9%) |
| Non-Hispanic white | 282,528 (80.4%) | 60,417 (21.4%, 84.7%) | 33,969 (82.4%) | 8721 (25.7%, 86.9%) | 52,557 (77.8%) | 8068 (15.4%, 82.0%) |
| Non-Hispanic black | 34,436 (9.8%) | 5230 (15.2%, 7.3%) | 3616 (8.8%) | 567 (15.7%, 5.7%) | 7966 (11.8%) | 934 (11.7%, 9.5%) |
| Other (including multiracial) | 7503 (2.1%) | 1110 (14.8%, 1.6%) | 809 (2.0%) | 153 (18.9%, 1.5%) | 1449 (2.1%) | 155 (10.7%, 1.6%) |
| Intent | | | | | | |
| Unknown | 58,768 (16.7%) | 5104 (8.7%, 7.2%) | 7014 (17.0%) | 805 (11.5%, 8.0%) | 11,238 (16.6%) | 603 (5.4%, 6.1%) |
| Unintentional | 262,340 (74.7%) | 57,120 (21.8%, 80.1%) | 29,855 (72.5%) | 7792 (26.1%, 77.6%) | 52,302 (77.4%) | 8218 (15.7%, 83.5%) |
| Intentional | 30,237 (8.6%) | 9074 (30.0%, 12.7%) | 4335 (10.5%) | 1438 (33.2%, 14.3%) | 4029 (6.0%) | 1019 (25.3%, 10.4%) |
| Cause of death | | | | | | |
| Multiple | 25,966 (7.4%) | 5093 (19.6%, 7.1%) | 3325 (8.1%) | 669 (20.1%, 6.7%) | 4391 (6.5%) | 622 (14.2%, 6.3%) |
| Underlying | 325,379 (92.6%) | 66,205 (20.3%, 92.9%) | 37,879 (91.9%) | 9366 (24.7%, 93.3%) | 63,178 (93.5%) | 9218 (14.6%, 93.7%) |
| County level factors | | | | | | |
| Urban-rural classification | | | | | | |
| Large central metro | 104,771 (29.8%) | 16,169 (15.4%, 22.7%) | 12,081 (29.3%) | 2070 (17.1%, 20.6%) | 20,500 (30.3%) | 2238 (10.9%, 22.7%) |
| Large fringe metro | 85,507 (24.3%) | 17,669 (20.7%, 24.8%) | 9443 (22.9%) | 2366 (25.1%, 23.6%) | 17,726 (26.2%) | 2809 (15.8%, 28.5%) |
| Medium metro | 78,218 (22.3%) | 16,512 (21.1%, 23.2%) | 9474 (23.0%) | 2492 (26.3%, 24.8%) | 14,959 (22.1%) | 2159 (14.4%, 21.9%) |
| Small metro | 31,798 (9.1%) | 8544 (26.9%, 12.0%) | 3773 (9.2%) | 1227 (32.5%, 12.2%) | 5672 (8.4%) | 1120 (19.7%, 11.4%) |
| Micropolitan | 30,584 (8.7%) | 7309 (23.9%, 10.3%) | 3709 (9.0%) | 1125 (30.3%, 11.2%) | 5383 (8.0%) | 900 (16.7%, 9.1%) |
| Noncore | 20,467 (5.8%) | 5095 (24.9%, 7.1%) | 2724 (6.6%) | 755 (27.7%, 7.5%) | 3329 (4.9%) | 614 (18.4%, 6.2%) |
| Coroner | | | | | | |
| No | 200,093 (57.0%) | 29,245 (14.6%, 41.0%) | 22,884 (55.5%) | 4114 (18.0%, 41.0%) | 49,562 (64.7%) | 4145 (8.4%, 42.1%) |
| Yes | 151,235 (43.0%) | 42,049 (27.8%, 59.0%) | 18,316 (44.5%) | 5921 (32.3%, 59.0%) | 27,006 (35.3%) | 5695 (21.1%, 57.9%) |

* Drug overdose mortality was classified using ICD-10 codes for accidental poisoning by and exposure to: nonopioid analgesics, antipyretics and antirheumatics (X40), antiepileptic, sedative-hypnotic, antiparkinsonism and psychotropic drugs, not elsewhere classified (X41), narcotics and psychodysleptics (hallucinogens), not elsewhere classified (X42), other drugs acting on the autonomic nervous system (X43), other and unspecified drugs, medicaments and biological substances (X44); intentional self-poisoning by and exposure to: exposure to nonopioid analgesics, antipyretics and antirheumatics (X60), antiepileptic, sedative-hypnotic, antiparkinsonism, and psychotropic drugs, not elsewhere classified (X61), narcotics, and psychodysleptics [hallucinogens], not elsewhere classified (X62), other drugs acting on the autonomic nervous system (X63), other and unspecified drugs, medicaments, and biological substances (X64); undetermined intent, poisoning by and exposure to: nonopioid analgesics, antipyretics and antirheumatics, undetermined intent (Y10), antiepileptic, sedative-hypnotic, antiparkinsonism and psychotropic drugs, not elsewhere classified, undetermined intent (Y11), narcotics, and psychodysleptics [hallucinogens], not elsewhere classified (Y12), other drugs acting on the autonomic nervous system, undetermined intent (Y13), and other and unspecified drugs, medicaments, and biological substances (Y14).

† Incomplete toxicology reporting (missingness) is indicated by ICD-10 T-code 50.9 (poisoning by, adverse effect of and underdosing of other and unspecified drugs, medicaments, and biological substances) and by the lack of a T-code entirely.

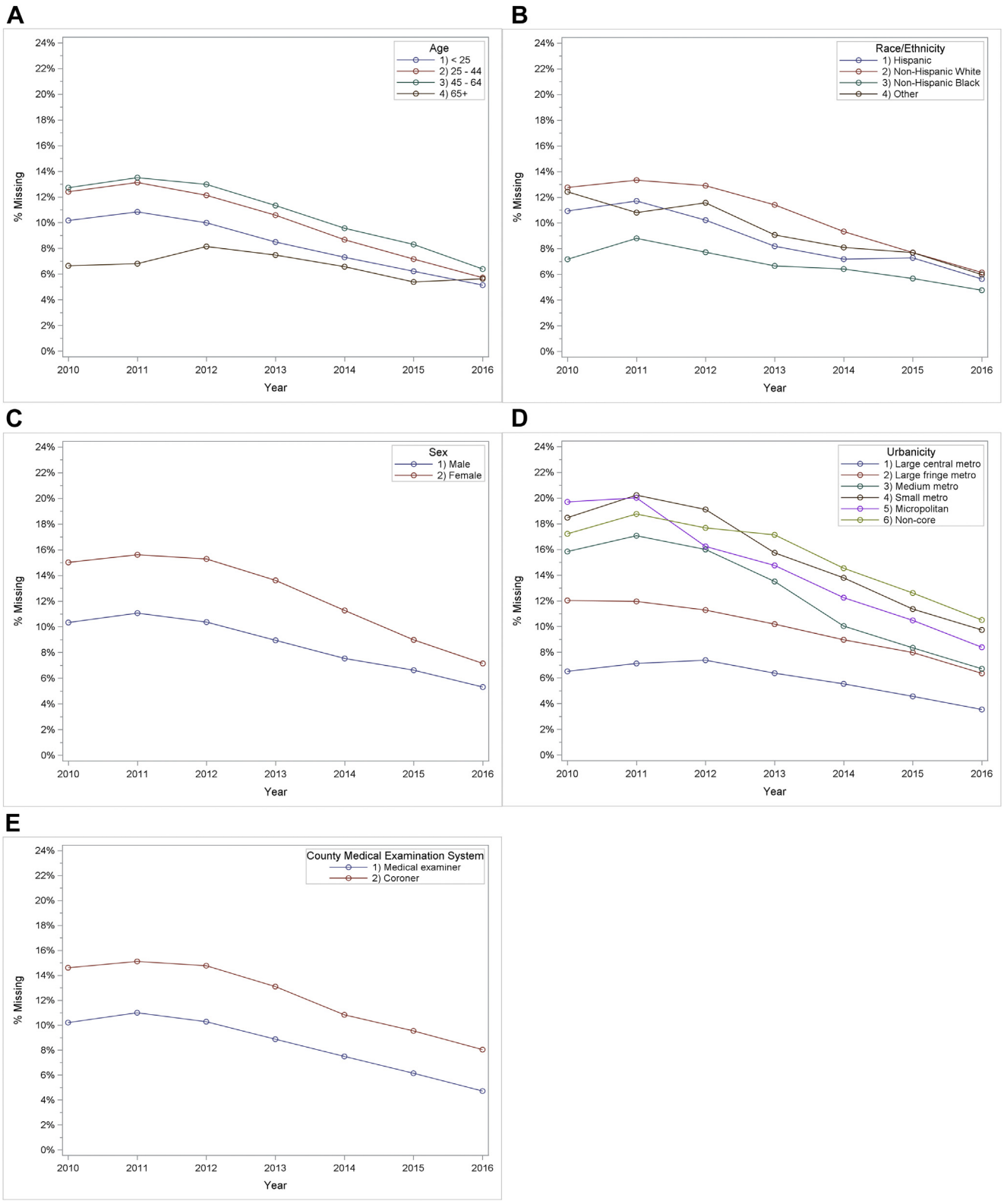


**Fig. 1.** Adjusted prevalence of T-code missingness by demographic and geographic characteristics, 2010–2016. The following variables were included in the adjusted model: sex, race/ethnicity, age group, year of death (nominal), county urbanicity, county death investigation system, and death circumstances (intent [undetermined, intentional, and unintentional], whether drug overdose was the underlying cause). The model takes into account county and state geographic clustering. (A) Adjusted prevalence of missingness by age. (B) Adjusted prevalence of missingness by race/ethnicity. (C) Adjusted prevalence of missingness by sex. (D) Adjusted prevalence of missingness by urbanicity. (E) Adjusted prevalence of missingness by county death investigation system.

estimates provide an incomplete and likely biased description of overdose deaths throughout the United States, and supplemental, innovative surveillance methods will ultimately be needed to reduce bias in these estimates.

## Conclusions

Overall and differential T-code missingness will likely continue to decline with increasing resources for toxicology testing for drug overdose deaths [20]. Ignoring differentially missing data in surveillance reports may adversely affect the validity of inferences, and creative data solutions are needed to facilitate valid comparisons in drug-specific overdose deaths across populations and over time as surveillance systems continue to evolve.

## References

[1] Scholl L, Seth P, Kariisa M, Wilson N, Baldwin G. Drug and opioid-involved overdose deaths - United States, 2013-2017. MMWR Morb Mortal Wkly Rep 2018;67(5152):1419–27.
[2] Hedegaard H, Minino AM, Warner M. Drug overdose deaths in the United States, 1999 - 2017. NCHS Data Brief 2018:1–8.
[3] Hedegaard H, Bastian B, Trinidad J, Spencer M, Warner M. Drugs most frequently involved in drug overdose deaths: United States, 2011–2016. Natl Vital Stat Rep 2018;67(9):1–14.
[4] Centers for Disease Control and Prevention NCfHS. National Vital Statistics System. http://www.cdc.gov/nchs/nvss/index.htm. [Accessed 15 January 2019].
[5] Harris J, Beatty K, Leider J, Knudson A, Anderson B, Meit M. The double disparity facing rural local health departments. Annu Rev Public Health 2016;37:17.
[6] Buchanich JM, Balmert LC, Williams KE, Burke DS. The effect of incomplete death certificates on estimates of unintentional opioid-related overdose deaths in the United States, 1999-2015. Public Health Rep 2018;133(4):8.
[7] Ruhm CJ. Drug poisoning deaths in the United States, 1999–2012: a statistical adjustment analysis. Popul Health Metr 2016;14:2.
[8] Slavova S, O'Brien DB, Creppage K, Dao D, Fondario A, Haile E, et al. Drug overdose deaths: Let's get specific. Public Health Rep 2015;130(4):339–42.
[9] Centers for Disease Control and Prevention NCfHS. NCHS urban-rural classification scheme for Counties 2013. https://www.cdc.gov/nchs/data_access/urban_rural.htm. [Accessed 15 January 2019].
[10] Centers for Disease Control and Prevention. Center for state, tribal, local, and territorial support, public health law program. Death Investigation Systems 2016. https://www.cdc.gov/phlp/publications/coroner/death.html. [Accessed 15 January 2019].
[11] Little RJA, Rubin DB. Statistical analysis with missing data. 3rd ed. Hoboken, NJ: John Wiley & Sons, Inc; 2019.
[12] Robinson R. County coroners and their role in the heart of the opioid epidemic. Acad Forensic Pathol 2017;7(1):6.
[13] Warner M, Paulozzi LJ, Nolte KB, Davis GG, Nelson LS. State variation in certifying manner of death and drugs involved in drug intoxication deaths. Acad Forensic Pathol 2013;3(2):6.
[14] Martin E, Bozlak C, Park Y. Get out the vote: the role of public health professionals in raising awareness of coroner elections. J Public Health Manag Pract 2018;24(6):3.
[15] Klugman J, Gondran G, Wray M. The role of medicolegal systems in producing geographic variation in suicide rates. Soc Sci Q 2013;94(2):17.
[16] Boslett AJ, Denham A, Hill EL, Adrams MCB. Unclassified drug overdose deaths in the opioid crisis: emerging patterns of inequity. J Am Med Inform Assoc 2019;26:767–77.
[17] O'Donnell JK, Gladden RM, Seth P. Trends in deaths involving heroin and synthetic opioids excluding methadone, and law enforcement drug product reports, by Census Region — United States, 2006–2015. MMWR Morb Mortal Wkly Rep 2017;66:6.
[18] VanHouten JP, Rudd RA, Balesteros MF, Mack KA. Drug overdose deaths among women aged 30–64 years — United States, 1999–2017. MMWR Morb Mortal Wkly Rep 2019;68:5.
[19] Rudd RA, Seth P, David F, Scholl L. Increases in drug and opioid-involved overdose deaths - United States, 2010-2015. MMWR Morb Mortal Wkly Rep 2016;65(50-51):1445–52.
[20] Prevention CfDCa. CDC RFA-CE19-1904: overdose data to action. Atlanta, GA: Centers for Disease Control; 2019.