Injury Burden in the United States: Accurate, Reliable, and Timely Surveillance Using Electronic Health Care Data

Current injury surveillance systems in the United States, including the National Electronic Injury Surveillance System (NEISS), are unable to draw reliable subnational and subannual incidence estimates.

Compared with the *International Classification of Diseases* (*ICD*), the clinical ontology system currently used widely in health care, NEISS's coding structure lacks specificity and consistency. In parallel, the quality of *ICD* codes depends on accurate and complete documentation by health care providers and skillful translation into *ICD* codes in electronic health care data. Additionally, there is no national mandate to collect external cause of injury data.

Electronic health care data, such as health records and claims, with updated codes and uniform adherence to recommendations for coding external cause of injury, have the potential to be used for a more robust and timely surveillance of injury to accurately and reliably reflect the injury burden in the United States. (*Am J Public Health*. 2019;109:1702–1706. doi:10.2105/AJPH.2019.305306)

Jae Min, PhD, Kelly K. Gurka, PhD, MPH, Bindu Kalesan, PhD, Jiang Bian, PhD, and Mattia Prosperi, PhD, MEng

Injuries are among the leading causes of mortality and morbidity in the United States. In 2016, more than 230 000 Americans died from injuries and 32 million suffered nonfatal injuries.[1] Capturing accurate and complete injury information in a timely manner is necessary to reduce this major health burden. Currently, national injury morbidity estimates provided by the Centers for Disease Control and Prevention (CDC) are constructed from the National Electronic Injury Surveillance System (NEISS).[1] However, NEISS lacks geographic detail, produces only annual estimates, and relies on a simple coding system that is inconsistent with the clinical ontologies currently used in health care.

We discuss the shortcomings of current injury surveillance systems and the advantage of using electronic health care data, such as electronic health records (EHRs), hospital discharges, and administrative claims data, as well as issues with secondary use of these data for surveillance. Injury surveillance in the United States could be improved by using routinely collected electronic health care data and their ontologies, with concurrent improvement of injury coding.

CURRENT SYSTEMS FOR INJURY SURVEILLANCE

In the United States, fatal injury surveillance is conducted using death certificate data from all states and territories that are reported to the National Vital Statistics System (NVSS).[1] The cause of death and external injury-related causes can be queried. Similarly, data from the National Violent Death Reporting System (NVDRS) can be queried with additional details on the circumstances of violent injury–related death, such as the relationship between the victim and the perpetrator.

In addition to the NVSS and NVDRS, several injury mortality surveillance systems covering specific settings also exist, such as the Census of Fatal Occupational Injuries for work-related injury and the Fatality Analysis Reporting System for road traffic injury (Table 1). There are also systems that focus on a specific type of injury, such as poisoning and burns. Many of these systems boast full geographic coverage of the United States, whereas the current system used for nonfatal injury surveillance is limited to a small number of participating hospitals.

Currently, national nonfatal injury morbidity estimates are generated through NEISS.[1] Despite the name of its overseeing organization, the US Consumer Product Safety Commission, NEISS has expanded beyond consumer products and collects data on fall-, firearm-, fire-, and motor vehicle–related injury.[2] Currently, NEISS serves as a nationally representative surveillance system of injury and is publicly available.[2]

In a stratified sample of 66 hospitals, NEISS reviews EHRs of all emergency department encounters and reports those related to injury.[3,4] Although the data from these hospitals are used to estimate the national incidence of injury, reliable regional- and state-level estimates cannot be made.[4] For many states, only one hospital in the state contributes to NEISS, and several states do not have any participating hospitals.[4] National-level estimates and state populations are used to extrapolate state-specific injury estimates, but these may not reflect the true injury burden for the states. In addition, stratified estimates for specific mechanisms of injury or by demographic

ABOUT THE AUTHORS

Jae Min, Kelly K. Gurka, and Mattia Prosperi are with the Department of Epidemiology, University of Florida, Gainesville. Bindu Kalesan is with the Department of Medicine, Boston University, Boston, MA. Jiang Bian is with the Department of Health Outcomes and Biomedical Informatics, University of Florida.

Correspondence should be sent to Mattia Prosperi, PhD, MEng, 2004 Mowry Rd, PO Box 100231, Gainesville, FL 32601 (e-mail: m.prosperi@ufl.edu). Reprints can be ordered at http://www.ajph.org by clicking the "Reprints" link.

This article was accepted July 21, 2019.

doi: 10.2105/AJPH.2019.305306

TABLE 1—Select Injury Surveillance Systems: United States, September 24, 2018

Surveillance System	Organization	Relevance to Injury	Population Based	Mortality	Morbidity	National Estimates	State Estimates	Local Estimates	*ICD*	External Cause Codes	Latest Available
NEISS	Consumer Product Safety Commission	Nonfatal injury	N; sampling	N	Y	Y	N	N	N	N	2017
NVSS	CDC, National Center for Health Statistics	All deaths	Y	Y	N	Y	Y	Y	Y	Y	2016
NVDRS	CDC, National Center for Health Statistics	Violent injury deaths	N; volunteer basis	Y	N	N	P	P	Y	Y	2015
NTDB	American College of Surgeons	Traumatic Injury	N; volunteer basis	Y	Y	N	P	P	Y	Y	2016
NEMSIS	National Highway Traffic Safety Administration	Prehospital care	N; volunteer basis	Y	Y	N	P	P	P	P	2016
FARS	National Highway Traffic Safety Administration	Motor vehicle crash	N; sampling	Y	N	Y	Y	Y	N	N	2016
CFOI	Bureau of Labor Statistics	Occupational injury	Y	Y	N	Y	Y	Y	N	N	2016
NPDS	American Association of Poison Control Centers	Poisoning	Y	Y	Y	Y	Y	Y	N	N	2018
NFIRS	US Fire Administration	Fire related	N; volunteer basis	Y	Y	N	Y	P	N	N	2016
NEDS	Agency for Healthcare Research and Quality	ED visits	N; sampling	Y	Y	Y	P	N	Y	Y	2015
NSSP	CDC, International Society for Disease Surveillance	ED visits	N; volunteer basis	Y	Y	N	P	P	Y	Y	?

Note. CDC = Centers for Disease Control and Prevention; CFOI = Census of Fatal Occupational Injuries; ED = emergency department; FARS = Fatality Analysis Reporting System; *ICD* = *International Classification of Diseases*; N = no, the system does not encompass this objective; NEDS = National Emergency Department Sample; NEISS = National Electronic Injury Surveillance System; NEMSIS = National EMS Information System; NFIRS = National Fire Incident Reporting System; NPDS = National Poison Data System; NSSP = National Syndromic Surveillance Program; NTDB = National Trauma Data Bank; NVDRS = National Violent Deaths Reporting System; NVSS = National Vital Statistics System; P = the objective is partially met; Y = yes, the system encompasses this objective; ? = unknown.

variables such as sex and race/ethnicity cannot always be generated because of the small sample size. Unweighted counts of less than 20 and weighted counts less than 1200 are unstable estimates of true injury incidence,[1] so accurate yearly incidence estimates of rare injuries cannot always be made with NEISS. In addition, NEISS focuses on reports of annual estimates, so injuries that occur with high incidence at specific times of the year, such as drowning and firework-related injury, cannot be queried by month or season.

Despite these limitations, using NEISS has several strengths in injury surveillance. Through the process of manual data abstraction, details of the injury, such as information on the cause or the setting of injury, are coded.[3] For an assault injury, this includes the relationship of the perpetrator to the victim and the context of assault, and for motor vehicle crash, whether the crash occurred on a public road. NEISS also has a relatively short lag time in reporting, with individual-level reports of NEISS from the entire year of 2017 being available in the first few months of 2018. Although this is not real-time surveillance, NEISS's quick turnaround is the timeliest and most comprehensive injury surveillance system given the current infrastructure and is conducted in an "efficient, cost-effective manner."[4] In addition to NEISS, several surveillance systems outlined here and in Table 1 are designed with their respective sponsoring agencies' missions and priorities in mind, including budgetary constraints.

EMERGING SURVEILLANCE SYSTEMS

In lieu of manual abstraction of injury cases, as in NEISS or survey administration, several emerging systems have demonstrated the utility of electronic health care data for injury surveillance. These data include EHR and claims data that have been coded and stored digitally. Notably, the CDC has taken steps toward automatically collecting health care data as part of an overall effort called the National Health Care Surveys (NHCS).[5] Although the availability of federal funds has affected continuous data collection, the National Hospital Care Survey (part of NHCS) was used to study traumatic brain injury using claims data.[6] Levant et al.

analyzed the age- and sex-specific differences (such subpopulation analysis is not always feasible using traditional methods with low sample sizes) as well as the care, services, and outcomes of those with traumatic brain injury. Because individuals can be longitudinally linked across encounters, these data can be used to examine risk factors, outcomes, and costs associated with injury.

In addition, electronic health care data have provided incidence estimates comparable to those of national survey data, even for injury mechanism subtypes and rare injuries.[7] For example, electronic health care data were used to generate stable annual incidence estimates for shaken baby syndrome, a rare but serious type of traumatic brain injury.

Moreover, electronic health care data do not need to be limited to a single hospital or health care system. North Carolina has successfully combined emergency department, poison center, and emergency medical services data to conduct real-time surveillance and examine local burden of drug overdose.[8] Similarly, the National Syndromic Surveillance Program has evolved to incorporate records of more than half of the emergency department visits in the United States as well as pharmacy and laboratory test records to conduct real-time surveillance.[9]

Therefore, the use of electronic health care data for surveillance could be a robust, cost-effective, and timely alternative to surveillance through manual record abstraction or survey administration. However, a major hurdle to using electronic health care data for injury surveillance is in the heterogeneous quality of injury coding.

MEDICAL ONTOLOGIES FOR INJURY

The *International Classification of Diseases, 10th Revision* (Geneva, Switzerland: World Health Organization; 2011; *ICD-10*) is a diagnosis classification created and maintained by the World Health Organization and used internationally for the collection of mortality data. The clinical modification (*International Classification of Diseases, 10th Revision, Clinical Modification*. Hyattsville, MD: National Center for Health Statistics; 2015; *ICD-10-CM*), an adaptation of the *ICD-10* developed by the United States for morbidity, is used on claims by health care providers and facilities in the United States. The *ICD-10-CM* is also the basis for the inpatient reimbursement system used by the Centers for Medicare and Medicaid Services (CMS). The main section of the *ICD* includes a chapter for the nature of injury codes. The external cause of injury section of the *ICD-10-CM* includes the codes for the intention (unintentional [accidental] self-harm, intentional self-harm, assault, and unknown), the mechanism (drowning, fall, motor vehicle accident, etc.), the place of occurrence, and the activity causing the injury. Notably, although poisoning is a type of injury, it does not follow the nature of injury and external cause of injury distinction. Poisoning codes are in the injury chapter of the *ICD-10-CM*, and the intention for poisoning are built into the poisoning codes themselves.

Despite the breadth of information contained in these external cause codes, *ICD* codes are not used in NEISS. Instead, NEISS uses its own ontology with 900 cause codes.[3] Although this coding system was internally audited and found to be valid for 90% of the records,[10] it is unclear how NEISS codes perform across injury intentions and mechanisms without external testing. Moderate to high agreement on the nature of injury between NEISS and the *ICD* has been found, but studies have indicated the need for manual review of the cases because of the broad nature of NEISS codes, limited specificity of the external cause, and limitations in ascertaining minor injury with NEISS.[11,12] As an example, NEISS coding of traumatic brain injury using a single code agreed with *ICD* coding in only 53% of the records; whereas, using two NEISS codes improved this agreement to 81%.[12]

Another ontology, or terminology system, the Systematized Nomenclature of Medicine Clinical Terms (SNOMED CT), a standardized dictionary of terms used in health care, has been shown to sufficiently indicate the nature of injury.[13] However, its utility in capturing mechanisms of injury has been found inadequate, and SNOMED overall is not structured for surveillance utility. Yet another ontology, the Logical Observation Identifiers Names and Codes (LOINC), indicating a laboratory test for carbon monoxide poisoning, has been used in conjunction with the *ICD*, but because only 16% of patients with confirmed, probable, or suspected poisoning had this laboratory test, those using this ontology only would not be able to identify the majority of the injured population.[14] In the future, an ontology-free system relying on natural language processing may be useful for injury surveillance; for example, including the free text "naloxone" using natural language processing was shown to aid detection of overdose.[8]

Thus, with a robust set of external cause codes (eight times as many as NEISS) and widespread use in electronic health care data, the *ICD* classification system is best suited for surveillance. However, the *ICD* is not without its own limitations. Research on the use of *ICD* external cause codes has shown that interrater reliability and accuracy can vary widely.[15] Incomplete documentation (e.g., missing intention) and inaccurate coding (e.g., misclassification of injury) are significant issues when using the *ICD*.[15,16] Mapping between the *ICD*'s versions and new releases (four for *ICD-10-CM* as of 2019) as well as against other coding systems is not trivial,[17,18] although significant improvements have been made with more readily available tools for conversions including general equivalence mappings.[19]

EXTERNAL CAUSES OF MORBIDITY AND MORTALITY CODES

Unlike the nature of injury codes that are commonly found in electronic health care data, the external cause codes can be missing because they are not required for billing purposes in the US health care system.[16] They are not included in the payment algorithm for the Medicare and Medicaid programs regulated by CMS, and because private payers often follow federal reimbursement guidelines, health care providers are not incentivized to include external causes in their health care data.[20] The current *ICD* guidelines read:

> There is no national requirement for mandatory *ICD-10-CM* external cause code reporting. Unless a provider is subject to a state-based external cause code reporting mandate or these codes are required by a particular payer,

> reporting . . . is not required. In the absence of a mandatory reporting requirement, providers are encouraged to voluntarily report external cause codes, as they provide valuable data for injury research and evaluation of injury prevention strategies.[21]

Despite the lack of a direct incentive to report external cause codes, health care providers may see value in their use if they are aware and educated on the importance of these codes for injury surveillance and quality improvement programs. CMS encourages secondary use of EHRs, such as sharing electronic health care data with registries and public health systems, through payment adjustments.[22] This is highly relevant to injury surveillance because accurate injury surveillance with health care data cannot be conducted without external cause codes. Certain states have already found the use of these codes to be a useful and important tool for injury surveillance and have set reporting requirements, such as mandating use in inpatient and emergency department encounter data.[20] However, according to the latest available figure, the prevalence of external cause code use varied by state, ranging from 65% to 100%.[23] Moreover, the CMS payment adjustment system for the adoption and secondary use of EHRs is set to expire in 2021, potentially affecting progress made toward EHR integration and interoperability as well as jeopardizing collaborative sharing of surveillance data with public health agencies.

INJURY SURVEILLANCE AND PREVENTION

We propose that the secondary use of electronic health care data for injury surveillance could be a robust, cost-effective, and timely enhancement to the current system. Because many providers have adopted EHRs for use in their practice, surveillance does not need to be limited to the small number of institutions that contribute to a surveillance system or rely on manual abstraction. Currently, 80% of hospitals in the United States have adopted EHRs.[24] Electronic health care data of various types, EHRs, and claims have been valuable sources for injury research in examining cost, care, and burden of injury.[6,7] New forms of real-time surveillance systems with electronic health care data incorporated across multiple agencies have also emerged.[8,9]

Accurate injury surveillance system via secondary use of electronic health care data hinges on accurate and complete external cause of injury coding. *ICD* codes are used for billing purposes in the United States and are not specifically designed for injury surveillance. Yet given their near universal adoption across the US health care system, the *ICD* is the most appropriate tool for injury surveillance. *ICD* codes were recently used to distinguish between prescription and illicitly manufactured opioid overdose deaths, illustrating their potency for injury surveillance on a significant public health issue.[25] Unmet needs include recognition of the importance of the external cause codes and continuous evaluation of these codes' relevance for health care providers and public health professionals. Mandating the use of external cause of injury codes would likely enable robust collection of injury data for surveillance, yet a good system would rely not on mandatory enforcement but on intrinsic utility and transparency supported by education and standard of practice.

In conclusion, the case for uptake of electronic health care data and the *ICD* for injury surveillance builds on (1) a concerted effort to increase reporting of injury-related information in health care data, (2) use of existing electronic health care data from geographically diverse settings to generate granular and subannual incidence estimates of injury, and (3) future revision of the *ICD* for better differentiating injury mechanisms, intention, and etiology with validation studies and performance evaluation of the coding system for surveillance. Should these needs be met with greater reporting of injury-related data, subnational and subannual estimation capabilities, and improvement of the ontology, *ICD* codes could be used for injury surveillance with improvement over the current, limited data systems. A uniform, accurate, and timely injury surveillance system built on these premises can help in conducting research at multiple scales (regional and national) and enable actions aimed at reducing the health burden affecting more than 30 million Americans per year. AJPH

CONTRIBUTORS

J. Min led the writing with substantial contributions from K. K. Gurka and M. Prosperi. B. Kalesan and J. Bian reviewed and edited the writing. All authors collaborated to conceptualize the commentary and approved the final version of the article.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

REFERENCES

1. Centers for Disease Control and Prevention. Welcome to WISQARS. 2018. Available at: https://www.cdc.gov/injury/wisqars/index.html. Accessed January 31, 2018.

2. US Consumer Product Safety Commission. National Electronic Injury Surveillance System (NEISS). Available at: https://www.cpsc.gov/Research–Statistics/NEISS-Injury-Data. Accessed October 11, 2018.

3. US Consumer Product Safety Commission. NEISS coding manual. 2018. Available at: https://www.cpsc.gov/s3fs-public/2018-NEISS-CPSC-only-CodingManual.pdf. Accessed March 3, 2018.

4. US Consumer Product Safety Commission. NEISS: the National Electronic Injury Surveillance System a tool for researchers. 2000. Available at: https://www.cpsc.gov/s3fs-public/pdfs/blk_media_2000d015.pdf. Accessed March 3, 2018.

5. Centers for Disease Control and Prevention. Welcome to the National Health Care Surveys Registry. Available at: https://www.cdc.gov/nchs/dhcs/nhcs_registry_landing.htm. 2018. Accessed March 4, 2018.

6. Levant S, Chari K, Defrances C. National hospital care survey demonstration projects: traumatic brain injury. 2016. Available at: https://www.cdc.gov/nchs/data/nhsr/nhsr097.pdf. Accessed July 25, 2018.

7. Taylor CA, Greenspan AI, Xu L, Kresnow MJ. Comparability of national estimates for traumatic brain injury-related medical encounters. *J Head Trauma Rehabil*. 2015;30(3):150–159.

8. Ising A, Proescholdbell S, Harmon KJ, Sachdeva N, Marshall SW, Waller AE. Use of syndromic surveillance data to monitor poisonings and drug overdoses in state and local public health agencies. *Inj Prev*. 2016;22(suppl 1):i43–i49.

9. Gould DW, Walker D, Yoon PW. The evolution of BioSense: lessons learned and future directions. *Public Health Rep*. 2017; 132(1 suppl):7S–11S.

10. Centers for Disease Control and Prevention. National estimates of nonfatal injuries treated in hospital emergency departments—United States, 2000. *MMWR Morb Mortal Wkly Rep*. 2001; 50(17):340–346.

11. Thompson MC, Wheeler KK, Shi J, Smith GA, Xiang H. An evaluation of comparability between NEISS and *ICD-9-CM* injury coding. *PLoS One*. 2014; 9(3):e92052.

12. Xiang H, Sinclair SA, Yu S, Smith GA, Kelleher K. Case ascertainment in pediatric traumatic brain injury: challenges in using the NEISS. *Brain Inj*. 2007;21(3): 293–299.

13. Mitchell RJ, Bambach MR, Muscatello D, McKenzie K, Balogh ZJ. Can SNOMED CT as implemented in New South Wales, Australia be used for road trauma injury surveillance in emergency departments? *Heal Inf Manag*. 2013;42(2): 4–8.

14. Oda G, Ryono R, Lucero-Obusan C, Schirmer P, Holodniy M. Carbon monoxide poisoning surveillance in the Veterans Health Administration, 2010–2017. *BMC Public Health*. 2019;19(1):190.

15. McKenzie K, Enraght-Moony EL, Walker SM, McClure RJ, Harrison JE. Accuracy of external cause-of-injury coding in hospital records. *Inj Prev*. 2009; 15(1):60–64.

16. Hunt PR, Hackman H, Berenholz G, McKeown L, Davis L, Ozonoff V. Completeness and accuracy of international classification of disease (ICD) external cause of injury codes in emergency department electronic data. *Inj Prev*. 2007;13(6):422–425.

17. Boyd AD, Li JJ, Burton MD. The discriminatory cost of *ICD-10-CM* transition between clinical specialties: metrics, case study, and mitigating tools. *J Am Med Inform Assoc*. 2013;20(4):708–717.

18. Turer RW, Zuckowsky TD, Causey HJ, Rosenbloom ST. *ICD-10-CM* crosswalks in the primary care setting: assessing reliability of the GEMs and reimbursement mappings. *J Am Med Inform Assoc*. 2015;22(2):417–425.

19. 3M. New release of 3M code translation tool simplifies *ICD-10* conversion for hospitals and payers. 2012. Available at: https://news.3m.com/press-release/company/new-release-3m-code-translation-tool-simplifies-icd-10-conversion-hospitals-an. Accessed July 12, 2019.

20. Centers for Disease Control and Prevention. Strategies to improve external cause-of-injury coding in state-based hospital discharge and emergency department data systems: recommendations of the CDC Workgroup for Improvement of External Cause-of-Injury Coding. *MMWR Morb Mortal Wkly Rep*. 2008; 57(RR-1):1–15.

21. Centers for Medicare and Medicaid Services. *ICD-10-CM* official guidelines for coding and reporting. 2018. Available at: https://www.cms.gov/Medicare/Coding/ICD10/Downloads/2018-ICD-10-CM-Coding-Guidelines.pdf. Accessed October 11, 2018.

22. Centers for Medicare and Medicaid Services. Promoting interoperability (PI). 2018. Available at: https://www.cms.gov/Regulations-and-Guidance/Legislation/EHRIncentivePrograms/index.html. Accessed October 3, 2018.

23. Barret M, Steiner C, Sheng M, Bailey M. Healthcare Cost and Utilization Project (HCUP-US). 2016. Available at: http://www.hcup-us.ahrq.gov. Accessed March 16, 2019.

24. Adler-Milstein J, Holmgren AJ, Kralovec P, Worzala C, Searcy T, Patel V. Electronic health record adoption in US hospitals: the emergence of a digital "advanced use" divide. *J Am Med Inform Assoc*. 2017;24(6):1142–1148.

25. Seth P, Rudd RA, Noonan RK, Haegerich TM. Quantifying the epidemic of prescription opioid overdose deaths. *Am J Public Health*. 2018;108(4):500–502.