Occupational Injury Trends Derived From Trauma Registry and Hospital Discharge Records

Lessons for Surveillance and Research

Jeanne M. Sears, PhD, RN, Stephen M. Bowman, PhD, MHA, Sheilah Hogg-Johnson, PhD, and Zeynep A. Shorter, PhD, MPH

Objective: The suitability of the Washington State Trauma Registry (WTR) for occupational injury surveillance was assessed via comparing estimated rates and trends with those derived from state hospital discharge data. **Methods:** Descriptive methods and negative binomial regression were used to model occupational injury trends (1998 to 2009). **Results:** Nonlinear trends based on WTR data closely tracked those based on hospital discharge data, beginning about 2002. Rate estimates differed somewhat by data source and were most similar when a severity threshold was applied. Conclusions regarding temporal trends in work-related injury rates were the same using either data source. **Conclusions:** This study found substantial similarity between occupational injury trends estimated using either WTR or hospital discharge data. We conclude that a mature state trauma registry with mandatory reporting requirements can be used for surveillance of severe work-related traumatic injuries.

Acute work-related trauma is a leading cause of death and disability among US workers. The CDC's NIOSH estimated that about 2.6 million workers were treated in emergency departments (EDs) for occupational injuries and illnesses, about 110,000 workers were hospitalized, and more than 4500 US workers died from occupational injuries in 2010.[1] Occupational injury surveillance involves efforts to accurately characterize trends in the extent and burden of work-related injuries and is necessary for the effective planning and evaluation of prevention programs as well as for policy development. Various local, state, national, and private databases have been used for this purpose, but all have significant limitations and gaps.[2–7] Researchers have a high degree of interest in exploring new data sources for occupational injury surveillance and research to address the filters and barriers to full and complete work injury reporting by employers, workers, and/or health care providers that differentially affect various databases.[2,5,6,8–11]

In particular, health care–based surveillance has the potential to avoid some of the reporting filters associated with workers' compensation (WC) claims data or employer surveys, specifically whether employers recognize or report a particular injury as work related and whether a WC claim is filed or accepted.[9] Population-based hospital discharge data are often used for occupational injury surveillance and research but require the use of payer fields to identify work-related injuries.[12–14] There are numerous documented problems with reliance on payer to estimate injury incidence and trends, including lack of capture of work injuries not reported to or covered by WC, barriers to WC claim filing, cost-shifting to other insurance coverage or to the worker, and temporal trends in health care billing practices.[15–17]

In contrast to hospital discharge databases, at least 21 state trauma registries include an indicator of work-relatedness that makes it possible to directly identify work-related trauma independently of payer.[4,17] Trauma registries are well positioned to capture severe work-related traumatic injuries and may avoid some recognized reporting and coverage filters afflicting other data sources.[9] Researchers in several states (eg, Alaska, Illinois, and Washington) are exploring these registries as a resource for occupational injury surveillance and research.[2,17–21] Trauma registries have several other advantages over hospital discharge data, including more staff resources for recording clinical details about the injury and initial treatment. The diagnosis and injury severity information in trauma registries are primarily captured for clinical purposes, in contrast to the billing and reimbursement purposes served by hospital discharge data. Nevertheless, trauma registries are generally not considered population based because of inclusion of only certain types of injuries and/or certain types of health care facilities (eg, designated trauma centers), and their characteristics and inclusion criteria vary widely by state.[4,22] The National Trauma Data Bank (NTDB) itself is a convenience sample of data submitted voluntarily by trauma hospitals.[23] In addition, trauma systems and trauma registries evolve and mature over time because of quality improvement efforts[4,24] and may thus capture an increasing proportion of eligible trauma over time.

In Washington State, mandatory reporting for state-designated trauma facilities began in 1995, and trauma coverage gradually increased as the trauma system added new hospitals. The purposes of the registry as defined in the Washington Administrative Code are "to (1) provide data for injury surveillance, analysis, and prevention programs; (2) monitor and evaluate the outcome of care of major trauma patients, in support of statewide and regional quality assurance and system evaluation activities; (3) assess compliance with state standards for trauma care; (4) provide information for resource planning, system design, and management; and (5) provide a resource for research and education."[25] Nevertheless, Washington State Department of Health staff have generally considered the state's hospital discharge database to be a more comprehensive and appropriate data source than the trauma registry for most surveillance purposes.

The aim of this study was to compare occupational injury rates and trends estimated using the Washington State Trauma Registry (WTR) with those estimated using Washington State's population-based hospital discharge database. Our working hypothesis was that a state trauma registry with mandatory reporting requirements was

reasonably representative of all severe traumatic injuries and could justifiably be used for work-related severe traumatic injury surveillance.

METHODS

Data Sources and Study Population

This study was approved by the Washington State Institutional Review Board. Data for traumatic injury–related inpatient hospital discharges were obtained from the following two databases maintained by the Washington State Department of Health: (1) the Comprehensive Hospital Abstract Reporting System (CHARS) and (2) the WTR. The CHARS contains inpatient hospital discharge information derived from billing records for all Washington State community hospitals. The WTR contains mandatory reporting data for traumatic injuries meeting specific inclusion criteria from all state-designated acute trauma facilities (levels 1 through 5). The WTR is described in more detail in an earlier publication.[20]

This study included traumatic injury hospital discharges occurring from 1998 through 2009, for Washington State residents aged 16 through 64 years. Traumatic injuries were defined using the International Classification of Diseases–Clinical Modification, 9th Revision (ICD-9-CM) diagnostic codes specified by the NTDB.[26] This allowed for a standard definition across data sets and ensured that superficial injuries incidental to admission did not result in inclusion. The definition required an ICD-9-CM diagnostic code in the range 800 to 959.9, excluding the following injuries: 905 to 909.9 (late effects of injury), 910 to 924.9 (superficial injuries, including blisters, contusions, abrasions, and insect bites), and 930 to 939.9 (foreign bodies). Burns (940 to 949.9) were excluded because the injury severity scoring system we used does not reliably classify burns (see the "Injury Severity" section). For the CHARS, inclusion was based on a qualifying injury being the first-listed diagnosis to exclude incidental/superficial injuries. This comports with injury surveillance recommendations promulgated by the Safe States Alliance (formerly STIPDA) and the Centers for Disease Control and Prevention.[27,28] For the WTR, traumatic injuries that did not result in inpatient admission were excluded.

For the CHARS, work-related injuries were identified as those having WC listed as primary expected payer, after the practice recommended by the Council of State and Territorial Epidemiologists (CSTE) for constructing state-based Occupational Health Indicators.[29] Washington has a single-payer WC system for the approximately 70% of workers covered by the Washington State Department of Labor and Industries (L&I) State Fund, as specified by the Industrial Insurance Act.[30] Self-insured employers account for the other 30%. The L&I performs the functions of an insurer for State Fund claims and administers the state WC system for both State Fund and self-insured employers. The L&I payer category captures both State Fund and self-insured WC coverage. Nevertheless, the covered population does not include federal employees or exempt/excluded employment (eg, sole proprietors and domestic workers). The CSTE states that "designation of WC as primary payer is a good proxy for the work-relatedness of hospitalized injuries."[29] A study based on New Jersey hospital discharge records found that, although WC as payer underestimated the number of work-related injuries by about 20%, it was a good to excellent proxy for self-reported work-relatedness ($\kappa = 0.78$; sensitivity $= 83\%$; and specificity $= 98\%$).[31] In a previous work linking WTR reports to WC claims, we found that WC as payer was 89% sensitive and 98% specific in identifying injuries resulting in an accepted WC claim.[17]

In contrast to the nearly complete payer data contained in the CHARS, the WTR has relatively high and inconsistent levels of missing payer data (see the "Results" section for data). For the WTR, reliance on payer, thus, presents a threat to estimating accurate trends in work-related injuries. Nevertheless, unlike

hospital discharge databases, the WTR contains a data field that can be used to directly identify work-related injuries independently of payer. This work-related field has been shown to be highly sensitive (87%) and specific (97%) in identifying work-related injuries.[17] Therefore, for the WTR, work-related injuries were identified using the work-related data field.

In addition to differences in the way we identified work-related injuries in the CHARS and the WTR, the two databases do not represent identical populations. Figure 1 depicts how these two databases overlap and differ with respect to capture of work-related traumatic injuries. In a nationwide survey, conducted in 2004 by Mann et al,[22] the WTR trauma manager estimated that the WTR captured about 85% of statewide trauma victims with injuries satisfying registry inclusion criteria. Nevertheless, the WTR does not capture data for the many occupational injuries that do not involve transport to or treatment at a trauma hospital or that do not otherwise meet inclusion criteria.[32]

The specific WTR inclusion criteria have undergone some refinements over time. For most of the years of this study, reports were mandatory for adult patients who (1) were discharged with ICD-9-CM diagnosis codes of 800 to 904 or 910 to 959 (injuries), 994.1 (drowning), 994.7 (asphyxiation), or 994.8 (electrocution) and (2) met at least one of the following criteria: trauma resuscitation team activation, dead on arrival, death during the ED visit or associated hospital stay, interfacility transfer by Emergency Medical Services (EMS) or ambulance, or inpatient admission of at least 48 hours. (Note that this study included only inpatient WTR cases to enhance comparability, but the full WTR database also includes patients treated only in the ED that were not admitted but that otherwise met reporting criteria, for example, patients transported in by EMS.) During the time frame of this study, there were two changes to the WTR inclusion criteria that may have marginally affected the number and severity of traumatic injury reports. In brief, as of May 6, 2000, drowning, asphyxiation, and electrocution were added as qualifying diagnoses. As of December 17, 2009, being flown in from the scene was added to the reporting criteria. Overall, these changes in the WTR inclusion criteria were a reflection of the maturation of Washington's EMS and trauma system.

Injury Severity

For some analyses, we restricted the samples to severe traumatic injuries to make the CHARS and WTR injury samples more comparable. The Abbreviated Injury Scale (AIS) was used to
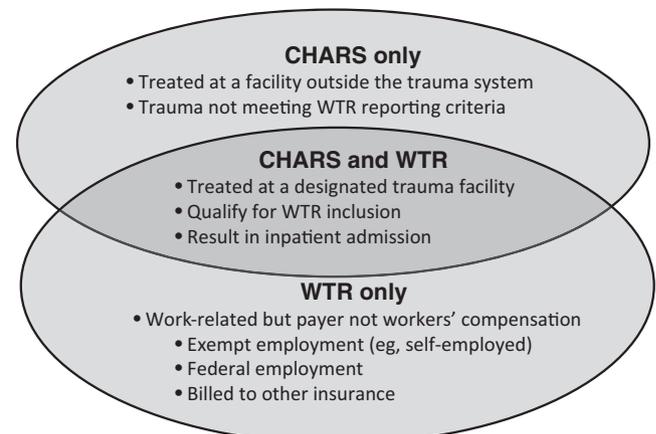
FIGURE 1. Work-related inpatient trauma cases captured by the WTR, the CHARS, or both. CHARS, Comprehensive Hospital Abstract Reporting System; WTR, Washington State Trauma Registry.

classify injury severity for this study.[33] The AIS is an anatomically based consensus-driven scoring system that rates injury severity based on threat to life and does not take comorbidity or complications into account. This type of severity score provides a clean measure of injury severity, independent of patient-specific factors that may influence hospitalization. In particular, the AIS provides more face validity and empirical support as a measure of injury severity than do hospital admission or length of stay, both of which can be considered outcome measures that are also related to coexisting conditions, health status, and trends in insurance coverage and standards of care.[34–37] AIS-based injury severity measures have been validated for prediction of mortality,[38–42] and recent studies have established their association with occupational injury outcomes such as work disability and medical costs.[43–45]

We used a recognized ordinal measure of injury severity, the overall maximum AIS score (MaxAIS).[41,42] MaxAIS ranges from 1 (minor) to 6 (maximal) and is a measure of the most severe injury. AIS scores are present as data fields in the WTR, having been calculated either by the trauma registrar or by the trauma registry software. For the CHARS, these scores were estimated from all 25 available ICD-9-CM diagnosis codes using the ICD Programs for Injury Categorization (-icdpic-), a Stata user-written program.[46] The -icdpic- contains a crosswalk from ICD-9-CM diagnosis codes to AIS severity, developed using the NTDB data.[46] Burns were excluded from this study because AIS does not reliably classify burns because of the importance of inhalation injuries (inhalation injuries are not scored by AIS), and -icdpic- does not score burns. For this study, we defined severe injury as a MaxAIS of 3 (serious) or higher; these injuries are more likely to be captured in both the trauma registry and the CHARS. These severe injuries also carry a high probability of hospital admission; observed trends in severe injuries are less likely to be affected by temporal trends in hospital admission practices and thus more reflective of trends in underlying injury incidence.[35,47]

Data Analysis

Rates of work-related traumatic injuries were based on employed population denominators obtained from the Bureau of Labor Statistics' Current Population Survey, as recommended by the CSTE.[29] Crude and age-adjusted rates for the period from 1998 through 2009 were calculated for work-related injury hospitalizations. Age adjustment was performed using direct standardization on the basis of the US 2000 Standard Population (aged 16+ years),[48] and gamma confidence intervals (CIs) were calculated.[49] Negative binomial regression models that included a continuous variable for discharge year and an offset for denominator at risk were used to model linear trends. Linear trends were estimated for the following two different time periods using the CHARS and WTR data: (1) 1998 through 2009, representing all years available for this study and (2) 2002 through 2009, representing all years after apparent WTR maturation. Negative binomial regression was used in preference to the Poisson models because the Vuong test often indicated overdispersion.[50,51] Models were run with and without severity restriction. All statistical tests were two-tailed, with statistical significance defined as $P \leq 0.05$. Analyses were performed using Stata/MP 13.0 for Windows (StataCorp LP, College Station, TX).

RESULTS

There were 136,046 CHARS records and 76,112 WTR records in the full samples (not restricted to work-related injuries). Figure 2 depicts the ratio of the number of traumatic injury–related hospital discharges captured by the WTR to that captured by the CHARS, for each year of this study. There was a 34% increase in the ratio during the first 4 years from 0.41 in 1998 to 0.55 in 2001; in comparison, the ratio increased less than 9% during the next 8 years from 0.57 in 2002 to 0.62 in 2009.

The CHARS contained 14,091 work-related injuries, and 4461 (32%) of those were severe. The WTR contained 7127 work-related injuries, and 4081 (57%) of those were severe. Payer was missing for 0.01% of CHARS records overall and for less than 0.1% in every year. Payer was missing for 3.4% of WTR records overall but notably for 5.6% in 2002, 13.1% in 2003, and 7.7% in 2004. The work-related field was missing for 2.1% of WTR records overall; 3% or less in every year, except for 5.6% in 1998.

Figure 3 depicts age-adjusted rate estimates and nonlinear trends based on CHARS and WTR data for all eligible work-related traumatic injuries. Figure 4 depicts the same information for the subset of severe injuries. The vertical capped bars depict 95% gamma CIs. On visual inspection, nonlinear trends based on WTR rate estimates closely tracked those based on CHARS (ie, vertical difference between rate estimates was stable over time), beginning approximately in 2002. When restricted to severe injuries (Fig. 4), WTR and
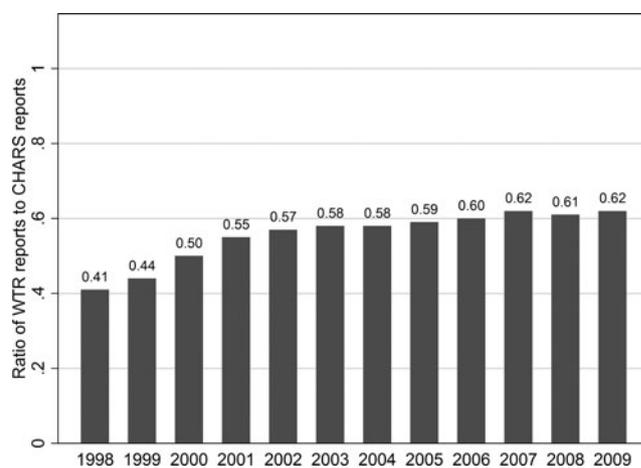
FIGURE 2. Annual ratio of the number of traumatic injury–related hospital discharges captured by the WTR to that captured by the CHARS (not restricted to work-related injuries). CHARS, Comprehensive Hospital Abstract Reporting System; WTR, Washington State Trauma Registry.
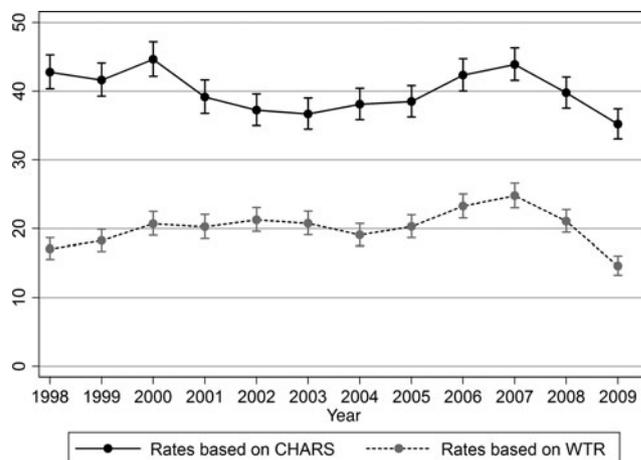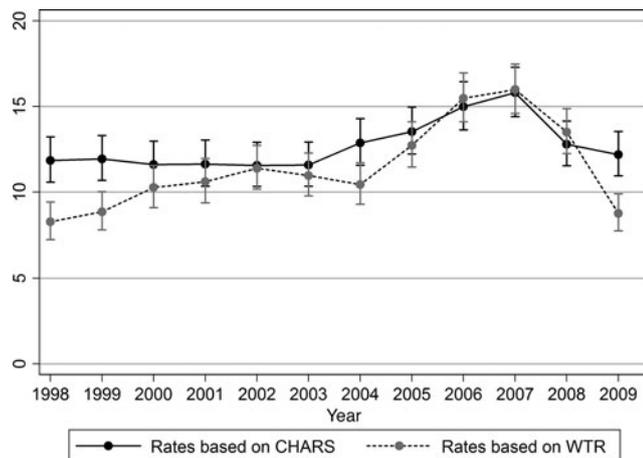
FIGURE 3. All work-related injuries—age-adjusted rates and 95% confidence intervals using the CHARS and the WTR. CHARS, Comprehensive Hospital Abstract Reporting System; WTR, Washington State Trauma Registry.

CHARS rate estimates had overlapping CIs in every year from 2000 through 2008.

Table 1 presents the raw number, crude rate, and age-adjusted rate of work-related injuries for each year of this study, calculated using the CHARS and WTR databases. Table 2 provides the same information for the subset of severe injuries. Table 3 presents estimates of linear trends in age-adjusted injury rates based on CHARS and WTR data for all injuries and for severe injuries. Trend estimates differed somewhat by data source; however, CIs were substantially similar, and general conclusions regarding whether work-related injury rates were significantly increasing over time (or were statistically flat) were the same using either data source (Table 3).

DISCUSSION

This study found substantial similarity between occupational injury trends estimated using either WTR or CHARS data. It is important to recognize that overlapping but somewhat distinct populations and types of injuries are captured by each data source. Hospital

FIGURE 4. Severe work-related injuries—age-adjusted rates and 95% confidence intervals using the CHARS and the WTR. CHARS, Comprehensive Hospital Abstract Reporting System; WTR, Washington State Trauma Registry.

discharge databases, including the CHARS, typically include all or nearly all community hospitals in a particular state, whereas trauma registries typically include a subset of reporting trauma facilities, and not every traumatic injury treated at those facilities would qualify for inclusion in the registry. When we restricted the sample to severe injuries to enhance comparability, we observed more similarity across the two data sources in injury rates. (The difference in severe injury rate estimates for 2009 across the two data sources was most likely due to random variation; we were unable to identify a probably cause.) Different methods were used to identify work-related injuries in each data set, and it is perhaps most remarkable that so little difference was observed.

It is also important to recognize that the incidence of occupational injury hospitalizations will be underestimated using either data source. In the case of CHARS, work-related injuries will not be counted if WC is not identified as the primary payer. In the case of the WTR, work-related injuries will not be counted if they are not identified by hospital personnel as being work related, do not meet WTR reporting criteria, or are treated at nonreporting hospitals.

Especially in the early years, the WTR staff were focused on training trauma registrars and improving the completeness and quality of reporting. There were also changes to inclusion criteria, and changes in the number of reporting trauma facilities as hospitals achieved trauma designation. As reflected by the increasing ratio of all injuries captured by the WTR compared with the CHARS (Fig. 2), it seems that the WTR was still maturing through approximately 2001, about 7 years after inception. This is consistent with other research, showing that trauma systems take about 10 years to fully mature.[24] Nevertheless, linear trend estimates did not substantially differ across the two data sets, whether the years 1998 through 2001 were included or excluded from the trend models. As shown in Fig. 3 and 4, linear trend estimates are a rough approximation and are sensitive to the specific start and end years selected. Though linear trend estimates are commonly used as a summary measure, occupational injury trends are not always linear in nature and tend to track economic cycles even after adjusting for the underlying employed population. Despite the results of the linear trend regression models, Fig. 3 and 4 suggest that injury rates and trends estimated using the WTR are likely to be more accurate reflections of underlying injury incidence if restricted to approximately 2002 forward.

TABLE 1. Rates of All Work-Related Traumatic Injuries, Using the CHARS and the WTR

	CHARS			WTR		
Year	Injuries, N	Crude Rate	Age-Adjusted Rate (95% CI)	Injuries, N	Crude Rate	Age-Adjusted Rate (95% CI)
1998	1,208	42.6	42.8 (40.4, 45.3)	485	17.1	17.1 (15.6, 18.7)
1999	1,198	41.7	41.6 (39.3, 44.1)	528	18.4	18.2 (16.7, 19.9)
2000	1,254	44.4	44.6 (42.2, 47.2)	578	20.5	20.7 (19.0, 22.5)
2001	1,044	38.1	39.1 (36.8, 41.7)	545	19.9	20.2 (18.6, 22.1)
2002	1,050	37.5	37.2 (35.0, 39.6)	603	21.5	21.3 (19.6, 23.1)
2003	1,046	37.0	36.7 (34.5, 39.0)	590	20.9	20.8 (19.1, 22.5)
2004	1,116	37.6	38.1 (35.8, 40.4)	560	18.9	19.1 (17.5, 20.8)
2005	1,161	38.2	38.5 (36.3, 40.8)	613	20.2	20.3 (18.7, 22.0)
2006	1,308	42.5	42.3 (40.0, 44.7)	718	23.3	23.2 (21.6, 25.0)
2007	1,378	43.6	43.9 (41.6, 46.3)	778	24.6	24.8 (23.0, 26.6)
2008	1,251	39.5	39.8 (37.6, 42.1)	671	21.2	21.1 (19.5, 22.8)
2009	1,077	34.7	35.2 (33.1, 37.4)	458	14.8	14.6 (13.3, 16.1)

CHARS, Comprehensive Hospital Abstract Reporting System; CI, confidence interval; WTR, Washington State Trauma Registry.

© 2014 American College of Occupational and Environmental Medicine

TABLE 2. Rates of Severe Work-Related Traumatic Injuries, Using the CHARS and the WTR

	CHARS			WTR		
Year	Injuries, *N*	Crude Rate	Age-Adjusted Rate (95% CI)	Injuries, *N*	Crude Rate	Age-Adjusted Rate (95% CI)
1998	331	11.7	11.8 (10.6, 13.2)	233	8.2	8.3 (7.2, 9.4)
1999	341	11.9	11.9 (10.7, 13.3)	255	8.9	8.8 (7.8, 10.0)
2000	322	11.4	11.6 (10.4, 13.0)	286	10.1	10.3 (9.1, 11.6)
2001	306	11.2	11.6 (10.3, 13.0)	279	10.2	10.6 (9.4, 12.0)
2002	326	11.6	11.6 (10.3, 12.9)	325	11.6	11.4 (10.2, 12.7)
2003	327	11.6	11.6 (10.3, 12.9)	311	11.0	11.0 (9.8, 12.3)
2004	371	12.5	12.9 (11.6, 14.3)	309	10.4	10.4 (9.3, 11.7)
2005	405	13.3	13.5 (12.2, 15.0)	384	12.6	12.7 (11.5, 14.1)
2006	463	15.1	15.0 (13.6, 16.4)	479	15.6	15.5 (14.1, 17.0)
2007	494	15.6	15.8 (14.4, 17.3)	505	16.0	16.0 (14.6, 17.5)
2008	400	12.6	12.8 (11.5, 14.1)	436	13.8	13.5 (12.2, 14.9)
2009	375	12.1	12.2 (11.0, 13.5)	279	9.0	8.8 (7.7, 9.9)

CHARS, Comprehensive Hospital Abstract Reporting System; CI, confidence interval; WTR, Washington State Trauma Registry.

TABLE 3. Linear Trends in Age-Adjusted Rates by Data Source and Sample

	1998–2009			2002–2009		
Sample and Data Source	Annual % Change	*P*	95% CI	Annual % Change	*P*	95% CI
All injuries						
CHARS	0.7↓	NS	1.8↓, 0.4↑	0.7↑	NS	1.4↓, 2.8↑
WTR	0.7↑	NS	1.5↓, 2.9↑	1.5↓	NS	5.7↓, 2.8↑
Severe injuries						
CHARS	1.8↑	0.01	0.4↑, 3.3↑	2.0↑	NS	1.1↓, 5.2↑
WTR	3.9↑	0.008	1.0↑, 6.9↑	1.4↑	NS	4.4↓, 7.7↑

CHARS, Comprehensive Hospital Abstract Reporting System; CI, confidence interval; NS, not significant; WTR, Washington State Trauma Registry.

Restricting the sample to severe injuries provided a different and less optimistic picture of occupational injury trends than did using all injuries. This is consistent with our previous research, suggesting that occupational injuries are not trending downward to the degree suggested by studies based on employer surveys or WC claims data.[20,52] Observed trends in severe injuries are less likely to be affected by temporal trends in hospital admission practices than are minor injuries, and thus more reflective of general trends in underlying injury incidence.[35,52]

Hospital discharge databases and trauma registries each offer a distinct set of strengths and limitations. Hospital discharge databases are typically population based, and many are publically available, but they are constructed for billing and reimbursement purposes. Hospital discharge records are generally available only for nonfederal, acute care hospitals. The WTR and many other trauma registries are better resourced, have more clinical input and validation, and contain more accurate and complete injury information, but they are not typically population based.

Hospital discharge records do not contain specific information about whether the hospitalization was work related (other than payer), limiting utility for occupational injury research. The use of WC as payer is known to undercount work-related injuries.[17,31] In addition, the expected payer on hospital discharge records may not be accurate and may not reflect the actual payer. The WTR also has limitations for occupational injury surveillance related to narrowly defined inclusion criteria and incomplete trauma coverage, as well as

changes over time in both. Nevertheless, unlike CHARS, the WTR does contain specific information about whether an injury was work related.

Trauma registries undergo ongoing oversight and scrutiny and require significant hospital commitment.[53] Greater resources are devoted to coding trauma registry records compared with hospital discharge records, including more input from clinical staff.[53] In addition, trauma charts are often abstracted concurrently (during the inpatient stay), providing more opportunity to update and correct data before discharge.[53] As a case in point, the WTR has conducted periodic validation studies assessing factors such as coding accuracy. The software used by the hospitals to collect and submit data to the WTR contains logic checks and error checks that facilitate data quality and completeness. The WTR has worked to improve reporting over time, which is reflected in the small amounts of missing data for most data fields. Nevertheless, trauma registries are also more directly affected by human factors, for example, changes in trauma registrars and documentation practices within and between hospitals over time.

Trauma registries are focused on complete coding of injury-related diagnoses and severity measures, which are used to guide clinical management and evaluation. The AIS severity scores contained in the WTR were generally assigned by the trauma registrars, based on injury documentation by the trauma surgeons and other clinicians. In contrast, the ICD-9-CM codes in hospital discharge data were generated primarily for billing and reimbursement

purposes by medical records or coding personnel at each facility (usually not clinical staff); to maximize potential reimbursement, billing optimization software is also typically used. The need to use software to estimate AIS scores from ICD-9-CM diagnosis codes introduces an additional approximation and potential source of error when using hospital discharge data. In a previous study using a set of linked WTR and WC records, we found moderate agreement between the Injury Severity Scores contained in the WTR and those estimated from WC billing data using -icdpic- ($\kappa = 0.43$).[43] Yet, despite ample sources of error, injury severity measures estimated from administrative databases have been found useful for predicting work disability and cost outcomes.[43,44]

Strengths and Limitations

Washington State has a well-developed trauma registry (available since 1995), statewide hospital discharge data (available since 1987), and a single-payer WC system. These factors jointly facilitate the ability to conduct population-based occupational injury research.

As previously discussed, relying on WC as payer introduces potential misclassification and undercounting of work-related injuries because of issues such as barriers to WC claim filing, occupational injuries that are not covered by WC, and cost-shifting to other insurance. An additional complication unique to Washington State is that L&I as payer can indicate either a WC claim *or* a (nonoccupational) crime victim claim, because L&I also manages the Washington State Crime Victims Compensation Program. Furthermore, federal WC coverage is captured in the other insurance category rather than the L&I category. Nevertheless, in a previous work linking WTR reports to WC claims, we found that WC as payer (from the WTR data) was 89% sensitive and 98% specific in identifying injuries resulting in an accepted WC claim.[17] Unfortunately, the level of missing payer data in certain years made it infeasible to compare injury rates and trends on the basis of the same indicator of work-relatedness for both data sources.

CONCLUSIONS

This study found substantial similarity between occupational injury trends estimated using either trauma registry or hospital discharge data, despite the somewhat different populations and injury types represented. Rate estimates differed by data source and were most similar when a severity threshold was applied. In the case of Washington State, trauma registry maturity for the purpose of estimating injury rates and trends occurred about 7 years after inception. We conclude that a *mature* state trauma registry with mandatory reporting requirements can be used as an alternative to population-based hospital discharge data for surveillance of severe work-related traumatic injuries, while acknowledging that the incidence of occupational injury hospitalizations will be underestimated using either data source.

ACKNOWLEDGMENTS

REFERENCES

1. National Institute for Occupational Safety and Health. Workplace safety and health topics: traumatic occupational injuries. Available at: http://www.cdc.gov/niosh/injury/. Accessed May 17, 2014.
2. Forst LS, Hryhorczuk D, Jaros M. A state trauma registry as a tool for occupational injury surveillance. *J Occup Environ Med.* 1999;41:514–520.
3. Friedman LS, Forst L. The impact of OSHA recordkeeping regulation changes on occupational injury and illness trends in the US: a time-series analysis. *Occup Environ Med.* 2007;64:454–460.
4. Guice KS, Cassidy LD, Mann NC. State trauma registries: survey and update–2004. *J Trauma.* 2007;62:424–435.
5. Murphy PL, Sorock GS, Courtney TK, Webster BS, Leamon TB. Injury and illness in the American workplace: a comparison of data sources. *Am J Ind Med.* 1996;30:130–141.
6. Smith GS, Veazie MA, Benjamin KL. The use of sentinel injury deaths to evaluate the quality of multiple source reporting for occupational injuries. *Ann Epidemiol.* 2005;15:219–227.
7. Rosenman KD, Kalush A, Reilly MJ, Gardiner JC, Reeves M, Luo Z. How much work-related injury and illness is missed by the current national surveillance system? *J Occup Environ Med.* 2006;48:357–365.
8. Alamgir H, Koehoorn M, Ostry A, Tompa E, Demers P. An evaluation of hospital discharge records as a tool for serious work related injury surveillance. *Occup Environ Med.* 2006;63:290–296.
9. Azaroff LS, Levenstein C, Wegman DH. Occupational injury and illness surveillance: conceptual filters explain underreporting. *Am J Public Health.* 2002;92:1421–1429.
10. Morse T, Dillon C, Warren N, Hall C, Hovey D. Capture-recapture estimation of unreported work-related musculoskeletal disorders in Connecticut. *Am J Ind Med.* 2001;39:636–642.
11. Fan ZJ, Bonauto DK, Foley MP, Silverstein BA. Underreporting of work-related injury or illness to workers' compensation: individual and industry factors. *J Occup Environ Med.* 2006;48:914–922.
12. Council of State and Territorial Epidemiologists. Occupational health indicators. Available at: http://www.cste.org/?OHIndicators. Accessed February 11, 2014.
13. Dembe AE, Mastroberti MA, Fox SE, Bigelow C, Banks SM. Inpatient hospital care for work-related injuries and illnesses. *Am J Ind Med.* 2003;44:331–342.
14. McGreevy K, Lefkowitz D, Valiante D, Lipsitz S. Utilizing hospital discharge data (HD) to compare fatal and non-fatal work-related injuries among Hispanic workers in New Jersey. *Am J Ind Med.* 2010;53:146–152.
15. Groenewold MR, Baron SL. The proportion of work-related emergency department visits not expected to be paid by workers' compensation: implications for occupational health surveillance, research, policy, and health equity. *Health Serv Res.* 2013;48:1939–1959.
16. Sears JM, Bowman SM, Adams D, Silverstein BA. Who pays for work-related traumatic injuries? Payer distribution in Washington State by ethnicity, injury severity, and year (1998–2008). *Am J Ind Med.* 2013;56:742–754.
17. Sears JM, Bowman SM, Silverstein BA, Adams D. Identification of work-related injuries in a state trauma registry. *J Occup Environ Med.* 2012;54:356–362.
18. Friedman LS, Forst L. Ethnic disparities in traumatic occupational injury. *J Occup Environ Med.* 2008;50:350–358.
19. Husberg BJ, Conway GA, Moore MA, Johnson MS. Surveillance for nonfatal work-related injuries in Alaska, 1991–1995. *Am J Ind Med.* 1998;34:493–498.
20. Sears JM, Bowman SM, Adams D, Silverstein BA. Occupational injury surveillance using the Washington State Trauma Registry. *J Occup Environ Med.* 2011;53:1243–1250.
21. Friedman LS, Forst L. Occupational injury surveillance of traumatic injuries in Illinois, using the Illinois trauma registry: 1995–2003. *J Occup Environ Med.* 2007;49:401–410.
22. Mann NC, Guice K, Cassidy L, Wright D, Koury J. Are statewide trauma registries comparable? Reaching for a national trauma dataset. *Acad Emerg Med.* 2006;13:946–953.
23. American College of Surgeons, Trauma Programs. National Trauma Data Bank. Available at: http://www.facs.org/trauma/ntdb/index.html. Accessed April 27, 2011.
24. Nathens AB, Jurkovich GJ, Cummings P, Rivara FP, Maier RV. The effect of organized systems of trauma care on motor vehicle crash mortality. *JAMA.* 2000;283:1990–1994.
25. State of Washington. Washington Administrative Code 246–976–420. Available at: http://apps.leg.wa.gov/wac/default.aspx?cite=246–976–420. Accessed April 27, 2011.
26. National Trauma Data Bank. National trauma data standard: data dictionary: 2012 Admissions. Available at: http://www.ntdsdictionary.org/dataElements/documents/NTDS2012_xsd.PDF. Accessed August 27, 2012.
27. STIPDA: Injury Surveillance Workgroup 5. *Consensus Recommendations for Injury Surveillance in State Health Departments.* Atlanta, GA: State and Territorial Injury Prevention Directors Association; 2007.
28. Thomas KE, Johnson RL. *State Injury Indicators Report: Instructions for Preparing 2010 Data.* Atlanta, GA: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control; 2012.

29. Council of State and Territorial Epidemiologists (CSTE). Occupational health indicators: a guide for tracking occupational health conditions and their determinants. March 2013; Available at: www.cste.org/resource/resmgr/OccupationalHealth/OHIGuidanceMarch2013.pdf. Accessed February 11, 2014.

30. State of Washington. RCW Title 51: Chapter 51.12. Employments and occupations covered. Available at: http://apps.leg.wa.gov/rcw/default.aspx?Cite = 51.12. Accessed August 19, 2012.

31. Sorock GS, Smith E, Hall N. An evaluation of New Jersey's hospital discharge database for surveillance of severe occupational injuries. *Am J Ind Med.* 1993;23:427–437.

32. Office of Community Health Systems, Health Systems Quality Assurance, Washington State Department of Health. Trauma in Washington State: a chart report of the first 15 years, 1995–2009. Available at: http://www.doh.wa.gov/Portals/1/Documents/Pubs/689001.pdf. Accessed August 19, 2012.

33. Association for the Advancement of Automotive Medicine. *The Abbreviated Injury Scale, 1990 Revision*. Des Plaines, IL: Association for the Advancement of Automotive Medicine.

34. Cryer C, Gulliver P, Langley JD, Davie G. Is length of stay in hospital a stable proxy for injury severity? *Inj Prev.* 2010;16:254–260.

35. Cryer C, Langley J. Developing indicators of injury incidence that can be used to monitor global, regional and local trends. Available at: http://www.otago.ac.nz/ipru/ReportsPDFs/OR070.pdf. Accessed June 17, 2014.

36. National Center for Health Statistics (NCHS) Expert Group on Injury Severity Measurement. Discussion document on injury severity measurement in administrative datasets. Available at: http://www.cdc.gov/nchs/data/injury/DicussionDocu.pdf. Accessed February 11, 2014.

37. Stephenson S, Langley J, Cryer C. Effects of service delivery versus changes in incidence on trends in injury: a demonstration using hospitalised traumatic brain injury. *Accid Anal Prev.* 2005;37:825–832.

38. Baker SP, O'Neill B, Haddon W Jr, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma.* 1974;14:187–196.

39. Harwood PJ, Giannoudis PV, Probst C, Van Griensven M, Krettek C, Pape HC. Which AIS based scoring system is the best predictor of outcome in orthopaedic blunt trauma patients? *J Trauma.* 2006;60:334–340.

40. Osler T, Baker SP, Long W. A modification of the injury severity score that both improves accuracy and simplifies scoring. *J Trauma.* 1997;43:922–925; discussion 925–926.

41. Meredith JW, Evans G, Kilgo PD, MacKenzie E, Osler T, McGwin G, et al. A comparison of the abilities of nine scoring algorithms in predicting mortality. *J Trauma.* 2002;53:621–628; discussion 628–629.

42. Kilgo PD, Osler TM, Meredith W. The worst injury predicts mortality outcome the best: rethinking the role of multiple injuries in trauma outcome scoring. *J Trauma.* 2003;55:599–606; discussion 606–597.

43. Sears JM, Blanar L, Bowman SM, Adams D, Silverstein BA. Predicting work-related disability and medical cost outcomes: estimating injury severity scores from workers' compensation data. *J Occup Rehabil.* 2013;23:19–31.

44. Ruestow PS, Friedman LS. Characterizing the relationship between in-hospital measures and workers' compensation outcomes among severely injured construction workers using a data linkage strategy. *Am J Ind Med.* 2013;56:1149–1156.

45. Sears JM, Blanar L, Bowman SM. Predicting work-related disability and medical cost outcomes: a comparison of injury severity scores and scoring methods. *Injury.* 2013;45:16–22.

46. Clark DE, Osler TM, Hahn DR. ICDPIC: Stata module to provide methods for translating International Classification of Diseases (Ninth Revision) diagnosis codes into standard injury categories and/or scores. Available at: http://ideas.repec.org/c/boc/bocode/s457028.html. Accessed March 2, 2012.

47. Sears JM, Wickizer TM, Schulman BA. Improving vocational rehabilitation services for injured workers in Washington State. *Eval Program Plann.* 2014;44:26–35.

48. Klein RJ, Schoenborn CA. *Age Adjustment Using the 2000 Projected U.S. Population. Healthy People Statistical Notes, No. 20*. Hyattsville, MD: National Center for Health Statistics; 2001.

49. Fay MP, Feuer EJ. Confidence intervals for directly standardized rates: a method based on the gamma distribution. *Stat Med.* 1997;16:791–801.

50. Liu W, Cela J. Count data models in SAS, paper 371–2008. *SAS Global Forum 2008, Statistics and Data Analysis*. San Antonio, TX; 2008.

51. Vuong QH. Likelihood ratio tests for model selection and non-nested hypotheses. *Econometrica.* 1989;57:307–333.

52. Sears JM, Bowman SM, Hogg-Johnson S. Using injury severity to improve occupational injury trend estimates. *Am J Ind Med.* 2014 May 8. [Epub ahead of print].

53. Bowman SM, Aitken ME. Assessing external cause of injury accuracy for transport injury hospitalizations. *Perspect Health Inf Manag.* 2011;8:1c.