Identification of Work-Related Injuries in a State Trauma Registry

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Objective: Many state trauma registries contain work-related information but are underutilized for occupational injury research/surveillance. We assessed three methods of identifying work-related injuries in the Washington State Trauma Registry (WTR). **Methods:** State-designated trauma facilities report traumatic injuries meeting specific inclusion criteria to the WTR. The WTR reports from 1998 to 2008 were linked to workers' compensation claims to generate sensitivity estimates. **Results:** The sensitivity of the WTR work-related indicator was 87%, varying significantly by injury mechanism/location. Sensitivity was 89% for payer and 60% for an indicator based on *International Classification of Diseases–9th Revision–Clinical Modification* external cause codes. **Conclusions:** The WTR work-related indicator is highly sensitive and may identify injuries that occur in the course of exempt/excluded employment, are not reported to workers' compensation, and/or are work-related using definitions that go beyond WC coverage. Judicious use of external cause codes may identify additional work-related injuries.

Trauma registries are well positioned to capture severe work-related traumatic injuries, including some that are high-priority areas for occupational injury surveillance and research such as work-related motor vehicle crashes, falls, traumatic brain injuries, and workplace violence. A nationwide survey conducted in 2004 found that 32 states maintained a voluntary or mandatory centralized trauma registry, and the researchers estimated that approximately 66% of registry-eligible trauma occurring in the United States was being captured in a state, regional, or hospital-specific trauma registry.[1] At least 21 state trauma registries include a data element that indicates whether the injury was work related, making it theoretically feasible to identify work-related trauma.[2] Researchers in several states (eg, Alaska, Illinois, Washington) are using trauma registry data for occupational injury surveillance and research,[3–7] but the validity of the information about work relatedness contained in these registries has not been established.

In this study, we investigate approaches for identifying work-related injuries in the Washington State Trauma Registry (WTR). In addition to assessing the WTR work-related indicator, we assess two other potential methods of identifying work-related injuries: payer and external cause of injury. Payer information that specifically points to workers' compensation (WC) as an actual or potential payer has been used as a method of identifying work-related injuries.[4,8] *International Classification of Diseases–9th Revision–Clinical Modification* (*ICD-9-CM*) external cause of injury codes (E-codes) were proposed by Alamgir et al[8] as an adjunct to payer information for identifying work-related injuries in hospital discharge records. In that study, kappa statistics were used to assess the agreement between payer and a work-related indicator based on E-codes, but WC records were not available for validation of either E-codes or payer. In this study, we were able to extend previous work by linking WTR reports and WC claims for validation purposes.

The aim of this study was to assess three methods of identifying work-related injuries in the WTR using linkage to a compensable WC claim as a partial gold standard (for sensitivity but not specificity estimates): (1) the WTR's work-related indicator, (2) whether WC was noted as a payer, and (3) the E-code–based indicator developed by Alamgir et al.[8]

METHODS

Study Population and Data Sources

This study involved obtaining and linking data from two databases maintained by two separate state government agencies: (1) the WTR, maintained by the Washington State Department of Health, and (2) WC claims data, maintained by the Washington State Department of Labor and Industries (L&I). All WTR traumatic injury reports and all WC claims were requested for the years 1998 through 2008, excluding injuries among those younger than 16 years and those occurring outside Washington State. In addition, the study excluded (1) WC claims for L&I employees due to special confidentiality-related restrictions, and (2) medical aid–only claims. Medical aid–only claims are those that cover medical treatment but do not involve time-loss payments because the injury did not cause any missed work days after the initial 3-day postinjury waiting period. In a preliminary assessment, we found that very few medical aid–only claims linked to the relatively severe traumatic injuries reported to the WTR. We use the phrase "compensable WC claim" throughout this article to indicate all accepted claims that were not medical aid–only or otherwise excluded, including claims for fatalities, total permanent disability, and those involving compensation for work missed due to the injury. This study was approved by the Washington State institutional review board.

The WTR contains reporting data for traumatic injuries meeting specific inclusion criteria from all state-designated acute trauma facilities (levels I through V). In a nationwide survey conducted in 2004 by Mann et al,[1] the WTR trauma manager estimated that the WTR captured approximately 85% of trauma victims with injuries satisfying registry inclusion criteria. The Department of Health designates trauma services as part of the comprehensive statewide emergency medical services and trauma care system. Mandatory reporting began in 1995, and trauma coverage gradually increased as the trauma system added new hospitals. 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

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who were discharged with *ICD-9-DM* diagnosis codes of 800 to 904 or 910 to 959 (injuries), 994.1 (drowning), 994.7 (asphyxiation), or 994.8 (electrocution) *and* met at least one of the following criteria: trauma resuscitation team activation, dead on arrival, death during the emergency department (ED) visit or associated hospital stay, interfacility transfer by Emergency Medical Services or ambulance, or inpatient admission of at least 48 hours. (The criteria for patients younger than 15 years are somewhat different but are not relevant to this study.) The WTR is described in more detail in an earlier related publication.[9]

Washington has a single-payer WC system for the approximately 70% of workers covered by the State Fund. Self-insured employers account for the other 30%; private WC insurers are not part of the system. 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. Providers are generally required to file an accident report within 5 days of identifying a work-related injury or illness, which usually initiates the claim (claims can also be filed by the worker or the employer). The L&I maintains a comprehensive administrative claims database for the approximately 200,000 WC claims that are filed each year, allowing for population-based research. Nevertheless, the covered population does not include federal employees or exempt/excluded employment (eg, sole proprietors, domestic workers).

Data Linkage and Consolidation of Injury Reports

The WTR has conducted periodic validity studies assessing factors such as coding accuracy. The software used by the hospitals to collect and submit data to the registry 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 amounts of and trends in missing data. The work-related field, of key importance to this project, was missing for 2.5% of records overall, decreasing over time from 5% to less than 1%. Payer was missing for 4%, decreasing over time from 8% to less than 1%. Primary E-code was missing for less than 1% of records. Injury place was missing for only 3%; however, another 8% had an "unspecified" place of injury.

Records were linked and consolidated at the injury event level using The Link King, a public-domain software program developed in Washington State for deterministic and probabilistic linkage of administrative records.[10] The Link King pulls together a variety of complex deterministic algorithms to increase the likelihood of finding matches across databases, including phonetic name matching, approximate string matching, and nickname matching.

A two-stage procedure was used so that the necessary identifiers were in hand only for the initial linking procedures (full name, date of birth, sex, last four digits of the social security number, and county and zip code where the injury occurred), and the bulk of the data was obtained only after linkage was complete and identifiers were stripped. In addition to confidentiality protection, this procedure isolated the work-related indicator, payer, and E-codes from the linkage procedure, so that sensitivity estimates could not be consciously or unconsciously affected by the researcher during linkage procedures (eg, by going to more lengths to link injuries identified as work-related in the WTR).

There were three main steps involved in linking the two databases: (1) unique individuals were identified within each database and across the two databases, (2) multiple WTR injury reports for the same injury event were grouped together within unique individuals, and (3) specific injury events were linked with associated WC claims within unique individuals. In step 2, WTR reports were grouped together if they were for the same individual *and* two reports had (a) the same injury date or (b) the same ED arrival date, (c) the injury date of one matched or was 1 day prior to the ED arrival date of another, or (d) were from different hospitals and the discharge date of one matched or was 1 day prior to the ED arrival date of another. Although some of these grouped reports could have originated from separate injuries occurring very close in time, injury descriptors were almost always the same or very similar and usually there was an ED disposition indicating interfacility transfer. A total of 16% of injury events had multiple records (up to 4), most commonly because several hospitals reported the same injury because of transfers within the continuum of care.

Measures

Three methods of identifying work-related injuries using WTR data were assessed: (1) the existing WTR work-related indicator (W), (2) whether L&I was noted as a payer (L), and (3) the E-code–based indicator (E) developed by Alamgir et al.[8] The definition and construction of these three indicators are described in detail later. For other data elements, where data varied by report within an injury event, we assumed that the most comprehensive trauma care hospital (ie, highest trauma designation level) provided the most reliable report, per the advice of WTR staff. Missing data were populated using other reports when feasible. For detailed information about each WTR data element, the reader is referred to the WTR data dictionary, available online.[11]

The WTR work-related indicator is minimally defined. The registry software (now used by all participating hospitals) asks "Work Related? Yes/No." The WTR data dictionary that guides the hospital-based trauma registrars in reporting registry data states only "Work related injury as documented in the patient's medical record." According to Mary Rotert, RN (personal communication, March 2011), there are several ways this information may be gathered: (1) the patient (if conscious) is typically asked about work relatedness during registration (to initiate a WC claim when appropriate), (2) work relatedness may be recorded on the hospital face sheet of admitted patients, (3) there may be information about work relatedness contained in the clinician or nursing notes or in the history section of the ED admitting form, and (4) the EMS records may indicate that the injury was work related. There is no specified standard that must be met before recording the injury as being work related either in the medical record or for WTR reporting. The W indicator was set to 1 if any report for a particular injury indicated that the injury was work related, and 0 otherwise.

The WTR contains two payer fields (primary and secondary) for each report. The presence of L&I in either payer field would indicate that L&I was identified as a potential payer, but not necessarily that a WC claim was actually filed or accepted. There is an additional and perhaps unique complication in that L&I also manages the Washington State Crime Victims Compensation Program. The trauma registrars are directed to indicate L&I as payer for both WC claims (State Fund and self-insured) and crime victim claims. Thus L&I in either payer field does not necessarily signify that an injury was work related. The L indicator was set to 1 if any report for a particular injury had L&I listed as either the primary or secondary payer, and 0 otherwise.

The purpose of *ICD-9-CM* E-codes is to capture the circumstances and external cause of an injury. Alamgir et al[8] presented a list of E-codes that could be used to identify a work-related injury based on the type of injury (eg, powered vehicles used solely within industrial and commercial buildings/premises), the person to whom the injury occurred (eg, railway employee, crew), and/or the place the injury occurred (eg, nonresidential farm premises, mine, industrial site). The WTR data contain two E-code fields as well as a place of injury field that is based on E-codes and other available information but follows the same coding structure as that for the E-code E849.X. The E indicator was set to 1 if either of the two E-code fields (in conjunction with place of injury when appropriate) contained in any report for a particular injury indicated work relatedness according to Alamgir et al,[8] and 0 otherwise. (Note that the range of E-codes

for water transport presented in Table 1 of the Alamgir et al study[8] contained typographical errors and should be E830 to E838.)

Indicators were also created for all possible combinations of the earlier three indicators (WL, WE, LE, WLE). Each combined indicator was set to 1 if any component indicator was set to 1, and 0 otherwise.

Data Analysis

We calculated sensitivity estimates for each of the seven resulting indicators (W, L, E, WL, WE, LE, WLE). We also calculated additional sensitivity estimates for the work-related indicator (W) stratified by place of injury and mechanism of injury (both fields were contained in the WTR data) and by external cause of injury based on *ICD-9-CM* E-codes (refer to citation for categorization scheme).[4] Sensitivity in this context refers to the number of true positives (injuries indicated as being work-related that also linked to a compensable WC claim) divided by all linked injuries (Table 1). False-negative rate refers to the number of injuries that were not indicated as being work related but did link to a compensable WC claim divided by all linked injuries. False-negative rates and confidence intervals (CIs) are simply the difference between 100 and the corresponding sensitivity estimates and CIs, and so are not presented separately in the tables. The percent of missing data decreased over time, but sensitivity estimates seemed fairly stable over time. Although sensitivity varied by hospital, there was no apparent correlation between sensitivity and facility characteristics (ie, trauma designation level, volume of trauma reports) that might indicate that more experience/resources tended to improve the validity of the W indicator.

Linkage to a compensable WC claim was used as the gold standard for sensitivity calculations. It is reasonable to assume that a WTR injury that was linked to a compensable WC claim was actually work related. The converse is not necessarily true, however. In addition to data entry errors, there are a number of valid reasons that a work-related injury captured by the WTR might not link to a compensable WC claim, including exempt/excluded employment, injured workers who did not file WC claims, and study exclusions (L&I employees and claims with special confidentiality protections and medical aid-only claims). As such, we did not have a suitable gold standard for specificity calculations. Instead, we approached the issue of false positives conceptually and by exploring patterns in the data. Specifically, we categorized injuries by age, place of injury, and external cause and examined patterns within the three subsets of injuries that were identified as work related by only one of the three indicators (and not the other two) and that also did not link to a WC claim. This was an exploratory process intended primarily to further describe the types of injuries identified as work related and to shed light on avenues for further validation of these indicators.

TABLE 1. Relationship Between Sensitivity and Specificity

	WTR Injury Linked to a Compensable WC Claim	WTR Injury Did Not Link to a Compensable WC Claim
WTR indicates work relatedness	True positive (TP)	False positive (FP)
WTR does not indicate work relatedness	False negative (FN)	True negative (TN)
	Sensitivity = TP/(TP+FN)	Specificity = TN/(FP+TN)

WC, workers' compensation; WTR, Washington State Trauma Registry.

Analyses were performed using Stata/SE 11.2 for Windows (StataCorp LP, College Station, TX). Confidence intervals were calculated using the exact binomial method. The Stata user-written program -diagt- was used to calculate sensitivity and related statistics.[12] The Stata user-written program -venndiag- was used to describe overlaps and discordancies between the three indicators.[13]

RESULTS

The WTR contained 125,625 unduplicated injury reports for the 11 years covered by this study (1998 through 2008). Overall, 5.3% of WTR injuries were linked to a compensable WC claim ($n = 6673$). Of the 9185 WTR injuries that were indicated as being work related, 63.2% were linked to a compensable WC claim. Of the 8143 WTR injuries that had L&I noted as a payer, 72.6% were linked to a compensable WC claim. Of the 6480 WTR injuries that had work-related E-codes, 61.4% were linked to a compensable WC claim.

The overall sensitivity of the WTR work-related indicator (W) was 87.0% (95% CI, 86.2%–87.8%), and the false-negative rate was 13.0% (95% CI, 12.2%–13.8%); in other words, only 13% of linked claims were misclassified by the W indicator as not being work related. Sensitivity estimates varied significantly by injury location and external cause (Table 2).

In addition to the W indicator, we also assessed the L and E indicators as potential methods to identify work injuries. Table 3 presents sensitivity estimates for each of these three indicators, as well as all possible combinations. The E indicator had very low sensitivity on its own (59.6%; 95% CI, 58.4–60.8). Because the low sensitivity might have been due to the limited types of injuries that can be classified by the E indicator (eg, the E-codes for motor vehicle traffic do not carry any usable work-relatedness information), we checked its sensitivity after limiting the sample to only those injuries that the E indicator could classify, but we did not observe great improvement (68.9%; 95% CI, 67.7–70.1). The L indicator had the highest sensitivity of the three solo indicators (88.6%; 95% CI, 87.8–89.3). By definition, combining all three indicators identified the most work-related injuries and resulted in the highest sensitivity (95.6%; 95% CI, 95.1–96.1).

The Venn diagram in Fig. 1 depicts the overlaps and discordancies between the three indicators (regardless of linkage to a WC claim). Of the 11,575 injuries identified as work related by any of the three methods, 37% were identified as work related by all three indicators. Another 31% were identified by some combination of two of the indicators. Notably, only 3.1% of those identified solely by the E indicator were linked to a compensable WC claim, compared with 12.5% of those identified solely by the W indicator and 31.5% of those identified solely by the L indicator.

Because of the lack of a suitable gold standard for specificity, we then assessed the issue of false positives by examining patterns within the three subsets of injuries that were identified as work related solely by one of the three indicators (and not the other two) and that also did not link to a compensable WC claim (Table 4). One striking pattern was that 58.3% of the unlinked injuries identified as work related solely by the L indicator ("L only") involved a homicide or assault (compared with only 1.4% for all linked injuries). Another striking pattern was that 46.4% of the unlinked injuries identified as work related solely by the E indicator ("E only") occurred on nonresidential areas of a farm (compared with only 4.1% for all linked injuries). Of those farm-based injuries, 52% involved falls and 20% involved animal bites. Only 4% of E-only farm-based injuries were sustained by Latinos, compared with 66% of linked farm-based injuries ($P < 0.0001$). Fully 37% of E-only farm-based injuries were sustained by those 65 years and older, compared with only 4% of linked farm-based injuries ($P < 0.0001$).

TABLE 2. Sensitivity of WTR Work-Related Indicator, Overall and by Injury Mechanism and Location

	Injuries	Work-Related*	For Injuries Compensable Linked to a WC Claim	
Stratum	***n***	**%**	**Sensitivity**	**95% CI**
Overall	125,625	7.3	87.0	86.2–87.8
Place of injury (WTR field)				
Home	44,365	1.2	62.5	56.9–67.9
Farm	1,153	39.5	94.5	91.1–96.9
Mine/quarry	80	33.8	100.0	84.6–100.0
Industrial	5,599	90.0	95.6	94.9–96.2
Sports/recreation	6,665	2.3	59.3	48.5–69.5
Street/highway	38,997	2.3	61.3	57.8–64.7
Public building	4,021	9.0	85.0	80.4–88.9
Residential institution	5,175	2.0	85.7	72.8–94.1
Other specified	7,752	11.7	84.4	81.0–87.4
Unspecified	11,818	6.2	81.9	78.2–85.1
Mechanism of injury (WTR field)				
Animal	1,683	7.5	84.7	73.0–92.8
Assault/fight	4,946	1.4	87.2	72.6–95.7
Bicycle	2,237	0.9	86.7	59.5–98.3
Blunt instrument	2,945	29.5	96.3	94.5–97.7
Burn	3,453	16.3	94.6	91.9–96.6
Drowning/strangulation/suffocation	469	2.6	87.5	47.3–99.7
Electrical shock/explosion	395	38.7	96.9	91.2–99.4
Fall	56,068	6.5	85.8	84.4–87.1
Firearms/gunshot	3,837	2.1	70.0	55.4–82.1
Machinery/equipment	2,595	65.1	96.8	95.7–97.7
Motor vehicle	26,190	2.9	63.5	59.7–67.3
Motorcycle	6,780	1.4	61.6	49.5–72.8
Other	2,802	19.3	90.6	86.8–93.6
Pedestrian vs. vehicle	3,701	4.3	73.7	65.9–80.5
Sharp instrument/knife	4,488	7.4	92.8	88.5–95.8
Sports/recreation/play	2,530	1.5	35.5	19.2–54.6
Unspecified	506	5.1	81.8	59.7–94.8
External cause (based on E-codes)				
Falls	55,367	6.3	85.6	84.2–86.9
Machinery	1,782	68.7	97.0	95.7–98.0
Motor vehicle traffic	33,395	2.5	62.7	59.1–66.2
Cutting/piercing objects	1,577	28.2	94.5	91.3–96.8
Struck by object	3,397	33.3	95.0	93.1–96.4
Caught between objects	724	52.8	96.3	93.4–98.1
Electrocution	182	78.6	96.9	91.3–99.4
Corrosive material/steam	1,062	26.9	95.7	91.9–98.0
Homicide/assault	9,830	1.5	77.4	67.6–85.4
Overexertion/movement related	881	7.7	86.4	72.6–94.8
Fire/flames	1,991	9.1	93.1	86.9–97.0
Explosive materials	385	13.5	93.5	78.6–99.2
Animal bites	727	9.4	85.7	69.7–95.2
Other specified	14,144	5.0	82.6	78.5–86.2
Unspecified/missing	181	3.9	80.0	28.4–99.5

*The percentage of WTR injuries indicated as work related by the WTR work-related indicator.
CI, confidence interval; WC, workers' compensation; WTR, Washington State Trauma Registry.

TABLE 3. Sensitivity of All Indicators, Individually and in Combination

Indicator	For Injuries Linked to a Compensable WC Claim		
	*n**	Sensitivity	95% CI
W: WTR work-related indicator	5,805	87.0	86.2–87.8
L: L&I noted as payer	5,911	88.6	87.8–89.3
E: *ICD-9-CM* E-code indicator	3,978	59.6	58.4–60.8
WL	6,353	95.2	94.7–95.7
WE	5,974	89.5	88.8–90.2
LE	6,199	92.9	92.3–93.5
WLE	6,381	95.6	95.1–96.1

*Number both identified by indicator as being work related and verified by linkage to a compensable WC claim.

CI, confidence interval; *ICD-9-CM, International Classification of Diseases–9th Revision–Clinical Modification*; L&I, Washington State Department of Labor and Industries; WC, workers' compensation; WTR, Washington State Trauma Registry.

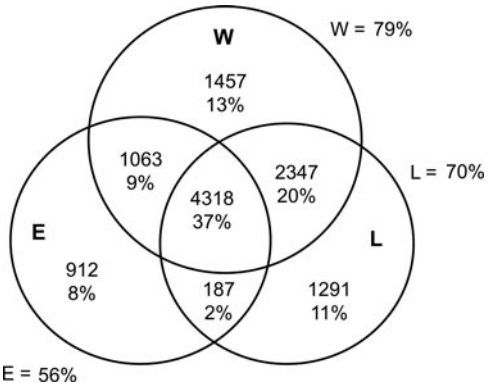

FIGURE 1. Venn diagram showing overlap and discordancies in injuries identified by the three work injury indicators (areas not to scale). The denominator for all percentages shown is the total number of work injuries identified using any of the three indicators (N = 11,575). E, *International Classification of Diseases -9th Revision -Clinical Modification* E-code indicator; L, Washington State Department of Labor and Industries noted as payer; W, Washington State Trauma Registry work-related indicator.

DISCUSSION

We found that the overall sensitivity of the existing WTR work-related indicator (W) was 87%. Only 13% of linked claims were misclassified by the W indicator as not being work related (and linkage to a compensable WC claim is strong evidence of work relatedness). Sensitivity estimates varied significantly by injury location and external cause. The work-related indicator misclassified fewer work-related injuries when the place, mechanism, or external cause of the injury was more tightly associated with work. For example, the observed sensitivity was 95% for farm locations, 96% for industrial locations, and approached 100% for mines, whereas it was less than 65% for home, sports/recreation, or street/highway locations. There were similar patterns for mechanism and external cause, with the lowest sensitivities observed for injuries that involved motor vehicles, motorcycles, sports/recreation, homicide/assault, and firearms/gunshots. This pattern is not surprising because all of these data elements relied on much of the same underlying information in the patient's medical record. Nevertheless, most strata exhibited respectable sensitivities of at least 80%, including many strata that did not contain high percentages of work-related injuries.

The L indicator had the highest sensitivity of the three solo indicators (89%), but using it to identify injuries over and above those identified by the W and/or E indicators may identify primarily crime victim claims rather than work-related injuries. We were able to obtain the number of crime victim claims from L&I for a roughly similar population during the same timeframe. There were 1571 claims for traumatic injuries other than sexual assault that resulted in an inpatient hospital stay (all ages). Even after this number was reduced to account for minors and trauma at nonreporting facilities, there were more crime victim claims meeting these criteria than there were injuries identified as work related solely by the L indicator. This suggests that the vast majority (though probably not all) of the L-only injuries were crime victim injuries rather than work-related injuries. Nevertheless, the L-only group may also include some work-related injuries that were misclassified by the W indicator, misclassified by or outside the scope of the E indicator, and were also either (1) claims excluded from the data provided for this study, or (2) linkage failures due to data entry errors, missing data, and/or substantially differing personal identifiers. We do not expect that either category would be large. This particular data challenge is likely unique to Washington State, and there may be little reason for concern about false-positive misclassification based on payer in other jurisdictions, aside from the caveat that an indicator based on payer is only positioned to capture the subset of work-related injuries that are expected to be reported to or covered by WC. Nevertheless, this issue does reinforce the need to develop a full understanding of the data-generating processes underlying any specific administrative data source used for research or surveillance.

The E indicator exhibited poor sensitivity (60%) and there is some indication that many of the injuries that were identified solely by the E indicator as work related may not have occurred during the course of employment as usually defined. Few (3%) of the injuries identified as work related by the E indicator but not by the W or L indicators linked to a compensable WC claim and nearly half of the E-only injuries occurred on nonresidential farm premises. Those injuries may have involved farm employees injured in the course of work (or not), family farmers who were working (or not) when the injury occurred, nonworking farm residents, or farm visitors. As described in the Results section, the farm-based E-only injuries did not fit the pattern we would expect if this group consisted mostly of injuries among those least likely to file a WC claim due to fear or vulnerable status (such as undocumented farmworkers or others in precarious employment situations).[14–17]

Alamgir et al[8] concluded that E-codes were useful for identifying work-related injuries based on substantial agreement between the E-code indicator and payer in a sample of probable occupational injuries among current and former sawmill workers ($\kappa = 0.75$; $P \leq 0.01$). The current study extends that work by assessing the performance of the E-code indicator in a broader sample that was unrestricted as to industry and that included many nonoccupational injuries. In this circumstance, the E-code indicator exhibited poor sensitivity for identifying known work-related injuries and identified many injuries occurring on nonresidential farm premises that may or may not be work related. Depending on the research focus and the characteristics of the sample, it may be most appropriate to exclude the nonresidential farm premises location code when constructing the E-code indicator and to use the E-code indicator only in conjunction with other information about work relatedness. Another potential concern is how reliably place of injury is correctly coded as "home" rather than "farm" when the injury occurred in a farm house or on the home premises of a farm. A systematic review of studies assessing the accuracy of E-codes in hospital records found limited

TABLE 4. Characteristics of Injuries Identified as Work Related Solely by One Indicator (and Not Linked to a Compensable WC Claim), Compared With All Linked Injuries

	W Only ($n = 1,275$)		L Only ($n = 884$)		E Only ($n = 884$)		All Linked Injuries ($n = 6,673$)	
Characteristic	**Category**	**%**	**Category**	**%**	**Category**	**%**	**Category**	**%**
Age, yr	≥65	12.2	≥65	3.3	≥65	28.5	≥65	3.6
Place of injury								
Most common	Other	22.8	Home	27.5	Farm	46.4	Industrial	57.2
2nd most common	Home	20.8	Street/ highway	26.0	Industrial	33.3	Street/ highway	11.9
External cause								
Most common	Falls	38.1	Homicide/ assault	58.3	Falls	51.7	Falls	39.1
2nd most common	Motor vehicle traffic	19.6	Falls	15.4	Animal bites	11.2	Machinery	14.5

CI, confidence interval; E, *International Classification of Diseases–9th Revision–Clinical Modification* E-code indicator; L, Washington State Department of Labor and Industries noted as payer; W, Washington State Trauma Registry work-related indicator; WC, workers' compensation.

research. Accuracy ranged from 64% when exact code agreement was examined to 85% when agreement for broader groups of codes was examined.[18] This adds a further caveat to the use of E-codes as a stand-alone identifier of work-related injuries.

The sensitivity estimates in Table 3 imply that the most comprehensive method to identify work-related injuries would be to use all three indicators in combination. Nevertheless, sensitivity tells only half the story and we do not know the false positive rate for each indicator, for example, how many non–work-related injuries were misclassified as work related. We cannot know for certain whether an injury that did not link to a WC claim was truly not work related, or just did not link due to one of the expected work-related exceptions discussed previously (eg, exempt/excluded employment, injured workers who did not file WC claims, study exclusions). Even though we did not have a gold standard that enabled precise specificity estimates, it does bear noting that observed specificities for all indicators were uniformly above 95% (the observed specificity of the W indicator was 97.2%). This can be considered a lower bound because cases incorrectly classified as false positives due to the absence of a WC claim for a truly work-related injury would push the observed specificity lower than the truth. Nevertheless, there were large numbers of injuries unrelated to work in this sample and, even with a 95% lower bound for specificity, we observed nearly as many false positives as true positives in some strata. A study identifying and implementing a suitable gold standard for specificity estimates and enabling the use of receiver operating characteristic analysis would be a constructive step forward. That is unlikely to be a simple task because the very definition of work-related injury is subject to interpretation and varies by jurisdiction and research objective.

Most (68%) of the injuries identified as work related by any of the three methods were identified as work related by at least two of the indicators. Injuries identified as work related by only the E indicator or only the L indicator accounted for 19% of injuries identified by any of the three indicators, and at least 20% of injuries of that subset (435 injuries) were in fact work related based on linkage to a compensable WC claim. The use of indicators based on administrative data will never provide 100% accuracy, but these indicators may be useful in various combinations tailored to particular purposes. For example, if the goal were to restrict injuries to those most arguably work related and there were no other verification source available, using only the existing WTR work-related indicator might be the best choice. If the goal were to identify and request WTR records for all injuries that might possibly be work related to create a sample for linkage to WC claims or other databases, using the combination of all three indicators (with a sensitivity of >95%) would probably be both adequate and the best choice; this approach would also reduce data management requirements and privacy concerns by enabling the identification of only a small subset of all WTR records as being possibly work related. On the contrary, the use of all three indicators might still result in overlooking substantial numbers of relevant injuries for studies focused on gunshots or vehicular crashes due to the lower sensitivities observed for those injury types (and many having these injuries may die at the scene and not be captured by the WTR).

Although minimally defined, the work-related indicator may be useful as an independent identifier of work-related traumatic injuries. Nearly 37% of the injuries identified by the work-related indicator did not link to a compensable WC claim. If used to supplement WC claims data, the work-related indicator may be useful to identify injuries that occur in the course of exempt/excluded employment, are not reported to WC, and/or are work related using definitions that go beyond WC coverage. To our knowledge, the WTR has no plans to further refine the definition of the work-related field. The minimal definition both allows for flexibility in interpretation by the trauma registrars and raises questions about the boundaries of the set of injuries coded as work related. Nevertheless, given that medical records often lack important details about occupational injuries, a more standardized definition that required specific elements be met could result in less sensitive capture of work-related injuries. The breadth of work-related injuries captured using a minimal definition may be a strength of the WTR, in that occupational injuries may be captured regardless of expectations of WC coverage or claim filing (in contrast to an indicator based on expected payer). The National Trauma Data Bank also employs a minimal definition: "Indication of whether the injury occurred during paid employment."[19] In contrast, many existing data sources used for occupational injury surveillance do not capture injuries that are arguably work related but occur in work settings that are excluded from the scope of surveillance for various reasons (eg, federal employees, the self-employed, domestic workers, workers on small farms, etc., depending on the specific source).

The poor sensitivity and limited scope of the indicator based on E-codes, along with the limitations inherent in using expected payer to identify work-related injuries (even outside Washington State), reinforce the potential value of the independent identifier of work relatedness available in the WTR and many other trauma registries. This added value should not be diminished by the major transition to *ICD-10-CM* slated for 2013 in the United States.[20] International efforts to include more work-related information (including causation, industry, and occupation) in electronic medical records and standardized billing documents should improve the utility of hospital discharge data for occupational injury research and surveillance.[21,22] In the meantime, even those trauma registries

containing this unusual and valuable feature have been underutilized for occupational research. Trauma registries could be made even more useful by the addition of industry and occupation information where lacking (following the leading example of the National Trauma Data Bank).[19]

CONCLUSIONS

We assessed three methods of identifying work-related injuries in a state trauma registry by linking trauma registry data to WC claims data. We believe this to be the first published instance of such linkage and an important step in validating the use of trauma registry data for occupational injury surveillance and research. Although minimally defined, the work-related indicator contained in the WTR was highly sensitive for most types of work-related injuries and may be useful as an independent identifier of occupational injuries. If used to supplement WC claims data, the work-related indicator may identify injuries that occur in the course of exempt/excluded employment, are not reported to WC, and/or are work related using definitions that go beyond WC coverage. The judicious use of E-codes to identify work-related injuries may add value, depending on the desired definition of work relatedness for particular purposes. The ability to reliably identify work-related injuries in trauma registry data opens new avenues for state-based occupational injury surveillance and research, and we are hopeful that researchers in other states will extend these findings. In addition, to the extent that these findings can be generalized across states, they may improve confidence in the use of the work-related injury data contained in the National Trauma Data Bank.[23]

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REFERENCES

1. 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.
2. Guice KS, Cassidy LD, Mann NC. State trauma registries: survey and update—2004. *J Trauma.* 2007;62:424–435.
3. 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.
4. 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.
5. Friedman LS, Forst L. Ethnic disparities in traumatic occupational injury. *J Occup Environ Med.* 2008;50:350–358.
6. 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.
7. Husberg BJ, Fosbroke DE, Conway GA, Mode NA. Hospitalized nonfatal injuries in the Alaskan construction industry. *Am J Ind Med.* 2005;47:428–433.
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. 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.
10. Campbell KM, Deck D, Krupski A. Record linkage software in the public domain: a comparison of Link Plus, The Link King, and a 'basic' deterministic algorithm. *Health Informatics J.* 2008;14:5–15.
11. Washington State Department of Health Trauma Registry. Hospital Data Dictionary, Collector Version 3.37. Available at: http://www.doh.wa.gov/hsqa/emstrauma/download/hospitaldictionary.pdf. Accessed April 27, 2011.
12. Seed PT. Summary statistics for diagnostic tests (sbe36.1). *Stata Technical Bulletin.* 2001;59:9–12.
13. Lauritsen JM. An update to drawing Venn diagrams (gr34.3). *Stata Technical Bulletin.* 2000;54:17–19.
14. Azaroff LS, Lax MB, Levenstein C, Wegman DH. Wounding the messenger: the new economy makes occupational health indicators too good to be true. *Int J Health Serv.* 2004;34:271–303.
15. Dembe AE. Access to medical care for occupational disorders: difficulties and disparities. *J Health Soc Policy.* 2001;12:19–33.
16. Pransky G, Snyder T, Dembe A, Himmelstein J. Under-reporting of work-related disorders in the workplace: a case study and review of the literature. *Ergonomics.* 1999;42:171–182.
17. Scherzer T, Rugulies R, Krause N. Work-related pain and injury and barriers to workers' compensation among Las Vegas hotel room cleaners. *Am J Public Health.* 2005;95:483–488.
18. McKenzie K, Enraght-Moony EL, Walker SM, McClure RJ, Harrison JE. Accuracy of external cause-of-injury coding in hospital records. *Inj Prev.* 2009;15:60–64.
19. National Trauma Data Bank. National Trauma Data Standard: data dictionary. 2012 admissions. Available at: http://www.ntdsdictionary.org/dataElements/documents/NTDS2012_xsd_Final_102011.pdf. Accessed January 23, 2012.
20. Centers for Medicare and Medicaid Services. The ICD-10 transition: an introduction. 2010. Available at: http://www.cms.gov/ICD10/Downloads/ICD10IntroFactSheet20100409.pdf. Accessed November 12, 2011.
21. Institute of Medicine. Incorporating occupational information in electronic health records: letter report. Washington, DC: The National Academies Press; 2011.
22. Chapter 32: Record systems and surveillance. In:Stellman JM, ed. *Encyclopaedia of Occupational Health and Safety*. 4th ed. Geneva, Switzerland: International Labour Office; 1998.
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.

