



The use of state workers' compensation administrative data to identify injury scenarios and quantify costs of work-related traumatic brain injuries[☆]

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Abstract

Problem: Traumatic brain injury (TBI) is a public health problem but little is known about the nature of that problem in the working population. *Method:* The author used a national definition to identify cases in Washington State from workers' compensation (WC) hospital billing data, quantified the cost of WC insurance benefits using actuarial cost estimates, and identified high risk industries using ANSI Z16.2 typology. *Results:* There were 928 cases of TBI with a lifetime claim cost of \$159 million from the Washington State Fund (1994–2001). Sixty percent of injuries resulted in death or disability. The highest risks of TBI are concentrated in 16 industrial insurance risk classes and the highest costs in 19 North American Industry Classification codes. Injury scenarios were identified for nine industrial insurance risk classes. *Conclusions:* TBI is a disabling and costly workplace injury in the state of Washington, affecting even teenagers and seniors who are not generally considered to be part of the workforce. Injury typology codes provide useful information for improving workplace safety. *Impact on industry:* This research provides industry with quantitative information regarding the cost of work-related traumatic brain injury and the usefulness of using workers' compensation claims data to reduce the burden of workplace injury.

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1. Problem

Traumatic brain injury (TBI) is a public health problem (Thurman, Alverson, Dunn, Guerrero, & Sniezek, 1999). The standard definition of TBI has been instrumental in establishing the magnitude of the problem and developing resources to meet the needs of children and the elderly in the

U.S. population (Thurman et al., 1995). This definition (i.e., a hospital stay that includes treatment for at least one of the ICD9CM diagnoses for skull fracture or one of the diagnoses for cerebral laceration) has not been applied to the working population.

Various case definitions have been used with WC administrative data to characterize the scope of TBI as a workplace injury in the state of Washington (Alexander, Franklin, & Fulton-Kehoe, 1999; Cohen, Kalat, & Silverstein, 1999; Heyer & Franklin, 1994). The problems of using the national definition of TBI to extract case information from a centralized state WC administrative data system, to characterize the scope of TBI in the working population, and to investigate injury etiology are addressed in this article.

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2. Methods

The CDC case definition requires that there be a hospital stay for treatment of brain injury as identified by diagnosis for skull fracture (ICD9CM codes beginning with 800, 801, 803, or 804) or cerebral laceration (ICD9CM codes beginning with 850-854; Thurman et al., 1995). Cases were identified from workers compensation claims accepted as valid for coverage from the State Fund, with date of injury between January 1, 1994 and December 31, 2001. The initial query identified a list of unduplicated claim identifiers containing at least one ICD9CM code for skull fracture or cerebral laceration in any of the fields reported in the hospital billing form, UB-92, for at least one hospital stay during the study period. A second query used the claim identifier to extract data for all hospital stays during the period under surveillance for each TBI case. The case extraction data were current when the queries were processed on April 7, 2003. Available case information included name, social security number, date of injury, gender, age at injury, date of death, lifetime claim cost, employer industrial risk class (Washington Department of Labor and Industries, 2000), North American Industrial Classification System (NAICS) economic classification system (U.S. Office of Management and Budget, 2002), standard occupation classes (U.S. Office of Management and Budget, 1980, 2000), and injury typology (American National Standards Institute, 1995). Death certificate information was obtained from the Washington Department of Health, Center for Health Statistics and was the source of causes of death.

For a closed claim, those in which all benefit costs have been paid, the total insured cost is the cost of benefits already paid. For open claims, those for which benefits are still being paid, the total insured cost are those that have been paid plus the actuarial accrued cost estimates of future benefits.

An industrial insurance risk classification system is a set of mutually exclusive insurance risk classes, a method of matching employers to their underlying risk classes, and a method for charging the appropriate risk-adjusted premiums rates. An insurance risk class is the set of industries that have similar exposures to occupational injury and disease.

NAICS is a classification system that assigns industries to the same economic class if they produce the same goods or services using similar work processes. Occupations from the two standard occupational classifications (SOC) 1980 and 2000 were used in the period 1994-2001. Some of the changes in SOC 2000 prevent exact matching to prior classifications. A partial matching was made for those classifications that include the same job descriptor, such as roofers or truckers. ANSI Z16.2 injury typology refers to five separate categories of data: (a) nature of injury, (b) affected body parts, (c) exposure (also called precipitating event or type of injury), (d) source of energy producing the injury, and (e) any associated source.

The information extracted from the hospital bill included provider identifiers, admission date, principal diagnosis, admitting diagnosis, and up to eight other diagnoses. Claim rates were computed using annual payroll hours submitted to the Department of Labor and Industries by employers. Employer reporting of payroll hours is an administrative requirement for calculating annual WC insurance premiums. Full time equivalents (FTE) were computed by dividing payroll hours by 2000 hours per year. The overall claim rate was used as the base rate in calculating rate ratios for industrial classes and risk ratios for insurance classes. Case fatality rate, per 100 cases, was obtained by dividing the total number of deaths by the total number of cases and multiplying by 100. Name and/or social security number were used to match claims to death records.

The deductive method of the systems approach (O'Reilly, 2001) was used to analyze hazards by industry. The systems approach uses the interacting circumstances described by the text in the accident/incident report to investigate injury etiology. The ANSI Z16.2 typology is the recommended coding system because it uses numerical coding that is comparable to benchmarking data published by the Bureau of Labor Statistics and the National Safety Council (O'Reilly). The deductive method of hazard analysis uses injury trees as the primary investigative tool. Hierarchical data clustering (partitioning of the 928 TBI cases into subsets that share a common trait) was used to create injury trees for this analysis.

Injury trees for industries with large numbers of cases were created using exposure/event and occupation. Injury source and associated source were used for additional partitioning. Injury trees with occupation as the first partitioning variable were created to investigate the possibility of exposures related to different job tasks.

An injury description is the list of codes that represent the common trait of the subset. A cluster is defined as a subset in an injury tree, containing at least eight cases, that also includes 50% or more of the cases in the set from which it was partitioned. Cluster size is the proportion of cases in the subset that were contained in the set from which it was partitioned. Thus, 0.50 is the minimum cluster size reported in this analysis.

The 95% confidence intervals for a proportion were calculated using the Wilson procedure with continuity correction (Newcombe, 1998). Two proportions were considered different if their 95% confidence intervals did not overlap.

3. Results

A total of 928 cases of TBI were identified from hospital billing records. About 11% of all injuries occurred in females. The age at the time of injury ranged between 15-71 for females and between 14-78 for males. The average age was 38.7 for women and 39.0 for men. About 5% of the

Table 1
Insurance Risk Classes with Seven or More Cases of TBI and Relative Risks Greater than Two

Insurance Risk Class	Risk Class Code	Claim Count	Actuary Incurred Total Cost	Relative Risk
Wood Frame Building Construction	0510	62	\$9,881,575	8.8
Trucking, Noc	1102	47	\$7,250,507	7.7
Logging	5001	38	\$18,022,706	34.2
Roofing	0507	33	\$8,287,430	25.2
Building Construction, Noc	0502	29	\$4,822,265	8.3
Road Construction	0101	23	\$5,352,454	5.8
Parcel Package Delivery	1101	20	\$1,931,590	3.4
Painting	0504	19	\$2,484,587	7.7
Carpentry, Noc	0516	19	\$1,965,361	8.6
Log Hauling	5003	11	\$1,793,867	14.3
Plumbing	0306	10	\$1,974,294	2.6
Diversified Field Crops	4804	10	\$884,971	3.4
Meat Dealers Wholesale	3304	9	\$2,337,025	2.9
Building Construction: Sheet Metal Work	0519	8	\$1,456,717	24.9
Dairy Farms	7301	8	\$1,488,833	4.2
Livestock Farms	7302	7	\$758,919	10.9
Vegetable Farms-Machine Harvest	4802	7	\$1,091,194	2.6

injuries happened to workers age 14-19, and 3% to workers over 65. About 8% of injuries took place out of state. There were 62 deaths for an annual case fatality rate of 6.7 per 100. Survival at the end of 90 days was 94%. Late effects of injury reduced survival to 93% at the end of six years. Case fatality rates did not vary by age or gender. Underlying causes of death were related to TBI in 85% of the deaths. Injuries from falls, traffic accidents, and violence were listed in the death certificate as underlying causes in 37%, 21%, and 11%, of the deaths, respectively.

The claim identifier for the initial TBI inpatient treatment was used to link to other WC administrative. These data include actuarial claim status, actuarial incurred claim cost, provider billing, industrial risk class, employer economic classification, employer hours, and injury description.

3.1. Actuarial claim status and cost

The lifetime claim cost for 928 cases with injury dates 1994-2001 is \$159 million or \$25,400 per case per year. Medical costs are estimated at \$12,600 per case per year, time loss at \$3,200 per case per year, and pension benefits to disabled workers \$4,000 per case per year. The annual incidence rate over the 8-year period was 8.4 per 100,000 FTE. Median claim cost was \$61,000. Six industries had median claim costs in excess of \$100,000: (a) building construction noc, (b) road construction, (c) janitorial services, (d) outside sales personnel not otherwise classified (noc), (e) plumbing, and (f) building construction-sheet metal.

Each workers' compensation claim is eventually assigned an actuarial status (fatal, total permanent disability,

Table 2
NAICS Industries with Eight or More Cases of TBI and Claims Rate Ratios Greater than Two Ranked by Claim Count

NAICS Industry	NAICS Code	Claim Count	Actuary Incurred Total Cost	Claims Rate Ratio
New Single-Family Housing Construction	236115	50	\$7,703,736	4.2
Logging	113310	47	\$19,952,923	18.1
Roofing Contractors	238160	35	\$8,875,466	12.6
Framing Contractors	238130	34	\$5,468,475	6.9
General Freight Trucking, Long-Distance, Truckload	484121	23	\$3,286,259	5.3
Drywall and Insulation Contractors	238310	19	\$2,596,068	3.8
Structural Steel and Precast Concrete Contractors	238120	18	\$2,645,534	18.6
Temporary Help Services	561320	18	\$1,699,596	2.2
Commercial and Institutional Building Construction	236220	17	\$1,979,230	3.5
Landscaping Services	561730	15	\$2,896,608	3.8
Highway, Street, and Bridge Construction	237310	15	\$4,951,332	5.3
General Freight Trucking, Local	484110	12	\$579,025	5.7
Poured Concrete Foundation and Structure Contractors	238110	11	\$1,711,672	4.7
Other Noncitrus Fruit Farming	111339	11	\$364,002	7.3
Painting and Wall Covering Contractors	238320	11	\$2,205,714	3.6
Specialized Freight (Except Used Goods) Trucking, Local	484220	10	\$1,789,989	3.4
All Other Specialty Trade Contractors	238990	8	\$419,662	4.3
Other Heavy and Civil Engineering Construction	237990	8	\$1,234,312	2.8
All Other Miscellaneous Crop Farming	111998	8	\$544,838	3.5

partial permanent disability, time loss, medical only, or other) based on the pattern of benefits paid on behalf of the injured worker. Sixty percent of injuries resulted in death or permanent disability. Six percent of TBI claims required only medical benefits. Time loss status was assigned to 28% of the injuries. However, time loss benefits do not represent the majority of the costs for claims with actuarial status time loss. Medical benefits represent about 75% of the benefits with time loss benefits being only 20%. Actuarial claim status of fatal refers to those cases that died within 90 days of the date of injury.

3.2. Treatment patterns

The 928 TBI cases had 1,496 hospital stays during the study period with 1-11 inpatient stays per case. Treatment for skull fracture or cerebral laceration was the principal diagnosis in two of three admissions. Fracture of neck, trunk, upper or lower extremities, was the principal diagnosis in another 18% of the admissions. In two admissions the diagnosis of skull fracture or cerebral laceration did not occur until the final listed diagnosis, indicating that the injury was present but not as significant as other conditions. About 70% of the diagnostically related groups (DRG) for first admissions were traumatic stupor and coma, craniotomies, concussions, and multiple significant traumas. Most first hospital stays, 97%, occurred within eight days of the injury.

In 21 cases the treatment patterns conformed to what may have been an initial mild traumatic brain injury (MTBI). In four cases there were hospital stays prior to the one with a confirming TBI diagnosis. Admitting diagnoses for the prior admissions included fractures of the extremities, a vertebral fracture, unspecified head injury, and headache/paralysis. There were 28 cases whose first TBI hospital stay occurred 7 to 1,674 days after the initial injury. In 17 of these cases, MTBI is suspected since there was hospital outpatient treatment, usually on the day of injury (Centers for Disease Control and Prevention, 1997, Revised June 15, 2001). A TBI treatment diagnosis was reported in only two of these outpatient treatments. It is possible that some of the other 11 cases received treatment in doctors' offices prior to the initial hospital stay.

3.3. Industry classifications and injury rates

The industrial insurance risk classes with eight or more cases and relative risks greater than two are shown in Table 1. These 16 risk classes contain about 8% of the working population, 37% of the cases, and 44% of the costs. Logging, roofing, log hauling, and building construction-sheet metal work have relative risks greater than 10.

The NAICS industries with eight or more cases of TBI and rate ratios in excess of two are shown in Table 2. These 19 industries include about 8% of the workforce, about 40% of the cases, and 45% of the costs. Structural steel and

Table 3
Occupations with High Frequency of TBI

Occupation	SOC 1980 Descriptors (ALL CAPITAL LETTERS) Or SOC 2000 Descriptors (Regular Type)	Total Cases
Truck Drivers	TRUCK DRIVERS, EXCEPT LOGGING Truck Drivers, Heavy and Tractor-Trailer Truck Drivers, Light or Delivery Services	100
Construction Workers	CONSTRUCTION LABORERS CONSTRUCTION TRADES, NEC Construction Craft Laborer Construction and Related Workers	61
Farm Workers	FARM WORKERS Farm workers and Laborers, Farm workers, Farm and Ranch Hands	48
Carpenters	CARPENTERS and APPRENTICES Carpenters	45
Supervisors	SUPERVISORS-CONSTRUCTION SUPERVISORS-PRODUCTION First-Line Supervisors/Managers	40
Managers	MANAGEMENT RELATED OCCUPATIONS MANAGERS and ADMINSTRATORS, NEC Managers, All Other	34
Loggers	FALLERS/BUCKERS, BUSHELERS LOGGERS, NEC Fallers Logging Equipment Operator Logging Workers, All Other	33
Roofers	ROOFERS Roofers	32
Sales/Retail Workers	SALES WORERS-RETAIL and PERSONAL SERICES Sales and Related Workers	16
Electricians	ELECTRICIANS and APPRENTICES Electricians	14
Painters	PAINTERS-CONSTRUCTION and MAINTENANCE Painters, Construction and Maintenance	12

precast concrete contractors, logging, and roofing contractors have claims rate ratios in excess of 10.

Logging is listed first among risk classes in Table 1 and second among NAICS industries in Table 2. About 95% of the claims in the logging risk class 5001 were assigned to logging as an economic activity NAICS code 113310, the set of establishments primarily engaged in one or more of the following: cutting timber, cutting and transporting timber, and producing wood chips in the field. One injury in the logging risk class was assigned to the NAICS industry new single-family housing construction (except operative builders) 236115. This injury resulted when the timber on a lot zoned for single-family housing was being harvested.

There is a separate insurance risk class for log hauling 5003, which is ranked fourth in Table 1. NAICS establishments engaged in trucking timber are assigned to class 484220, specialized freight (except used goods) trucking: local, which is ranked 17th in Table 2.

Table 4
Injury Scenarios and Cluster Size for Workplace Traumatic Brain Injury in Industries with 20 or More Cases

Risk Class	Exposure	Cluster Size	Occupation	Cluster Size
Wood Frame Building Construction	Fall From Elevation ^a	.84	Carpenters and Construction Laborers	.79
Trucking	Highway Motor Vehicle Accident ^c		Truck Driver	
	AND Fall From Elevation ^a	.81		.97
Building Construction	Fall From Elevation ^a	.79	Carpenters and Construction Laborers	.58
Road Construction	Highway Motor Vehicle Accident ^c	.78	No Occupation Cluster	–
	AND Fall From Elevation ^a			
Roofing	Fall From Elevation ^a	.90	Roofers	.84
	AND Fall From Roof ^b	.85	Roofers	.85
Parcel Post Delivery	Highway Motor Vehicle Accident ^c	.65	Truck Driver	.54
Orchards	Fall From Elevation ^a	.54	Farm Worker	.92
		.79		
Logging	Fall From Ladder ^d		Farm Worker	1.00
	Struck By ^e	.77	No Occupation Cluster	–
	Struck By Wood Item ^f	.88		
Sales Personnel	Highway Motor Vehicle Accident ^c	.63	Fallers and Buckers	.53
			Sales Workers/Managers	.92

^a Exposure Codes Beginning with 03.

^b Exposure Code 037.

^c Exposure Codes Beginning with 3.

^d Exposure Code 032.

^e Exposure Codes Beginning with 02.

^f Exposure Codes Beginning with 02 and Source Code with 57.

3.4. External causes of injury, exposures and high risk occupations

External causes of injury codes (E-Codes) were reported for 84% of first hospital stays. One in six of these E-codes were place codes rather than external cause. An industrial premise was reported eight times more frequently as a place code than street or highway. Only 66.8% of the first hospital inpatient stays had E codes that could be tabulated as recommended by CDC (U.S. Department of Health and Human Services, 1995). Falls represented 37.4% of the unintentional injuries; motor-vehicle traffic injuries, 19.9%; and struck by an object, 11.8%. In motor-vehicle traffic accidents an occupant was injured 86% of the time and a pedestrian 12% of the time. There was one injury to a motorcyclist. Assaults represented 2% of the reported external causes. Accidents caused by machinery and accidents involving animals represent 3.5% and 1.3%, respectively.

The accident event/ exposure pattern is similar to those reported earlier (Cohen et al., 1999; Heyer & Franklin, 1994). Falls from elevation were the most frequent exposure/event at 39%. Struck by an object was the exposure in 21% of the injuries, followed by highway motor-vehicle accidents at 18%, and fall on same level at 8%. Between 1994 and 2001 the relative proportion of falls from elevation increased from 0.305 to 0.403 and the relative proportion of TBI cases from struck by an object decreased from 0.300 to 0.170. However, neither of these changes was statistically significant.

The occupational coding was 66% SOC 1980 (modified), 22% SOC 2000, and 12% not classified. Occupations with similar job titles in both coding systems were grouped

to identify high-risk occupations. The eleven groupings with more than 10 TBI per year are shown in Table 3. They represent about 53% of reported occupations. Truck drivers experience about 12% of TBI. The combined groups of managers and supervisors experienced about 11% of TBI. The occupations with high frequencies for TBI appear similar to those reported for 1990-1997 (Cohen et al., 1999). TBI deaths are spread across a large number of occupations. There were three deaths among the four cases with occupation descriptors of general office clerk, administrative support occupations, or receptionist and information clerks. The case fatality rate of 22.2% for supervisors (construction, farm work, production, or mechanics and repair) was significantly higher than the overall rate of 6.7%.

3.5. Hazard analysis, cluster analysis, and injury descriptions

A data cluster was identified in the injury tree of the nine risk classes with 20 or more cases of TBI. The results, shown in Table 4, confirmed the existence of previously identified predominant patterns in logging, trucking, roofing, and building construction (Heyer & Franklin, 1994). A new cluster involving motor-vehicle accidents among sales workers/managers was also identified.

Logging had a cluster of size 0.62 in the exposure class struck by an object (codes 020, 021 and 029), in which there was a cluster of size 0.70 for being struck by trees/limb/snags. Fallers/buckers (those logging workers responsible for felling a tree and cutting into lengths suitable for transportation) form a cluster of size 0.50 within this group. By a ratio of 6 to 1 faller/buckers were more likely to be

struck by a tree/limb/snag than by a log. This scenario is similar to that reported for logging fatalities and nonfatal injuries in South Carolina and West Virginia (Bell & Helmkamp, 2003; U.S. Department of Health and Human Services, 1995).

Fall from elevation from ladders by farm workers represents an injury scenario in the orchard risk class. Much is known about ladder fall accidents (Cohen & Lin, 1991a, 1991b; Partridge, Virk, & Antosia, 1998). But some ladders used in orchards are unusual in that they have only three legs. This design enhances their stability on uneven ground and improves access to fruit that is located closer to the tree trunk. Classifications in ANSI Z16.2 do not distinguish ladders by the number of legs.

Injury scenarios involving truck drivers were identified in the trucking and parcel package delivery risk classes. In the trucking risk class TBI are evenly divided between highway motor-vehicle accidents and falls from elevation. A retrospective review of workers' compensation data has identified that the most frequent site of falls as the back of the truck/trailer, the cargo, or from the truck step (Jones & Switzer-McIntyre, 2003). Falls from elevation, occurring during loading/unloading, were not a component of the injury scenario for parcel package delivery.

4. Discussion

TBI is a serious and costly injury in the working population. The average lifetime insured costs for work related TBI in this study is \$171,000. This is about 25% greater than previously estimated for the state of Washington. There are two reasons for the increase in the estimate. This study includes a broader case definition of TBI than previously used and the actuarial incurred total cost includes estimates of future costs for open claims. The total amount still represents a lower estimate of the total costs in the state because it does not include cases covered by employers who self insure and it excludes monies that are recouped from other insurers who share liability for the injured worker (e.g., those for whom workers' compensation insurance provides secondary benefits). Fifty percent of the insurance cost is for medical care, 16% for pension costs, and 13% for time loss. Some of the burden of TBI among teenagers and among the elderly is work-related. Ten percent of TBI cases have ages of injury below 20 or greater than 64. Two percent of cases were MTBI in that documented ambulatory care preceded the first hospital stay for TBI.

There were significant improvements in the relative risks of TBI in a variety of risk classes (e.g. diversified field crops, machine shops, garbage collection, wood product manufacturing, grain milling, livestock farming, vegetable farms-machine harvest, meat dealers wholesale, state government-law enforcement, and plumbing). There were no significant changes in relative risk of TBI for logging,

roofing, log hauling, building construction-sheet metal work, painting, and parcel package delivery.

The system approach to accident prevention using ANSI Z16.2 coding of injury descriptions, available from the claims initiation process, was used successfully in identifying hazards in all industries with 20 or more cases of TBI. For some industries, such as logging, it was also possible to identify the exposure/event, occupation, source, and associated source of injury. This injury scenario is similar to those already reported in the literature for logging in other states. It would be worthwhile to review prevention efforts in logging, roofing, and building construction-sheet metal work, where the relative risks are over 25 and have not changed since 1990.

This study confirms both the challenges and the opportunities previously identified in using state administrative data from workers' compensation insurance to study injury patterns and etiologies (Johantagen, Trinkoff, Gray-Siracusa, Muntaner, & Nielsen, 2004). WC data also contain outputs from other insurance processes, such as payment for non-hospital services and drugs; disability determination; and the planning/provision of vocational rehabilitation services. Research using these additional WC administrative data would improve our understanding of treatment pathways, quality of care, and outcomes in TBI.

5. Summary

A lower estimate of the average lifetime WC insurance cost for a work-related case of TBI is \$171,000. Logging, roofing, and building construction-sheet metal work continue to have relative risks in excess of 20. Major exposures to TBI are falls from elevation, being struck by an object, and highway motor-vehicle accidents. Truck drivers, construction workers, farm workers, and managers/supervisors experience a high proportion of non fatal TBI.

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