ORIGINAL ARTICLE

MAYO CLINIC PROCEEDINGS:
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MAYO CLINIC

Type 2 Diabetes Increases the Risk of Serious and Life-Threatening Conditions Among Adults With Traumatic Spinal Cord Injury

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Abstract

Objective: To compare the incidence of and adjusted hazards for serious and life-threatening morbidities among adults with traumatic spinal cord injury (TSCI) with and without type 2 diabetes (T2D).

Participants and Methods: A retrospective longitudinal cohort study was conducted from September 1, 2022 to February 2, 2023, among privately insured beneficiaries if they had an International Classification of Diseases, 9th Revision or 10th Revision, Clinical Modification diagnostic code for TSCI (n=9081). Incidence estimates of serious and life-threatening morbidities, and more common secondary and long-term health conditions, were compared at 5 years of enrollment. Survival models were used to quantify unadjusted and adjusted hazard ratios for serious and life-threatening morbidities.

Results: Adults living with TSCI and T2D had a higher incidence of all of the morbidities assessed as compared with nondiabetic adults with TSCI. Fully adjusted survival models reported that adults with TSCI and T2D had a greater hazard for most of the serious and life-threatening conditions assessed, including sepsis (hazard ratio [HR]: 1.65), myocardial infarction (HR: 1.63), osteomyelitis (HR: 1.9), and stroke or transient ischemic attack (HR: 1.59). Rates for comorbid and secondary conditions were higher for individuals with TSCI and T2D, such as pressure sores, urinary tract infections, and depression, even after controlling for sociodemographic and comorbid conditions.

Conclusion: Adults living with TSCI and T2D have a significantly higher incidence of and risk of developing serious and life-threatening morbidities as compared with nondiabetic adults with TSCI.

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Traumatic spinal cord injury (TSCI) is associated with increased risks for long-term and secondary diseases.[1-3] In a series of studies, we and others compared the prevalence and incidence of psychological, cardiometabolic, and musculoskeletal morbidities, and multimorbidity, among adults with and without TSCI.[2-4] Adults with TSCI experience a significantly higher prevalence of common cardiometabolic comorbidities when compared with adults without TSCI.[2] In particular, adults living with TSCI experience a 66% higher risk of developing type 2 diabetes (T2D) than the general population, even after adjusting for key risk factors such as smoking, hypertension, body mass index (BMI [calculated as the weight in kilograms divided by the height in meters squared]), daily physical activity, alcohol intake, and diet.[2,3]

Type 2 diabetes is a preventable, common, and complex metabolic disease characterized by obesity, impaired insulin production, insulin resistance, and elevated blood glucose levels. Diabetes affects nearly every part of the body, and individuals with T2D in the general population have subsequent morbidity and mortality.[5] Among adults with TSCI, previous research has linked T2D to higher rates of and delayed healing of pressure sores,[6] higher incidence of microvascular and macrovascular conditions among veterans with SCI,[7] and higher health care costs[8]; however, these studies have generally failed to account for relevant covariates, including differences associated with race or ethnicity, income, and the role of other long-term conditions.

The objective of this study was to compare the incidence of and adjusted hazards for

serious and life-threatening morbidities among adults with TSCI with and without T2D.

PARTICIPANTS AND METHODS

Data Source

We used the Clinformatics DataMart Database (OptumInsight, Eden Prairie), which is a deidentified administrative claims database of over 80 million adults and children with commercial insurance representing those on a single, large United States private payer who had both medical and pharmacy coverage throughout the enrollment. Enrolled beneficiaries' emergency department, outpatient, and inpatient encounters are captured. This dataset enables the capture of all health care utilization for billable services while enrolled on the plan. This study was deemed exempt by the University of Michigan Institutional Review Board and took place from September 1, 2022 to February 2, 2023.

Sample Selection

Informed by previous work,[2-4] we first identified adults (aged 18 years and older) at enrollment who had evidence of TSCI while enrolled on their insurance plan using International Classification of Diseases, 9th Revision or 10th Revision, Clinical Modification (ICD-9-CM; ICD-10-CM) codes. The cohort included individuals aged 18 years and older at enrollment (from January 1, 2007 to December 31, 2017). Patients with TSCI whose continuous enrollment was less than 12 months before the initial injury were excluded in order to have a sufficient enrollment to detect evidence of long-term comorbidities. All patients had at least 4 years of continuous enrollment after their initial TSCI injury (1 year of preinjury enrollment, 4 years of postinjury enrollment) to enable sufficient longitudinal follow-up. Because reasons for disenrollment from the plan were not known in this administrative claims data, we chose to retain patients that had sufficient longitudinal follow-up. Reasons for disenrollment could have included death, a change in insurance to another private payer, loss of insurance, or a conversion to a public insurance option, among others. All medical claims except for laboratory and outpatient pharmacy records were used to identify the cohort. A comparison cohort of controls with TSCI but without evidence of prevalent (occurring before incident TSCI) or incident T2D (occurring after initial TSCI diagnosis) throughout their enrollment were identified. For details regarding the process used to identify patients with TSCI, please refer to Figure.

Exposure

We identified patients with TSCIs with and without evidence of T2D throughout their enrollment using ICD-9-CM or ICD-10-CM. Patients with T2D before onset of TSCI were considered prevalent with the condition, whereas those without T2D in the year before injury with evidence of diagnosis of T2D after injury were considered incident. A comparison cohort of controls with TSCI but without evidence of prevalent or incident T2D throughout their enrollment was identified. Those with any evidence of type 1 diabetes throughout the study period were excluded from the study.

Physical and Psychological Morbidities and Outcomes

Serious and life-threatening health conditions were selected on the basis of clinical experience and research findings,[7-9] and physician-diagnosed conditions were identified on the basis of a single encounter that included at least 1 of the pertinent ICD-9-CM or ICD-10-CM diagnosis codes (in any position; see Supplemental Table S1 for the list of 35 morbidities, available online at http://www.mcpiqojournal.org). We defined prevalent morbidity as evidence of any of the conditions in the patient's 1 year of enrollment before injury and incident morbidity as evidence of the identified conditions in the 4-year follow-up period that did not have diagnoses of any of these conditions in their preinjury period.

Covariates. Age groups at the time of injury (18-44 years, 45-64 years, and 65 years or older), sex, race or ethnicity (classified as Black, White, Hispanic, and other/unknown race), educational level, household net worth, and a modified Elixhauser comorbidity index that removed 3 conditions (diabetes uncomplicated, diabetes complicated, and obesity) that would be correlated with incident T2D are included as explanatory covariates. There are a total of 28 possible conditions for the

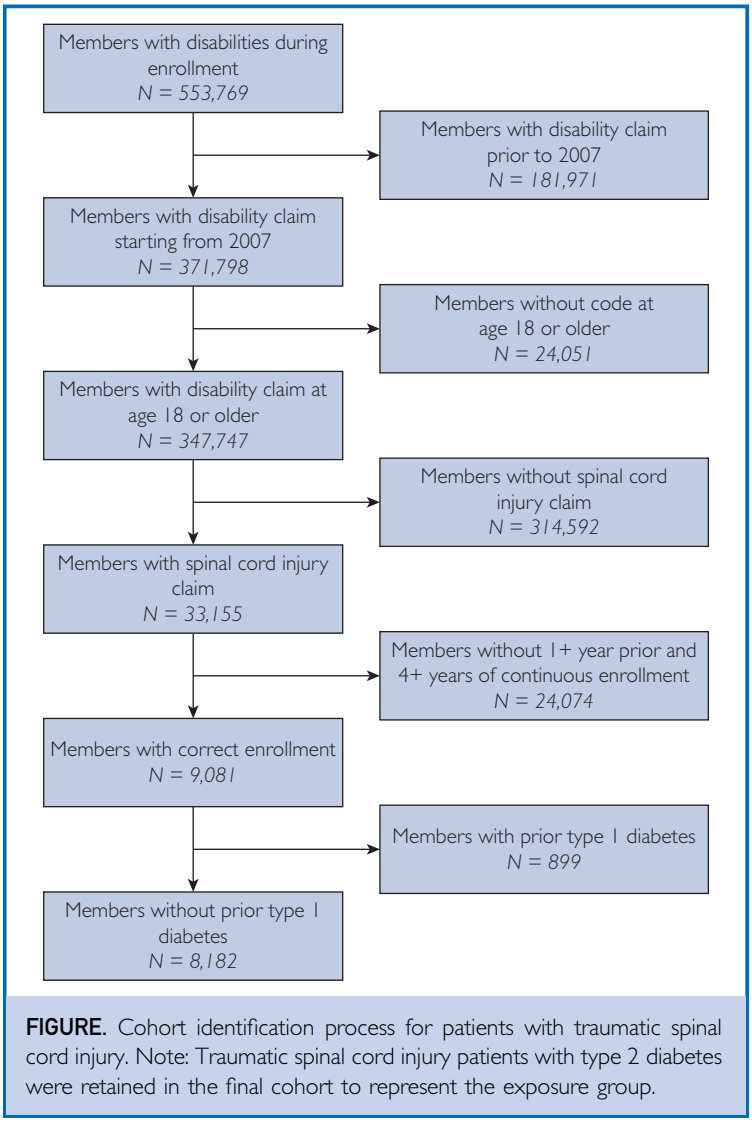

FIGURE. Cohort identification process for patients with traumatic spinal cord injury. Note: Traumatic spinal cord injury patients with type 2 diabetes were retained in the final cohort to represent the exposure group.

modified Elixhauser comorbidity index with this adjustment (see Supplemental Table S2).

Statistical Analyses

A comparison of baseline demographic characteristics between patients with TSCI with T2D and their non-T2D control counterparts was conducted by bivariate analyses. To address the statistically significant yet clinically less meaningful results sometimes obtained in overpowered studies because of large sample sizes, Cohen's w, as a measure of effect sizes, was used when performing a test of association for meaningful differences in the frequency distribution of 2 categorical variables. Cohen's w has guidelines surrounding meaningful differences.[10]

For each health condition, crude cumulative incidence rates of these morbidities in both the T2D and control groups with TSCI were compared and reported, respectively. We developed a series of unadjusted and adjusted survival models with clinically relevant patient attributes to estimate the hazards ratio (HR) of the individual outcomes, given T2D exposure. In each of the models, patients whose outcome developed before their TSCI diagnosis index date were excluded, and the proportional hazards assumption was checked using graphic analysis, including Kaplan Meier curves with log (-log) transformation. Patients were rightly censored if no outcome occurred in the 4-year follow-up period or if they were disenrolled from the plan. We first fit a bivariate Cox proportional hazards model that included only our main effect for T2D exposure during enrollment to estimate the unadjusted HR for composite morbidity. Subsequently, we estimated adjusted HRs with T2D as the main exposure to examine the effects of incremental adjustment on the exposure variable (T2D) for each outcome (individual and composite morbidity) accordingly.

To examine the differential risk of morbidity in the 4-year follow-up period from initial TSCI injury on the basis of race or ethnicity, we estimated the marginal odds of morbidity by fitting a fully adjusted multivariable logistic regression model with an interaction effect for race or ethnicity and T2D exposure. The adjustment covariates that were used for model estimation were identical to those used for the aforementioned survival models. All analyses were conducted using SAS 9.4 (SAS Institute). Statistical testing was 2-tailed with a significance level of .05, and effect sizes used a 0.2 meaningful difference cutoff per previous guidance from the literature.

RESULTS

The baseline demographic characteristics of adults with TSCI with T2D and their non-T2D control counterparts and associated effect sizes (Cohen's w) are presented in Table 1. Odds ratios calculated for different racial and ethnic groups suggest that individuals who are Black or Hispanic are significantly more

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TABLE 1. Demographic Characteristics of Cohort

Variable	No. (%) of patients (TSCI and T2D; n=2567)	No. (%) of patients (TSCI only; n=5615)	Cohen's w
Age group (y)			0.200
18-44	169 (6.6)	1173 (20.9)	
45-64	661 (25.7)	1643 (29.3)	
≥65	1737 (67.7)	2799 (49.8)	
Sex			0.003
Female	1490 (58.0)	3241 (57.7)	
Male	1077 (42)	2374 (42.3)	
Race and ethnicity			0.098
Black	218 (8.5)	327 (5.8)	
Hispanic	274 (10.7)	346 (6.2)	
White	1516 (59.1)	3690 (65.7)	
Other/unknown race	559 (21.8)	1252 (22.3)	
Educational level			0.091
Less than high school diploma	24 (0.9)	25 (0.4)	
High school diploma	770 (30.0)	1331 (23.7)	
Less than bachelor's degree	1401 (54.6)	3110 (55.4)	
Bachelor's degree	331 (12.9)	1030 (18.3)	
Unknown/missing	41 (1.6)	119 (2.1)	
Net worth			0.065
<$25,000	459 (17.9)	830 (14.8)	
$25,000-$149,000	488 (19.0)	968 (17.2)	
$150,000-$249,000	268 (10.4)	527 (9.4)	
$250,000-$499,000	386 (15.0)	865 (15.4)	
≥$500,000	539 (21.0)	1459 (26.0)	
Unknown/missing	427 (16.6)	966 (17.2)	

TSCI, traumatic spinal cord injury; T2D, type 2 diabetes.

likely to have been diagnosed with T2D than individuals who were either White or Asian or whose race or ethnicity was unknown. Details of these comparisons are presented in Table 2.

Adults living with TSCI and T2D had a higher 4-year incidence of all identified morbidities as compared with nondiabetic adults with TSCI (controls). In particular, adults with TSCI and T2D had significantly higher incidences of sepsis (15.6% [n=400] vs 7.6% [n=425]), stroke (19.2% [n=493] vs 10.8% [n=606]), and myocardial infarction (10.9% [n=281] vs 5.3% [n=296] as

TABLE 2. Race and Ethnicity Comparisons Among Patients With Traumatic Spinal Cord Injury for Type 2 Diabetes Risk, Adjusted for Patient Attributes

Target group	Reference group	Estimate	Standard error	Odds ratio[a] (95% CI)	*P*
Black	Hispanic	−0.186	0.121	0.83 (0.66-1.05)	.05
Black	Asian or unknown	0.267	0.106	1.31 (1.06-1.61)	.04
Black	White	0.388	0.095	1.47 (1.22-1.77)	<.01
Hispanic	Asian or unknown	0.453	0.100	1.57 (1.29-1.91)	<.01
Hispanic	White	0.573	0.088	1.77 (1.49-2.11)	<.01
Other/unknown race	White	0.121	0.065	1.13 (0.99-1.28)	.03

[a]Adjusted for sex, education level, net worth, and Elixhauser comorbidities.

TABLE 3. Prevalence and Incidence of Long-term and Secondary Conditions Among a Cohort of Adults With Traumatic Spinal Cord Injury[a]

Condition	Prevalent + Incident[b]		Incident outcome only (condition not present at baseline)	
	Controls/ denominator, no. (%) of patients (TSCI only; n=5615)	Cases/denominator, no. (%) of patients (TSCI and T2D; n=2567)	Controls/ denominator, no. (%) of patients (TSCI only; n=variable)	Cases/denominator, no. (%) of patients (TSCI and T2D; n=variable)
Abscess	2123 (37.8%)	1226 (47.8%)	1026/4518 (22.7%)	577/1918 (30.1%)
Alzheimer's and related diseases	867 (15.4%)	571 (22.2%)	505/5253 (9.6%)	291/2287 (12.7%)
Atherosclerosis of native arteries of the extremities	421 (7.5%)	451 (17.6%)	225/5419 (4.2%)	223/2339 (9.5%)
Cardiovascular disease	1215 (21.6%)	945 (36.8%)	629/5029 (12.5%)	397/2019 (19.7%)
Cellulitis	1980 (35.3%)	1175 (45.8%)	971/4606 (21.1%)	552/1944 (28.4%)
Dementia	454 (8.1%)	357 (13.9%)	332/5493 (6%)	249/2459 (10.1%)
Depression	1846 (32.9%)	1049 (40.9%)	727/4496 (16.2%)	421/1939 (21.7%)
Diseases of intestines and peritoneum	3385 (60.3%)	1851 (72.1%)	1244/3474 (35.8%)	579/1295 (44.7%)
Diseases of urinary system	3636 (64.8%)	2049 (79.8%)	1220/3199 (38.1%)	585/1103 (53%)
Heart failure	999 (17.8%)	908 (35.4%)	526/5142 (10.2%)	410/2069 (19.8%)
Hypertension	3812 (67.9%)	2406 (93.7%)	742/2545 (29.2%)	276/437 (63.2%)
Inflammatory diseases of central nervous system	143 (2.5%)	120 (4.7%)	60/5532 (1.1%)	59/2506 (2.4%)
Myocardial infarction	296 (5.3%)	281 (10.9%)	164/5483 (3%)	143/2429 (5.9%)
Macular degeneration	1183 (21.1%)	822 (32.0%)	480/4912 (9.8%)	304/2049 (14.8%)
Male genital organ diseases[c]	1286/2374 (54.2%)	805/1077 (74.7%)	424/1524 (27.8%)	228/513 (44.4%)
Obstructive sleep apnea	4748 (84.6%)	2395 (93.3%)	1193/2060 (57.9%)	442/614 (72%)
Osteoarthritis	3151 (56.1%)	1862 (72.5%)	1126/3590 (31.4%)	564/1269 (44.4%)
Osteomyelitis	291 (5.2%)	248 (9.7%)	191/5515 (3.5%)	161/2480 (6.5%)
Peripheral vascular disease	982 (17.5%)	834 (32.5%)	521/5154 (10.1%)	396/2129 (18.6%)
Pneumonia	491 (8.7%)	405 (15.8%)	330/5454 (6.1%)	268/2430 (11%)
Pressure sores	768 (13.7%)	587 (22.9%)	473/5320 (8.9%)	349/2329 (15%)
Pulmonary hypertension	82 (1.5%)	81 (3.2%)	67/5600 (1.2%)	60/2546 (2.4%)
Restrictive lung disease	1180 (21%)	767 (29.9%)	604/5039 (12%)	352/2152 (16.4%)
Sepsis	425 (7.6%)	400 (15.6%)	314/5504 (5.7%)	271/2438 (11.1%)
Transient ischemic attack/stroke	606 (10.8%)	493 (19.2%)	300/5309 (5.7%)	240/2314 (10.4%)
Urinary tract infection	3183 (56.7%)	1839 (71.6%)	1222/3654 (33.4%)	628/1356 (46.3%)
Venous insufficiency with lower extremities	36 (0.6%)	35 (1.4%)	36/5615 (0.6%)	35/2567 (1.4%)

[a]TSCI, traumatic spinal cord injury; T2D, type 2 diabetes.
[b]Prevalence and incidence represent 2 distinct timeframes. Prevalence represents the evidence of at least 1 or more visits with a diagnosis of the specified condition across the entire study period for each patient, including 1 year before the TSCI diagnosis and the 4 years of follow-up. Incident outcomes reflect that the patient did not have evidence of a visit for that condition in the year before the TSCI diagnosis; however, the patient has evidence of 1 or more visits with a diagnosis of that condition in the 4-year follow-up period. Therefore, prevalent + incident reflects 5-year crude rates, and incident outcome only reflects 4-year crude outcome rates.
[c]Denominator for this condition is male patients only.

compared with controls (all $P<.01$ and SMD ≥ 0.2) and more common but serious conditions including osteoarthritis (72.5% [n=1862] vs 56.1% [n=3151), abscesses (47.8% [n=1226] vs 37.8% [n=2123), and urinary tract infections (71.6% [n=1839] vs 56.7% [n=3183). Table 3 provides descriptive statistics of both prevalence and incident morbidities.

Unadjusted survival models reported a significant HR for each of the incident morbidities among adults with TSCI and T2D,

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TABLE 4. Hazard Ratios for Occurrence of Long-term and Secondary Conditions among a Cohort of Adults with Traumatic Spinal Cord Injury[a]

Condition	Hazard ratios of T2D vs non-T2D								Event rate			
	Unadjusted model		Adjusted models[b]									
	(95% CI)	*P*	Model 2 (95% CI)	*P*	Model 3 (95% CI)	*P*	Model 4 (95% CI)	*P*	TSCI only[c]		TSCI and T2D[c]	
Abscess	1.38 (1.25-1.53)	<.0001	1.34 (1.21-1.5)	<.0001	1.28 (1.14-1.42)	<.0001	1.27 (1.14-1.42)	<.01	1026/4518	22.71%	575/1918	29.98%
Alzheimer's and related diseases	1.35 (1.17-1.56)	<.0001	1.05 (0.91-1.22)	.50	0.98 (0.84-1.13)	.75	0.98 (0.85-1.14)	.83	504/5253	9.59%	290/2287	12.68%
Atherosclerosis of native arteries of the extremities	2.34 (1.95-2.82)	<.0001	1.75 (1.45-2.12)	<.0001	1.57 (1.3-1.91)	<.0001	1.57 (1.29-1.91)	<.01	224/5419	4.13%	220/2339	9.41%
Cardiovascular disease	1.64 (1.45-1.86)	<.0001	1.29 (1.14-1.47)	<.0001	1.17 (1.02-1.33)	.022	1.17 (1.02-1.33)	.02	628/5029	12.49%	396/2019	19.61%
Cellulitis	1.4 (1.26-1.56)	<.0001	1.35 (1.21-1.5)	<.0001	1.26 (1.13-1.41)	<.0001	1.26 (1.12-1.41)	<.01	970/4606	21.06%	549/1944	28.24%
Dementia	1.71 (1.45-2.01)	<.0001	1.28 (1.08-1.51)	.005	1.18 (1-1.4)	.06	1.17 (0.99-1.39)	.07	331/5493	6.03%	246/2459	10.00%
Depression	1.39 (1.23-1.57)	<.0001	1.45 (1.28-1.64)	<.0001	1.35 (1.19, 1.54)	<.0001	1.33 (1.17-1.51)	<.01	726/4496	16.15%	421/1939	21.71%
Diseases of urinary system	1.53 (1.39-1.69)	<.0001	1.36 (1.22-1.5)	<.0001	1.31 (1.18-1.46)	<.0001	1.31 (1.18-1.45)	<.01	1219/3199	38.11%	584/1103	52.95%
Heart failure	2.04 (1.8-2.33)	<.0001	1.61 (1.41-1.84)	<.0001	1.48 (1.3-1.7)	<.0001	1.46 (1.28-1.67)	<.01	525/5142	10.21%	409/2069	19.77%
Hypertension	2.82 (2.46-3.24)	<.0001	2.08 (1.8-2.4)	<.0001	1.99 (1.71-2.3)	<.0001	1.95 (1.68-2.27)	<.01	742/2545	29.16%	276/437	63.16%
Inflammatory diseases of central nervous system	2.11 (1.46-3.04)	<.0001	2.43 (1.66-3.56)	<.0001	2.13 (1.43-3.18)	.0002	2.16 (1.45-3.23)	<.01	59/5532	1.07%	56/2506	2.23%
Myocardial infarction	1.97 (1.57-2.47)	<.0001	1.61 (1.28-2.03)	<.0001	1.43 (1.13-1.82)	.003	1.41 (1.11-1.79)	<.01	163/5483	2.97%	140/2429	5.76%
Macular degeneration	1.56 (1.35-1.8)	<.0001	1.18 (1.02-1.37)	.026	1.13 (0.97-1.31)	.12	1.12 (0.97-1.31)	.13	479/4912	9.75%	301/2049	14.69%
Male genital organ diseases[d]	1.68 (1.43-1.99)	<.0001	1.31 (1.10-1.60)	.002	1.29 (1.08-1.55)	.005	1.28 (1.07-1.53)	.01	418/1524	27.40%	216/513	42.11%
Obstructive sleep apnea	1.44 (1.29-1.6)	<.0001	1.3 (1.16-1.46)	<.0001	1.3 (1.15-1.46)	<.0001	1.29 (1.15-1.46)	<.01	1193/2060	57.91%	442/614	71.99%
Osteoarthritis	1.56 (1.41-1.73)	<.0001	1.2 (1.08-1.33)	.001	1.16 (1.04-1.29)	.001	1.14 (1.03-1.27)	.02	1125/3590	31.34%	564/1269	44.44%
Osteomyelitis	1.88 (1.52-2.32)	<.0001	1.82 (1.47-2.27)	<.0001	1.63 (1.3-2.05)	<.0001	1.63 (1.3-2.05)	<.01	190/5515	3.45%	158/2480	6.37%
Peripheral vascular disease	1.93 (1.69-2.2)	<.0001	1.57 (1.37-1.79)	<.0001	1.42 (1.24-1.63)	<.0001	1.41 (1.23-1.62)	<.01	520/5154	10.09%	395/2129	18.55%
Pneumonia	1.85 (1.58, 2.18)	<.0001	1.57 (1.33-1.86)	<.0001	1.45 (1.22-1.72)	<.0001	1.44 (1.21-1.71)	<.01	329/5454	6.03%	265/2430	10.91%
Pressure sores	1.73 (1.51-1.99)	<.0001	1.55 (1.34-1.79)	<.0001	1.42 (1.22-1.64)	<.0001	1.42 (1.23-1.65)	<.01	472/5320	8.87%	346/2329	14.86%
Pulmonary hypertension	1.91 (1.34-2.72)	<.0001	1.55 (1.08-2.22)	.02	1.28 (0.88-1.87)	.19	1.28 (0.88-1.86)	.20	66/5600	1.18%	57/2546	2.24%
Restrictive lung disease	1.39 (1.22, 1.58)	<.0001	1.22 (1.06-1.39)	.005	1.13 (0.98-1.3)	.09	1.13 (0.99-1.3)	.08	603/5039	11.97%	350/2152	16.26%
Sepsis	1.99 (1.69-2.35)	<.0001	1.75 (1.48-2.07)	<.0001	1.52 (1.28-1.8)	<.0001	1.52 (1.28-1.8)	<.01	313/5504	5.69%	268/2438	10.99%
Transient ischemic attack/ stroke	1.87 (1.57-2.21)	<.0001	1.52 (1.28-1.81)	<.0001	1.38 (1.15-1.65)	.0004	1.39 (1.16-1.66)	<.01	299/5309	5.63%	237/2314	10.24%
Urinary tract infection	1.49 (1.35-1.64)	<.0001	1.32 (1.19-1.45)	<.0001	1.27 (1.14-1.4)	<.0001	1.26 (1.14-1.4)	<.01	1221/3654	33.42%	626/1356	46.17%

Continued on next page

TABLE 4. Continued

Condition	Hazard ratios of T2D vs non-T2D							Event rate	
	Unadjusted model (95% CI)	*P*	Adjusted models[b] Model 2 (95% CI)	*P*	Model 3 (95% CI)	*P*	Model 4 (95% CI)	*P*	TSCI only[c]	TSCI and T2D[c]
Venous insufficiency with lower extremities	2.01 (1.24-3.24)	.004	1.67 (1.02-2.72)	.0415	1.3 (0.77-2.17)	.33	1.34 (0.8-2.25)	.27	35/5615 0.62%	32/2567 1.25%

[a]TSCI, traumatic spinal cord injury; T2d, type 2 diabetes.
[b]Interaction term T2D*Race was tested and not statistically significant. Model 2 is adjusted for demographic characteristic variables (age, sex, race and geographic region); Model 3: Model 2 + modified Elixhauser comorbidity index; Model 4: Model 2 + Model 3 + education + household income.
[c]Denominator reflects patients who did not have the condition of interest at baseline.
[d]Denominator for this condition is male patients only.

ranging from 1.39 for depression to 2.82 for hypertension (all $P<.001$). Fully adjusted survival models (see Table 4) reported that adults with TSCI and T2D have a greater hazard for most identified morbidities, with the exceptions of macular degeneration, pulmonary hypertension, Alzheimer's disease and related dementias, and venous insufficiency in the lower extremities, once adjusting for other long-term health conditions as identified by the modified Elixhauser index.

DISCUSSION

Research on adults living with TSCI has consistently found higher rates of T2D as compared with the non-SCI general population but has been limited in its ability to determine the effect of coexisting T2D on morbidity outcomes and the effects of the social determinants of health (including education, income, and race) and premorbid and comorbid conditions.[3,11-13] Our findings provide clear evidence that not only are adults with TSCI and T2D at increased risk for serious and life-threatening conditions but also that the risk continues to be clinically meaningful for most of these conditions when controlling for race, sex, education, and income.

This cohort of private insurance beneficiaries with TSCI and T2D was diagnosed with secondary and long-term health conditions that were both serious and life-threatening at rates of approximately 1.5 to 2 times higher than that of nondiabetic adults with TSCI. Moreover, HRs (in Model 4) ranging from 1.2 to 2.54 indicate that the risk of experiencing these conditions remains significant even after controlling for both sociodemographic factors and other long-term health conditions. Of note, our use of HRs rather than odds ratios helps to reduce the effect of selection bias associated with the identified end point, as they represent risk over the follow-up period used for the study (in this case, 4 years).

Results from this study highlight the urgency for diabetes prevention and management among adults with TSCI. Unfortunately, these can be complicated for individuals with TSCI, as relevant screening and treatment approaches are often not informed by their unique needs. To begin with, the primary care physicians who are most often tasked with screening and

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managing diabetes often do not receive specialized education to do so.[14,15] Diabetes may be easily missed in individuals with TSCI owing to masking of common diabetic risk factors or symptoms, including normal weight obesity (ie, normal BMI with excess adiposity) and the loss of polyuria symptoms as a result of their catheter use.[9] Moreover, most physicians are not aware of the reduced caloric requirements and atypical nutritional needs of adults with TSCI, nor are they trained to address the diminished abilities of this population to engage in or benefit from regular physical activities.[16-19] Finally, management strategies that require fine motor movements to independently access glucose monitoring are likely to be inaccessible to a significant portion of adults with TSCI.

Strengths and Weaknesses

A major strength of this study is the large and longitudinal sample of adults living with TSCI. It can be challenging to gather data on these clinical subpopulations, and little is known about the effect of diabetes among individuals with TSCI at the population level. Moreover, most large administrative claims databases do not contain some socioeconomic indicators such as net worth, race, and location (division). However, in this study, we were able to use a national sample to provide incidence estimates and adjusted hazards for serious and life-threatening conditions while considering various sociodemographic variables. Finally, although clinical trials may be considered the gold standard in clinical research, cohort studies are less expensive, include broader patient populations, and are more efficient.

Our study also has several limitations that should be acknowledged. First, we were unable to determine the severity of disability or spinal level of TSCI through claims-based data. However, we suspect that our sample may be more reflective of a healthier, higher-functioning segment of the TSCI population, because they had to be enrolled in private insurance, either by purchasing their own insurance, or by being covered through employment or marriage to someone who had private insurance. Therefore, results and comparisons to adults without TSCI are likely conservative estimates, and the true extent of morbidity may be underestimated in this study. Because our patient sample includes those with 4 or more years of continuous insurance enrollment in the follow-up period, it is conceivable that immortal time bias may be evident. Furthermore, because of a lack of death information in the study, we were unable to consider death as a competing risk. Reasons for disenrollment from their insurance plan are not documented and are sufficiently heterogeneous (eg, death, loss of insurance, conversion of insurance to another private payer, and conversion to public insurance). Moreover, by using administrative data, we were unable to adjust for issues like BMI or obesity, both of which are known predictors of T2D.

Of importance, administrative claims data may be susceptible to inaccurate coding of medical diagnoses, such as TSCI and long-term diseases, which may affect our incidence estimates. Although validation studies have shown that using greater than 1 claim for a medical condition improves the ability to identify beneficiaries with that medical condition,[20,21] single claim-based algorithms have been reported to have moderate to high positive predictive value (~80%) or specificity (~96%).[20,22,23] However, the accuracy of identifying medical conditions using claims data depends on the number of years for the study period[22] and the medical condition examined.[20,22-24] Finally, we cannot rule out time-varying confounding because baseline measurements of all covariates were included in our final models. Thus, whether having a TSCI causes an elevated risk for earlier-onset morbidity or if changes in other health parameters (eg, diabetes, a known predictor of morbidity) themselves are a cause of poorer health, is an interesting topic. Thus, we were unable to determine if other competing risks or unmeasured confounding (ie, other risk factors [eg, family history of health disorders, lack of physical activity, poor glycemic control, and loss of functional independence]) may have influenced the observed findings. This would lend credence to additional follow-up work to understand the care pathway to success for these patients.

CONCLUSION

Adults with TSCI and T2D have an elevated risk of developing a variety of serious and life-threatening morbidities compared with privately insured beneficiaries with TSCI and

without T2D. Individuals with TSCI frequently use health care services as part of their routine clinical care. Therefore, increasing clinical awareness of the effect of T2D and its risks among adults with TSCI, improving clinical screening strategies, providing accessible diabetes monitoring equipment, and developing efficient referral resources for coordinated care may help reduce morbidity and mortality in this high-need population.

POTENTIAL COMPETING INTERESTS

The authors report no competing interests.

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SUPPLEMENTAL ONLINE MATERIAL

Supplemental material can be found online at http://www.mcpiqojournal.org. Supplemental material attached to journal articles has not been edited, and the authors take responsibility for the accuracy of all data.

Abbreviations and Acronyms: **HR,** hazard ratio; **ICD,** International Classification of Disease; **TSCI,** traumatic spinal cord injury; **T2D,** type 2 diabetes

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