Research Article

The lifetime cost of spinal cord injury in Ontario, Canada: A population-based study from the perspective of the public health care payer

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Objective: To determine the publicly funded health care system lifetime cost-of-illness of spinal cord injury (SCI) from the perspective of the Ontario Ministry of Health and Long-term Care.

Methods: Individuals hospitalized for their first SCI between the years 2005 and 2011 were identified and their health care costs were calculated using Ontario administrative health care data. From this information, lifetime costs were estimated using phase-based costing methods. The spinal cord injured cohort was matched to a non-spinal cord injured using propensity score matching. Net costs were determined by calculating the difference in costs between the two matched groups. Net costs were also presented for subgroups stratified by demographic characteristics.

Results: A total of 1,716 individuals with SCI were identified and matched in our study. The net lifetime cost of SCI was \$336,000 per person. Much of the costs were observed in the first year post-SCI. The lifetime cost of SCI for individuals with a concurrent pressure ulcer at the initial hospitalization rises to \$479,600. Costs were also higher for individuals with cervical or thoracic injury or requiring inpatient rehabilitation.

Conclusions: Spinal cord injury is a substantial burden to the health care system. Our results are limited to the direct health care costs from the publicly funded health care payer perspective. Further analysis with a broader perspective is needed to understand the full economic impact of this catastrophic condition.

Keywords: Costs and cost analysis, Spinal cord injuries

Introduction

Spinal cord injury (SCI) is a traumatic life-changing event that has a significant impact on the affected individual as well as the health system. This includes hospitalizations, frequent visits for rehabilitation and medical care^{1,2} and assistance with activities of daily living over a lifetime.^{3,4} In a 6-year follow-up of an SCI cohort in Alberta, individuals had more re-hospitalizations, family physician visits and home care services compared to a matched non-SCI cohort.² In Ontario, an

individual with traumatic SCI will have on average 31.7 physician visits (family and specialist) in their first year alone. This translates to an increase in health care costs for people with SCI. A recent review of SCI cost-of-illness studies⁵ identified that most studies focused on cross-sectional SCI cost per person for a specific setting,^{6–10} cross-sectional total SCI cost for a health care system^{11,12} or on specific periods of time post-injury.^{13,14} In the US, total cost for a hypothetical individual injured at age 25 was estimated to be between \$1 and \$3.5 million, \$0.85 to \$2.1 million if the individual is injured at 50 years of age depending

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on severity of injury.¹⁵ In a recent Canadian study, total lifetime cost for an individual injured at the age of 35 years was between \$1.5 million for an individual with an incomplete paraplegic injury and \$3.0 million for a tetraplegic with a complete injury from a societal perspective.¹⁶ Both the US and Canadian studies provide valuable information on the cost of SCI. However, there remain a few gaps in understanding the lifetime cost of SCI. First, no studies have examined the lifetime cost of SCI exclusively from a publicly funded health care system perspective. In the Canadian study, hospitalization costs were based on data from Alberta, but all other costs were based on U.S. data.¹⁶ Cost and care patterns may differ from the extensively private health care system in the U.S. compared to Canada. Second, studies presenting lifetime costs for SCI have presented costs for the SCI cohort without a matched non-SCI cohort. As a result, total health care costs of the SCI cohort are presented, but the attributable cost of SCI is unknown. To address these knowledge gaps, the purpose of our study was to estimate the mean public health care payer net cost for an individual with SCI in Ontario over a lifetime. We also examined whether patient characteristics have an impact on lifetime costs.

Methods

Our study will examine the cost of SCI from the perspective of the public payer in Ontario, the Ministry of Health and Long-term Care (MOHLTC). The MOHLTC funds and administers the delivery of health care to all residents of Ontario (with the exception of First Nations and Inuit individuals). With the provision of health care services in Ontario, data are collected on the services administered. This administrative data is used by the MOHLTC decision-makers for the arrangement of health care and the funding of health care providers and facilities. An expanded review of the use and history of administrative data in Canada have been published elsewhere. This study included information on demographics, acute care, ambulatory care, residential and hospital-based continuing care, home care, inpatient rehabilitation, physician billing for visits, diagnostic and medical procedures, and drugs for individuals over 65 years of age. All these databases are housed at the Institute for Clinical Evaluative Sciences (ICES). This organization is non-profit and independent of the provincial government. The ability of ICES to link the different databases by patient using encrypted identifiers allow researchers to analyze health care utilization at the patient level over time. Administrative data was collected through the Ontario Cancer Data Linkage Program (CD-link).

CD-link is an initiative of the Ontario Institute for Cancer Research/Cancer Care Ontario Health Services Research Program, whereby risk-reduced coded data from the ICES Data Repository managed by the Institute for Clinical Evaluative Sciences is provided directly to Researchers with the protections of a comprehensive Data Use Agreement.

Spinal cord injured individuals were identified through administrative data by identifying all inpatient hospital discharge abstracts where the most responsible diagnosis for inpatient admission was traumatic spinal cord injury. International Classification of Disease 10th revision (ICD-10) diagnosis codes for identifying SCI were based on a validated algorithm with the best combination of sensitivity and specificity¹⁷ compared to other combinations of codes. Individuals identified in the hospital inpatient discharge abstracts between April 1, 2005 and March 31, 2011 were followed until death or until March 31, 2012.

The SCI cohort was matched to a non-SCI cohort based on a 5% random sample of the Ontario general population using propensity score methods. Age group, sex, neighbourhood income quintile, index hospitalization year, disease co-morbidity (using Johns Hopkins Adjusted Clinical Groups case-mix system¹⁸) and rurality at baseline were included in the propensity score calculation. Individuals in the SCI cohort were matched to the non-SCI cohort by their propensity score using calipers of width 0.2 of the standard deviation of the logit of the propensity score.¹⁹ The balance of covariates between the matched cohort was observed by calculating standardized mean differences between the two cohorts. The Johns Hopkins Adjusted Clinical groups case-mix system describe health care utilization and predicts future utilization and costs. This case-mix system is categorizes health status through mutually exclusive Aggregated Diagnosis Group, using acute inpatient hospitalization diagnoses and physician visits from the last two years prior to SCI. We used a collapsed version of the Aggregated Diagnosis Group that compresses 32 groups to 12 groups (Collapsed Aggregate Diagnostic Group) for our analysis for easier computation.

The health care service utilization of the SCI cohort was translated to costs using different methods. The Canadian Institute for Health Information assigns a case-mix service utilization weight for every ambulatory care visits, inpatient admissions and rehabilitation in Ontario, based on the disease profile, services provided and length of stay reported at discharge. Conversion of the weights to cost is provided by published sources through a cost per weighted case.²⁰ Length of stay in a

long-term care facility was calculated indirectly by identifying the presence and absence 2 consecutive long-term flags in the medication database. Long-term care costs were calculated by multiplying the length of stay at a facility with an estimated cost per diem.²⁰ Medication fill, laboratory test, diagnostic test, physician visit costs and home care service costs were provided by the administrative database. Where home care information was not available, costs were calculated by consolidating the hours of services provided by the different service providers with estimates of hourly wages as reported by the Government of Canada Job Bank.²¹

Net cost was estimated by subtracting the mean total lifetime cost for the SCI cohort from the lifetime cost of the non-SCI cohort. We used phase-based methods to measure lifetime costs.^{22,23} Prior studies have observed that cost trajectories produce a “U” shape with increased costs at the period following disease diagnosis, consistently lower costs during a stable phase and then another increased cost phase just prior to death.^{22–27} The phase-based approach allows a researcher to calculating lifetime costs while adjusting for censoring and elevated costs prior to death. Further details on the calculation of lifetime costs are presented in the Appendix. Bootstrapping methods were used to account for the uncertainty in estimating lifetime costs. Further details available in the Appendix.

Mean costs at 30-day intervals from the hospital admission for SCI until death or censored was plotted for the entire cohort to explore the potential phases in the cost trajectory for SCI. Phases were determined by observing the changes in 30-day costs over time and identifying points where costs appear to suddenly increase, decrease or stabilize. Similar to past studies in other disease areas,^{22–27} 3 phases were expected, a post-SCI injury cost phase, a death phase that occurs shortly before death and a maintenance phase between the post-injury and death phase when costs are relatively stable.

Means and 95% confidence intervals were calculated and presented for each costing phases. Results were stratified by demographic variables such as sex, income quintile, rurality, concurrent traumatic brain injury (ICD-10 code S06), concurrent pressure ulcer (ICD-10 code L89) at initial hospitalization, whether the individual received inpatient rehabilitation and location of injury. Mean total lifetime cost was presented for SCI, non-SCI cohorts and net (difference between SCI and non-SCI costs) discounted at 3% per annum. Net costs discounted at 0% and 5% are also presented. Five-year unadjusted follow-up net costs in the SCI cohort was calculated and compared to the 5-year net costs

calculated using phase based costing methods to observe the difference between costs calculated from observed data versus costs calculated from our estimated survival curve.

Results

In total 1,868 individuals were identified as having SCI from April 1, 2005 to March 31, 2011. Propensity score matching paired a total of 1,716 with individuals from the non-SCI cohort. The SCI cohort was well matched to the non-SCI cohort as observed by standardized mean differences falling below 0.1 for all demographic variables Table 1. Pre-match cohort characteristics can be found in Appendix Table A6. The SCI cohort was predominantly male, with slightly more individuals in the lower income quintiles. About 12% had a concurrent traumatic brain injury at initial hospitalization. Most individuals had an injury of the cervical spine (68%) followed by thoracic (20%) and lumbar (11%). A total of

Table 1 Proportions and standardized mean differences between SCI and non-SCI cohorts after propensity score matching.

Variable	Post-match		
	SCI	non-SCI	Standardized mean differences
Female	0.24	0.23	0.02
Income Quintile 1	0.22	0.22	-0.01
Income Quintile 2	0.22	0.21	0.03
Income Quintile 3	0.19	0.20	0.00
Income Quintile 4	0.19	0.20	-0.02
Income Quintile 5	0.18	0.18	-0.01
Rural residence	0.16	0.16	0.02
Age group 18-34	0.18	0.19	-0.04
Age group 35-49	0.24	0.23	0.02
Age group 50-64	0.26	0.27	-0.03
Age group 65-79	0.22	0.21	0.04
Age group 80 older	0.09	0.08	0.02
CADG 1	0.96	0.94	0.08
CADG 2	0.98	0.97	0.08
CADG 3	0.71	0.70	0.03
CADG 4	0.05	0.05	0.00
CADG 5	0.53	0.52	0.04
CADG 6	0.63	0.62	0.04
CADG 7	0.14	0.14	0.00
CADG 8	0.13	0.12	0.03
CADG 9	0.24	0.23	0.04
CADG 10	0.47	0.47	0.01
CADG 11	0.50	0.49	0.03
CADG 12	0.01	0.01	0.02
2005	0.16	0.16	-0.00
2006	0.14	0.13	0.03
2007	0.15	0.14	0.02
2008	0.14	0.14	-0.01
2009	0.12	0.12	0.02
2010	0.14	0.15	-0.04
2011	0.15	0.16	-0.01

CADG, collapse aggregated diagnostic group.

Figure 1 Adjusted mean thirty-day costs post-spinal cord injury for individuals with at least 2 years of follow-up.

46% of individuals in our cohort required inpatient rehabilitation.

Adjusting for mortality, costs appear to decrease over time post-injury (Figure 1). Costs post-injury phase post-SCI was estimated to be a total of 11 thirty-day periods in duration. From this point forward, costs remain stable with 30-day costs ranging between \$1,600 and \$1,900. Given the substantial costs in the first 60 days post-SCI relative to the rest of the post-injury phase, the post-injury phase was further stratified to the first 60-day period and the following (third to eleventh) 30-day periods. The costs in the 30-day periods prior to death are presented in Figure 2. The 30-day costs remain consistently between \$2,100 and \$2,500 until 6 months prior to death when costs begin to increase. From these results the pre-death phase was estimated to be 6 thirty-day periods in duration.

Figure 2 Mean thirty-day costs prior to death for spinal cord injury individuals with at least 2 years of follow-up.

The mean 30-day cost for different cost phases is presented in Table 2. The mean 30-day cost for the first 60 days post-SCI injury was almost 6 times higher than the rest of the first year. The maintenance period mean 30-day cost in the SCI cohort was more than 3 times the cost of the non-SCI cohort. Mean 30-day cost in the 90 days prior to death was 7 times higher in the SCI versus non-SCI cohort. In the SCI cohort, acute inpatient hospitalization was the main cost driver for all cost phases. For the post-injury period, inpatient rehabilitation was another relevant cost driver. Emergency department and outpatient hospital visits were additional relevant cost drivers observed in the maintenance period. The proportion of the total costs for each phase contributed by each of the different health care settings is presented in Table 3.

The survival curve (using a Kaplan-Meier curve) for the SCI cohort and non-SCI cohort is presented in Figure 3. The Weibull distribution was the best fit for extrapolating both SCI and non-SCI cohorts and was used to calculate lifetime costs.

The net lifetime cost of SCI per person is \$336,100 (95% CI, \$326,300-\$344,900). The lifetime costs were higher for individuals with a concurrent pressure ulcer and for individuals requiring inpatient rehabilitation (Table 4). SCI was more costly if the individual was younger at the onset of SCI, had a concurrent traumatic brain injury or had a thoracic injury. The net lifetime costs calculated using 0% and 5% discount rates are presented in Table 5.

The 5-year mean net cost of SCI was \$178,374 (95% CI, \$173,835-\$182,302) (no discounting). This represents 39% of the total lifetime net cost of SCI. In comparison, the unadjusted 5-year mean net cost of SCI was \$197,611 (95% CI, \$176,977-\$219,744).

Discussion

The results of our study present total health care costs for SCI individuals to be almost seven and a half times higher than non-SCI individuals with an observed net cost of \$336,100 CAD from the perspective of the Ontario MOHLTC. Most of the higher costs appear to occur in the first year post injury and in the period prior to death. Approximately 40% of estimated lifetime costs occurred in the first 5 years post-injury.

The number of SCI individuals identified in our study translates to an incidence of 24 per million using historical Ontario population estimates.²⁸ This is much lower than the Canadian incidence estimated previously by Noonan and colleagues (41 per million).²⁹ The discrepancy may be due to the incidence estimated by Noonan and colleagues representing all ages, while

Table 2 Mean 30-day period costs for SCI and matched non-SCI individuals at different cost phases.

Phase	Mean (95% CI) [n], 30-day period cost	
	SCI	Non-SCI
Post-injury period (0-60 days after injury)(0-330 days for non-SCI cohort)	\$30,500 (\$28,900-\$32,100) [1,389]	\$330 (\$250-\$390) [1,652]
Post-injury period (61-330 days after injury)	\$7,400 (\$6,700-\$8,200) [1,389]	
Maintenance period	\$1,500 (\$1,200-\$1,700) [1,280]	\$360 (\$280-\$450) [1,246]
Pre-death period (0-150 days before death)	\$6,200 (\$5,400-\$7,100) [466]	\$690 (\$523-\$845) [137]

Table 3 Distribution of SCI costs by resource category for the four phases of care.

Phase	Proportion of total cost of phase			
	Post-injury period (0-60 days after injury)	Post-injury period (61-360 days after injury)	Maintenance period	Pre-death period (0-90 days before death)
Acute inpatient hospitalization	0.56 (\$17,114)	0.20 (\$1,480)	0.23 (\$332)	0.72 (\$4,431)
Ambulatory care visit	0.03 (\$758)	0.08 (\$630)	0.34 (\$500)	0.06 (\$392)
Inpatient rehabilitation	0.38 (\$11,464)	0.63 (\$4,680)	0.11 (\$160)	0.13 (\$805)
Same day outpatient surgery	<0.01 (\$15)	<0.01 (\$13)	0.01 (\$12)	<0.01 (\$8)
Home Care	<0.01 (\$62)	0.02 (\$130)	0.06 (\$86)	0.01 (\$68)
Drugs	<0.01 (\$32)	0.01 (\$93)	0.07 (\$107)	0.01 (\$70)
Physician visits/ Diagnostic test	0.03 (\$984)	0.04 (\$286)	0.08 (\$123)	0.05 (\$310)
Long term care	<0.01 (\$37)	0.02 (\$131)	0.10 (\$148)	0.02 (\$112)

our study was limited to individuals 18 years and older. Also, as noted by Noonan and colleagues, their estimates were based on individuals from the province of Alberta, a population that is younger and have a higher proportion of males compared to the rest of Canada. Thus, the estimated incidence may be an overestimate. Our estimates are in line with the incidence rates reported by Couris and colleagues (23.1 to 24.2 per million) in an Ontario population also using the

same data source.³⁰ In a comparison with prior studies, the direct Canadian SCI health care lifetime cost observed by Krueger *et al.* (\$428,000 to \$162,000)¹⁶ were in line with the observations in our study. We could not compare the results of our analysis with the lifetime cost estimates from a US cohort¹⁵ since their study included resource categories (attendant care, equipment of environmental modifications) not included in our analysis. In a study by Dryden *et al.*, the net cost of SCI inflated to 2015 Canadian dollars³¹ is \$177,300 in the first year for complete injury, \$62,044 for incomplete and \$8,000 for complete injury, \$4,400 for incomplete in the following years. The first year results of our study of \$125,100 (\$129,100 ((2 x \$30,500) + (9 x \$7,400) + \$1,500) less \$4,000 (\$330 x 12)) in comparison would fall between the first year cost of complete and incomplete injury. Our estimated second year cost, using the maintenance cost observed in our study, is \$13,700 (\$18,000 (\$1,500 x 12) less \$4,320 (\$430 x 12)) which results in second year cost that is higher than Dryden's study. This may be a result of changes in patterns of health care since the early 1990s with shifting care from the acute care setting to the community setting. In another Ontario study of the total cost of SCI per person in an incident SCI cohort injured between fiscal years 2003/4 and 2005/6, annual first year costs were observed to be between \$102,900 and \$123,674.¹² Our estimated first

Figure 3 Kaplan-Meier plot of overall survival of SCI and matched non-SCI cohorts.

Table 4 Mean lifetime cost per person for SCI and matched non-SCI individuals.

Cohort	SCI Mean (95% CI)	Non-SCI Mean (95% CI)	Net cost Mean (95% CI)
All	\$388,000 (\$378,600-\$397,900)	\$51,800 (\$50,500-\$53,300)	\$336,100 (\$326,300-\$344,900)
PU at initial hospitalization	\$531,700 (\$519,200-\$544,200)	\$52,300 (\$50,900-\$53,700)	\$479,600 (\$466,400-\$491,900)
No PU at initial hospitalization	\$360,900 (\$352,500-\$369,000)	\$52,100 (\$50,600-\$53,700)	\$308,800 (\$300,400-\$316,900)
Male	\$390,900 (\$382,900-\$399,700)	\$46,700 (\$45,500-\$48,000)	\$344,300 (\$336,600-\$351,800)
Female	\$333,600 (\$326,100-\$341,500)	\$55,900 (\$54,500-\$57,400)	\$277,800 (\$269,900-\$285,900)
Required inpatient rehabilitation	\$505,900 (\$497,500-\$515,100)	\$49,600 (\$48,200-\$50,900)	\$456,200 (\$447,300-\$464,500)
No inpatient rehabilitation required	\$294,300 (\$288,000-\$300,900)	\$53,900 (\$52,500-\$55,300)	\$240,300 (\$233,000-\$247,200)
Rural residence			
Yes	\$419,100 (\$409,600-\$428,900)	\$43,400 (\$42,100-\$44,500)	\$375,800 (\$366,900-\$385,500)
No	\$376,800 (\$368,400-\$385,400)	\$55,300 (\$53,700-\$56,800)	\$321,400 (\$312,000-\$329,300)
Age group			
18-34	\$408,000 (\$399,800-\$417,600)	\$64,500 (\$62,600-\$66,200)	\$343,400 (\$334,200-\$352,500)
35-49	\$422,000 (\$412,500-\$431,300)	\$47,400 (\$46,000-\$48,700)	\$374,700 (\$365,500-\$383,700)
50-64	\$400,800 (\$392,200-\$409,400)	\$45,200 (\$43,900-\$46,400)	\$355,500 (\$347,000-\$364,000)
65-79	\$286,100 (\$279,600-\$292,600)	\$45,800 (\$44,600-\$46,900)	\$240,200 (\$233,800-\$246,600)
80 to above	\$221,400 (\$215,200-\$227,800)	\$44,900 (\$43,600-\$46,000)	\$176,600 (\$170,000-\$182,800)
Location of injury			
Cervical injury	\$379,400 (\$370,200-\$389,100)	\$49,600 (\$48,300-\$51,000)	\$329,600 (\$320,300-\$338,200)
Thoracic injury	\$413,800 (\$404,500-\$422,900)	\$48,800 (\$47,500-\$50,000)	\$364,900 (\$355,600-\$373,500)
Lumbar injury	\$273,700 (\$267,100-\$280,200)	\$50,100 (\$48,800-\$51,500)	\$223,700 (\$216,800-\$230,300)

year cost is slightly higher than the upper limit of these values.

Several studies in other disease areas have used similar methods in an Ontario cohort to calculate health care costs. In an analysis of the phase-based costs of all different types of cancer, the initial phase costs for the first 6 months for SCI was twice the cost of the highest cancer cost identified (esophagus) (\$75,908 vs. \$32,500).³² The annual maintenance phase net costs of SCI was similar to the highest maintenance cancer

costs (myeloma) (\$12,840 vs. \$11,000 to \$12,000).³²

The net costs during the last year of life for SCI (\$31,745) were similar to the net cost of leukemia in male patients (\$30,000) but lower than the pre-death cost of cancer of the testis (\$45,000) and brain (\$48,000).³² When compared to hepatocellular carcinoma, initial phase 30-day costs for SCI was more than 3 times higher between 0-60 days post-injury (\$28,600 vs. \$7,812), but lower in 30-day costs after the first 61 days (\$5,160 vs. \$7,812).³³ The pre-death

Table 5 Mean lifetime cost per person for individuals post-SCI and for matched non-SCI individuals at 0, 3% and 5% discount rates.

	Net cost		
	0%	3%	5%
All	\$459,700 (\$443,700-\$476,700)	\$336,100 (\$326,300-\$344,900)	\$290,400 (\$284,000-\$296,800)
PU at initial hospitalization	\$611,600 (\$589,900-\$634,700)	\$479,600 (\$466,400-\$491,900)	\$432,000 (\$422,900-\$441,400)
No PU at initial hospitalization	\$419,300 (\$403,000-\$433,800)	\$308,800 (\$300,400-\$316,900)	\$269,200 (\$262,800-\$275,400)
Male	\$463,000 (\$448,300-\$478,000)	\$344,300 (\$336,600-\$351,800)	\$294,300 (\$277,400-\$290,400)
Female	\$358,100 (\$344,400-\$371,400)	\$277,800 (\$269,900-\$285,900)	\$251,200 (\$244,400-\$258,000)
Required inpatient rehabilitation	\$707,800 (\$689,700-\$725,700)	\$456,100 (\$447,300-\$464,400)	\$372,100 (\$365,500-\$378,300)
No inpatient rehabilitation required	\$307,400 (\$296,100-\$318,200)	\$240,200 (\$233,000-\$247,200)	\$214,800 (\$209,300-\$220,400)
Rural residence			
Yes	\$570,200 (\$550,600-\$588,200)	\$375,800 (\$366,900-\$385,500)	\$315,100 (\$308,400-\$322,300)
No	\$425,400 (\$410,300-\$440,900)	\$321,300 (\$312,000-\$329,300)	\$285,100 (\$278,500-\$292,000)
Age group			
18-34	\$465,800 (\$450,600-\$481,600)	\$343,300 (\$334,200-\$352,500)	\$306,800 (\$299,500-\$313,500)
35-49	\$598,600 (\$578,800-\$618,700)	\$374,800 (\$365,500-\$383,700)	\$306,000 (\$299,600-\$312,000)
50-64	\$520,400 (\$503,700-\$537,500)	\$355,500 (\$347,000-\$364,000)	\$300,900 (\$294,200-\$307,300)
65-79	\$285,300 (\$275,400-\$296,200)	\$240,200 (\$233,800-\$246,600)	\$218,600 (\$212,800-\$224,400)
80 to above	\$179,800 (\$172,200-\$187,300)	\$176,600 (\$170,000-\$182,800)	\$168,000 (\$161,900-\$174,100)
Location of injury			
Cervical injury	\$455,700 (\$439,100-\$472,600)	\$329,600 (\$320,300-\$338,200)	\$286,400 (\$279,400-\$292,900)
Thoracic injury	\$499,800 (\$483,200-\$516,000)	\$364,800 (\$355,600-\$373,500)	\$314,800 (\$307,400-\$321,500)
Lumbar injury	\$267,900 (\$257,700-\$277,800)	\$223,700 (\$216,800-\$230,300)	\$209,200 (\$203,500-\$214,700)

phase was 5 times lower for SCI compared to short-term survivors of hepatocellular carcinoma (\$5,730 vs. \$25,613) but higher compared to long-term survivors (\$5,730 vs. -\$452). The 30-day maintenance and pre-death net cost of SCI observed in our study was lower than individuals with *Clostridium difficile* infection (\$1,070 vs. \$1,843 and \$4,851 vs. \$9,963).³⁴ In summary, initial phase costs were higher than cancer care costs, maintenance phase costs were similar to the highest cancer costs but lower than *Clostridium difficile*, and pre-death phase costs were within the range of cancer care costs but lower than *Clostridium difficile*.

The cost drivers for SCI costs in the first year appear to be the initial cost of hospitalization and re-hospitalization as well as inpatient rehabilitation. After the first year, costs are driven mainly by re-hospitalizations and emergency department visits/outpatient clinic visits. In an earlier study by Munce *et al.*, inpatient acute care costs was 35% of first year costs, which is in between the 30% to 60% of costs observed in our study. Inpatient rehabilitation costs were observed to represent 58% of first year costs in their study, which is in between the results of our study (38% in the first two 30-day periods, 63% in the following ten 30-day periods).

Analyzing lifetime costs stratified by demographic factors, we observed that individuals requiring inpatient rehabilitation, had a concurrent pressure ulcer or had a cervical or thoracic injury had higher costs. Individuals who require inpatient rehabilitation and have a pressure ulcer in the initial hospitalization likely have a more serious SCI injury and require more health care compared to individuals who do not. A concurrent pressure ulcer, for instance, may double the length of stay of the initial hospitalization for SCI.³⁵ Unfortunately, the data source for our study did not have information on SCI severity.

Phase-based costing methodology remains one of the most powerful tools for projecting lifetime costs. In a comparison of this methodology versus other lifetime cost estimation methods, phase-based costing provides similar results.²⁴ This study has several strengths. First, this study includes a large number of health care cost components. The comprehensiveness of the Ontario administrative health care data, makes it a viable data source for evaluating cost-of-illness over various health care settings since it links epidemiological data with resource utilization of health care services attached to costs and demographic information. Second, mortality was included in our lifetime calculation of SCI by extrapolating survival data from our SCI cohort. This ensured that the survival curve extrapolated was based

on data from our study cohort. Third, net costs were determined by comparing the SCI cohort with a non-SCI matched on numerous demographic variables. We matched for comorbidities using the Johns Hopkins ACG System. This system predicts future health care resource use by grouping individuals based on the presence of clusters of comorbidities.³⁶ The result is a strongly matched cohort in which to calculate costs attributed to SCI. A more detailed explanation of this comorbidity measure, including its validity has been presented elsewhere.³⁷

There are several study limitations that warrant caution when interpreting the data. This study was based on data from publicly funded health system administrative databases. These databases are primarily developed to inform government in the provision of health care. This results in limitations to the capture of the SCI cohort as well as the capture of health care resources. First, although the diagnosis code algorithm for capturing SCI cases has been validated,¹⁷ there will still be cases that will be missed due to transcription errors. Second, although most direct health care costs are included in the administrative databases, some health care resources were not captured. If an individual has a concurrent traumatic brain injury, the cost of attendant care is paid for through a separate funding envelope from the Ministry of Health and Long-term Care that was not captured in our datasets. Information that is also not captured include attendant care provided by community groups,³⁸ or hired directly by the SCI individual through the Direct Funding Program. The Ontario administrative data also does not capture outpatient rehabilitation, physician payments outside of fee-for-service and prescription drugs for those under 65 years of age. Third, the costs that were captured represent early SCI patients (6 years post-injury) and long-term cost projections may not accurately reflect individuals having lived with SCI for more than 6 years. Individuals with SCI are at a higher risk for other complications later in life that may increase health care costs such as respiratory issues, orthostatic hypotension, autonomic dysreflexia, neurogenic bowel, spasticity and osteoporosis.³⁹ Our analysis did not capture long-term complications and may underestimate the true lifetime SCI costs. Fourth, important information regarding the individual's injury severity (level of neurological impairment) and functional independence after rehabilitation was not available in administrative data. As a result, we could not examine the impact that these factors have on the estimated economic burden of SCI. Finally, although we explored the differences in costs between SCI

subgroups, these differences are likely a result of different demographic characteristics in the subgroups. To fully explore the additional costs for individuals with concurrent pressure ulcer or in need of inpatient rehabilitation, individuals in these subgroups would need to be matched with SCI individuals without these factors. An adequate match would be difficult to obtain due to the small cohort size in our study. A larger population database would be required to properly study costs in SCI subgroups.

Our study provides a grand total health care cost that should be expected for each new case of SCI in Ontario from the perspective of the MOHLTC. This does not include costs from other perspectives such as social assistance (including home and vehicle modification), private insurance and patient out-of-pocket costs. Though the number of new cases of SCI reported in Ontario is not large (in our study, over 1,700 new cases identified over 6 years), the total net cost per SCI case suggests that this condition requires special attention. Interestingly, our SCI cohort appears to skew slightly towards the older population when compared to the pre-matched non-SCI population. This is in line with observations that the age-adjusted incidence of SCI for individuals over the age of 65 is higher than young groups.⁴⁰ Our study observed that 30% of new cases of SCI are over the age of 65. This is higher than the rates reported in Canada in the late 1990s.⁴¹ It is predicted that the proportion of individuals experiencing an SCI at a later age will continue to grow as the population ages.⁴² The majority of SCI in the older population are a result of falls.^{40,41} Continual support for public policy focused on preventing SCI in younger individuals and additional investment in programs to raise awareness of fall prevention in the older population will help reduce the substantial downstream financial burden of SCI freeing up limited resources to be used to treat other individuals requiring health care.

Conclusions

The results of our study show a lifetime increase in publicly funded health care costs for an individual with SCI that is almost eight times that of a similar individual without SCI. The net lifetime cost of SCI is \$336,100 for an average individual. These costs will increase when considering direct costs outside the jurisdiction of the Ontario MOHLTC, such as outpatient rehabilitation, pharmacological treatments, attendant care, home and vehicle modifications, vocational training, and indirect costs such as lost income and informal caregiver burden. With the inclusion of these costs, the lifetime

cost of SCI is expected to be substantially higher, again highlighting the catastrophic effects of this life-changing event.

Acknowledgement

The authors would like to acknowledge the Ontario Neurotrauma Foundation and the Rick Hansen Institute for providing funding for the doctoral work of the primary author. The authors would also like to acknowledge the Ontario Institute for Cancer Research and Cancer Care Ontario Health Services Research Program for funding the data extraction costs for this study.

Disclaimer statements

Contributors None.

Conflict of Interest: The authors report no conflicts of interest.

Ethics approval This study was approved by the University of Toronto Research Ethics Board.

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Appendices

Appendix A: additional table

An additional table that provides the demographic characteristics and standardized mean differences of the SCI and non-SCI cohort prior to matching.

Table A6 Proportions and standardized mean differences between SCI and non-SCI cohorts before propensity score matching.

Variable	Pre-match		Standardized mean differences
	SCI	non-SCI	
Female	0.24	0.51	-0.63
Male	0.76	0.49	0.63
Income Quintile 1	0.22	0.20	0.05
Income Quintile 2	0.22	0.20	0.04
Income Quintile 3	0.19	0.196	-0.02
Income Quintile 4	0.19	0.201	-0.02
Income Quintile 5	0.18	0.200	-0.05
Non rural	0.84	0.886	-0.13
Rural	0.16	0.11	0.13
Age group 18-34	0.18	0.28	-0.26
Age group 35-49	0.24	0.31	-0.15
Age group 50-64	0.26	0.24	0.05
Age group 65-79	0.22	0.12	0.23
Age group 80 older	0.09	0.05	0.15
CADG 1	0.96	0.66	1.49
CADG 2	0.98	0.61	3.09
CADG 3	0.71	0.52	0.41
CADG 4	0.05	0.05	0.01
CADG 5	0.53	0.22	0.64
CADG 6	0.63	0.40	0.50
CADG 7	0.14	0.04	0.29
CADG 8	0.13	0.08	0.17
CADG 9	0.24	0.07	0.41
CADG 10	0.47	0.27	0.44
CADG 11	0.50	0.41	0.49
CADG 12	0.01	0.04	-0.27
2005	0.16	0.14	0.07
2006	0.14	0.14	0.01
2007	0.15	0.14	0.02
2008	0.14	0.14	-0.02
2009	0.12	0.15	-0.07
2010	0.14	0.15	-0.03
2011	0.15	0.15	0.01

Appendix B: Technical appendix

Additional details on the development of lifetime survival curve and calculation of lifetime costs using the survival curve.

Additional details on the incorporation of uncertainty in the calculation of lifetime costs.

Calculation of lifetime costs using the survival curve

To model lifetime cost using mean costs for the different phases, a survival curve for the SCI cohort was constructed. This was accomplished by using mortality data collected in the administrative data. From this data, a Kaplan-Meier survival curve was created for the duration of the follow-up period post-SCI and lifetime survival was modelled by fitting common survival curve distributions²⁹. Using visual inspection and Akaike Information Criterion results, the distribution which best fit all curves was chosen to extrapolate the survival curve to a lifetime. The total lifetime cost was determined by calculating the probability that an individual would be in each phase at every 30-day period post initial hospital admission and multiplying each probability by the corresponding cost of the phase. The total lifetime cost was calculated by summing the total cost for each 30-day period.

Incorporating uncertainty into life time costs

We sampled from a gamma distribution calculated for the 30-day costs in each of the costing phases. This distribution is ideal for estimating uncertainty in cost estimates since it is confined between 0 and positive infinity and can be skewed to reflect the skewness of costing data.³⁰ To account for uncertainty of the survival curve, Choleski's decomposition was applied to determine the joint uncertainty of survival curve parameters and to calculate a distribution for all survival curve parameters.³⁰ This accounts for the correlation of survival between 30-day periods. Sampling from these distributions 1,000 times, a range of lifetime costs was calculated.