The economic burden of traumatic spinal cord injury in Canada

H. Krueger, PhD (1, 2); V. K. Noonan, PhD, PT (1, 3); L. M. Trenaman, BSc (2); P. Joshi, PhD (3); C. S. Rivers, PhD (3)

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Abstract

Introduction: The purpose of this study is to estimate the current lifetime economic burden of traumatic spinal cord injury (tSCI) in Canada from a societal perspective, including both direct and indirect costs, using an incidence-based approach.

Methods: Available resource use and cost information for complete/incomplete tetraplegia and paraplegia was applied to the estimated annual incidence of tSCI, by severity, in Canada.

Results: The estimated lifetime economic burden per individual with tSCI ranges from $1.5 million for incomplete paraplegia to $3.0 million for complete tetraplegia. The annual economic burden associated with 1389 new persons with tSCI surviving their initial hospitalization is estimated at $2.67 billion.

Conclusion: While the number of injuries per year in Canada is relatively small, the annual economic burden is substantial.

Keywords: *traumatic spinal cord injury, economic burden, morbidity, mortality*

Introduction

Traumatic spinal cord injuries (tSCI) exact an extensive burden on the injured individual, their family and carers, and society as a whole. In addition to the physical and psychosocial trauma, the economic burden is thought to be substantial, due to increased health care costs as well as higher rates of morbidity and premature mortality. Information on the lifetime economic burden following a tSCI, however, is limited, especially in Canada.

Existing literature on the costs of tSCI tends to focus on subgroups of tSCI patients (e.g. veterans,[1,2] those admitted to the United States Spinal Cord Injuries Model Systems hospitals,[3,4,5] and work-related injuries[6]), a particular aspect of the economic burden (e.g. rehabilitation and unplanned hospitalizations[7,8]) or a specific time frame following the tSCI.[9]

Two research groups, one in Canada[9,10,11] and the other in the United States,[12,13] have taken a population-based approach. The study from Alberta collected direct cost information for the first six years following a tSCI;[9,10,11] the U.S. study considered lifetime direct and indirect costs, but these are from 1988 and need to be updated. Direct costs tend to include injury-related expenditures by the health care system and by the patient and/or the caregiver(s).[12,13] Indirect costs ''refer to the value of potential output that is lost as a result of any reduction or elimination of work or other activity due to SCI. These costs are measured as the losses that occur due to the reduction in productivity that results from morbidity or mortality attributable to SCI.''[12,p12]

Both the Alberta and the U.S. studies found that a population-based approach yielded a significantly different mix of patients when compared with an institution-based approach.[10,12] That is, individuals with tSCI cared for by the U.S. Model System, for example, tend to have, on average, much more severe injuries compared with the general population of patients with tSCI.[12] This difference can have an important effect on estimating the economic burden of tSCI.

Further, as most of the existing literature is from the U.S. and differences between the U.S. and Canadian health care systems make comparison difficult, there is a need for research on costs from a Canadian perspective.

This study uses the best information available in the literature to model the current lifetime economic burden of tSCI in Canada based on a societal perspective.

Methods

We used data from a variety of published sources to develop a model of the lifetime economic burden of tSCI by injury severity. Whenever possible, we used data from Canadian population-based studies.[9,10,11] These were largely supplemented by data from the two U.S. population-based studies, one published in 1992[12,13] and the other in 1998[14] (see Table 1). Costs based on the Canadian study were adjusted to 2011 dollars based on the Health and Personal Care (HPC) component of the Canadian Consumer Price Index (CPI).[15] U.S. costs were adjusted to 2011 Canadian dollars by first converting them into equivalent Canadian dollars for the given year and then increasing them to 2011 Canadian dollars as above.

Author references:

1. University of British Columbia, Vancouver, British Columbia, Canada
2. H. Krueger & Associates Inc., Delta, British Columbia, Canada
3. Rick Hansen Institute, Vancouver, British Columbia, Canada

Correspondence: Carly Rivers, 6400 Blusson Spinal Cord Centre, 818 West 10th Avenue, Vancouver, BC V5Z 1M9; Tel.: 604-707 2171; Fax: 604-707 2121; Email: crivers@rickhanseninstitute.org

TABLE 1
Base model assumptions

Area of Focus	Values used				Sensitivity analysis	Source
	Tetraplegia		Paraplegia			
	Complete	Incomplete	Complete	Incomplete		
Direct Costs						
Initial hospitalization (acute and rehab)						
ALOS, days	153.0	49.0	123.0	42.2		Dryden et al. (2005)[9]
Cost, $	158 049	46 760	109 418	42 609		Dryden et al. (2005)[9]
Number of physician services	53	16	38	15		Dryden et al. (2005)[9]
Cost, $	10 989	3156	7131	3551		Dryden et al. (2005)[9]
Subsequent hospitalizations in year 1						
Average number of admissions	0.30	0.31	0.26	0.23		Dryden et al. (2004)[11]
ALOS per admission, days	10.1	8.6	8.7	5.2		Dryden et al. (2004)[11]
Cost per acute care day, $	1124	1124	1124	1124		Ontario Case Costing Initiative
Cost, $	3416	3036	2545	1321		Calculated
Subsequent annual hospitalizations						
Average number of admissions	0.30	0.31	0.26	0.23	+/- 25%	Dryden et al. (2004)[11]
ALOS per admission, days	10.1	8.6	8.7	5.2	+/- 25%	Dryden et al. (2004)[11]
Cost per acute care day, $	1124	1124	1124	1124		Ontario Case Costing Initiative[16]
Cost, $	3416	3036	2545	1321		Calculated
Annual HCP						
Number of physician visits	27.9	19.9	20.3	15.4	+/- 25%	Harvey et al. (1992)[13]
Number of non-physician visits[a]	88.1	82.1	34.3	17.8	+/- 25%	Harvey et al. (1992)[13]
Cost per visit, $	64.31	63.80	71.33	77.81	+/- 25%	Calculated
Cost, $	7460	6507	3895	2583		Berkowitz et al. (1992)[12]
Home modifications						
One-time cost, $						
Current residence	31 149	29 015	24 540	25 492		Berkowitz et al. (1998)[14]
Other residence[b]	9610	8912	9973	9701		Berkowitz et al. (1998)[14]
Annual Costs, $						
Prescription drugs	791	308	278	538		Berkowitz et al. (1992)[12]
Non-prescription items[c]	4867	4029	3376	2619		Berkowitz et al. (1992)[12]
Adaptive equipment (< 5 years)[d]	9724	6261	4890	3147		Harvey et al. (1992)[13]
Adaptive equipment (> 5 years)[d]	3695	2548	1578	885		Harvey et al. (1992)[13]
Vehicle modifications	1015	1015	1015	1015		Berkowitz et al. (1998)[14]
Annual institutional care						
% of SCI population in institutions	10.1	3.7	2.1	0.7		Berkowitz et al. (1992)[12]
Cost, $	1729.4	467.4	347.1	104.5		Berkowitz et al. (1992)[12]
Annual attendant care						
Hours per week	56.3	31.9	13.5	16.9	+/− 25%	Berkowitz et al. (1992)[12]
Hours per year	2928	1659	702	879		Calculated
% of hours paid for[e]	50	50	41	18		Berkowitz et al. (1992)[12]
Estimated cost per hour[f], $	17.52	17.52	17.52	17.52	+/− 25%	Statistics Canada[18]
Cost[f], $	51 292	29 062	12 299	15 397		Calculated
Indirect costs						
% early deaths (between injury and initial hospital discharge)	27.8		13.3			Dryden et al. (2003)[10]
Disability weighting	0.45	0.45	0.45	0.45	0.75, 0.65, 0.55, 0.45	Andresen et al. (1999)[20]

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TABLE 1 (continued)
Base model assumptions

Area of Focus	Values used				Sensitivity analysis	Source
	Tetraplegia		Paraplegia			
	Complete	Incomplete	Complete	Incomplete		
Life years lost (35-year-old SCI survivor)	19.05	5.70	12.50	5.70	25–45 year old SCI survivor	NSCISC Annual Statistical Report, 2009[21]
Value of a saved life year[g], $	47 834	47 834	47 834	47 834		Statistics Canada Survey of Labour, Income & Dynamics[19]
% of surviving SCI population	7.7	46.8	11.7	33.8		Dryden et al. (2005)[9]
Discount rate	2.0	2.0	2.0	2.0	0%–4.0%	

Abbreviations: ALOS, average length of stay; CPI, Consumer Price index; HPC, health and personal care; HCP, health care practitioner; SCI, spinal cord injury.

[a] Physiotherapists, occupational therapists, psychologists, nurses, chiropractors, etc.

[b] Includes other homes owned by the SCI survivor as well as modifications to homes of family and friends specifically to accommodate the person with SCI.

[c] Includes non-prescription pain medication, catheters, dressings and bandages, laxatives, vitamins, rubber gloves, etc.[12]

[d] Includes breathing / handling aides (e.g. ventilators, head pointers, mouth sticks, etc.), mobility aids (e.g. wheelchairs, braces, crutches, etc), bed / hygiene aids (e.g. hospital beds, special mattresses, bed or bath lifts, commode seats, etc.) and exercise and other miscellaneous items (e.g. exercise bikes, weights, special telephones, etc.)

[e] A proportion of the hours worked for which the person providing the service received remuneration.

[f] Based on the median Canadian hourly wage for "Assisting Occupations in Support of Health Services", 2005 value of $15.669 adjusted to 2011 using the HPC component of the CPI (+11.8%).[18]

[g] Based on the median Canadian earnings of full-year full-time workers, 2009 value of $45,600 (Survey of Labour, Income and Dynamics) adjusted to 2011 using the CPI (+4.9%).[19]

Direct costs

We derived costs associated with initial hospitalization from the work by Dryden et al.[9] in Alberta.

We calculated the cost per acute care day for hospitalizations following the initial hospitalization based on costs from the Ontario Case Costing Initiative[16] using a mix of in-patient admissions for diseases of the genitourinary system (47%), skin and subcutaneous tissue (35%) and the respiratory system (18%).[17] This approach was used because the majority of hospitalizations after an initial injury are for these three complications. We then applied the cost per acute care developed in this fashion in valuing all acute hospitalizations, including those for depression, substance abuse, etc.

Visits to non-physicians included services provided by physiotherapists, occupational therapists, psychologists, nurses, chiropractors, etc.[13] Home modifications included all those designed specifically to accommodate the person with SCI in both the principal and any secondary homes, in addition to the homes of family and friends.[14] Non-prescription items included non-prescription pain medication, catheters, dressings and bandages, laxatives, vitamins and rubber gloves.[12] Adaptive equipment includes breathing/handling aides (e.g. ventilators), mobility aids (e.g. wheelchairs, braces, crutches), bed/hygiene aids (e.g. hospital beds, special mattresses, bed or bath lifts, commode seats) and exercise and other miscellaneous items (e.g. exercise bikes, weights, special telephones).[13]

The cost per hour for attendant care was based on the median Canadian hourly wage for ''Assisting Occupations in Support of Health Services.''[18]

Indirect costs

We used a modified human-capital approach (in which unpaid time is explicitly valued) to calculate indirect costs; in this way, a quality-adjusted life year (QALY) was valued at $47 834 (the average Canadian annual wage rate in 2011)[19] regardless of the individual's age or work status. Life years lost were quality-adjusted based on a utility of 0.45, which has been reported for persons with SCI.[20] Thus, one year of life with an SCI would receive a value of 0.45 QALYs. The loss of 0.55 QALYs was thus valued at $26 309 (0.55 × $47 834). In this way, indirect costs would accumulate post-injury for persons living with SCI.

Life years lost associated with an SCI were based on the age and life expectancy based on injury severity derived from the 2009 National Spinal Cord Injury Statistical Center (NSCISC) Annual Statistical Report[21] and adjusted for differences in the life expectancy of the Canadian population.[22] That is, individuals with an SCI die sooner than if they did not have that injury, with the number of life years lost increasing with the severity of the injury. Each of these life years lost were assigned a value of $47 834.

The economic burden of tSCI in Canada was developed using an incidence-based approach. ''An incidence-based approach measures the (lifetime) costs associated with all new injuries occurring within a given period (usually a year), while a prevalence-based approach measures costs incurred by all SCI individuals alive in a given period.''[12,p14] We took the annual incidence of tSCI surviving hospitalization in Canada (1389) from Noonan et al.,[23] and derived the distribution of injury severity (106 [7.7%] with complete tetraplegia, 651 [46.8%] with incomplete tetraplegia, 163 [11.7%] with complete

paraplegia and 469 [33.8%] with incomplete paraplegia) from Dryden et al.[10]

All costs were discounted at an annual rate of 2%. The discount rate ''is the rate at which we devalue the costs incurring into the future.''[12,p168] This rate was varied from 0% to 4% in the sensitivity analysis.

Sensitivity analysis is frequently used in economic studies to vary key assumptions and determine if these changes have an important effect on the overall results. In this study, we applied sensitivity analyses to the major cost drivers including age at injury, disability weighting, discount rate, hospital admissions, health care practitioner (HCP) visits and attendant care (see Table 1).

Results

The estimated lifetime economic burden associated with a tSCI in Canada ranges from $1.47 million for a person with incomplete paraplegia to $3.03 million for one with complete tetraplegia (see Table 2). Of the total costs, direct costs represent between 44% and 51% in patients with paraplegia and between and 56% and 66% in patients with tetraplegia. Within direct costs, the most significant cost driver was the cost of attendant care following the injury. These costs alone ranged from $0.29 million to $1.02 million (38%–60% of direct costs). Hospitalization costs ranged from $0.08 million to $0.23 million (5%–13% of direct costs) while HCP costs ranged from $0.07 million to $0.15 million (10%–13% of direct costs).

The estimated annual economic burden associated with tSCI in Canada is $2.67 billion ($1.57 billion in direct costs and $1.10 billion in indirect costs; see Table 3). Costs associated with hospitalizations ($0.17 billion or 6.5% of total costs), HCP visits ($0.18 billion or 6.7%), equipment and home modifications ($0.31 billion or 11.6%) and attendant care ($0.87 billion or 32.7%) are the major direct cost drivers.

The results of the sensitivity analyses are summarized in Table 4. Costs are most sensitive to the choice of discount rate. Excluding any discounting (an effective

TABLE 2
Lifetime economic burden associated with spinal cord injury

	Injury occurring at age 35 years 2011 Canadian dollars, 2% Discount Rate							
	Tetraplegia				*Paraplegia*			
	Complete		Incomplete		Complete		Incomplete	
	$ Value	% of Total	$ Value	% of Total	$ Value	% of Total	$ Value	% of Total
Direct costs								
Health care								
Hospitalization	226 137	7.5	130 139	6.2	170 385	9.6	78 900	5.4
HCP	152 231	5.0	175 368	8.3	96 543	5.4	71 914	4.9
Prescription drugs	15 747	0.5	8443	0.4	18 929	1.1	8443	0.6
Subtotal health care	**394 115**	**13.0**	**313 951**	**14.9**	**285 857**	**16.0**	**159 256**	**10.8**
Equipment and modifications								
Non-prescription items	96 917	3.2	110 565	5.3	80 815	4.5	71 870	4.9
Adaptive equipment	102 921	3.4	88 014	4.2	53 840	3.0	35 257	2.4
Home modifications	40 759	1.3	37 927	1.8	34 513	1.9	35 193	2.4
Vehicle modifications	20 203	0.7	27 842	1.3	24 285	1.4	27 842	1.9
Subtotal equipment and modifications	**260 801**	**8.6**	**264 348**	**12.6**	**193 453**	**10.9**	**170 162**	**11.6**
Long-term care								
Institutional care	34 439	1.1	12 826	0.6	8308	0.5	2868	0.2
Attendant care	1 021 420	33.8	797 590	37.9	294 418	16.5	422 548	28.7
Subtotal long-term care	**1 055 859**	**34.9**	**810 417**	**38.5**	**302 726**	**17.0**	**425 416**	**28.9**
Total direct costs	**1 710 776**	**56.5**	**1 388 715**	**65.9**	**782 036**	**43.9**	**754 835**	**51.3**
Indirect costs								
Morbidity	428 655	14.2	590 746	28.1	515 279	28.9	590 746	40.1
Premature mortality	886 597	29.3	126 350	6.0	485 384	27.2	126 350	8.6
Total indirect costs	**1 315 252**	**43.5**	**717 096**	**34.1**	**1 000 662**	**56.1**	**717 096**	**48.7**
Overall total	**3 026 028**	**100.0**	**2 105 811**	**100.0**	**1 782 698**	**100.0**	**1 471 931**	**100.0**

Abbreviation: HCP, health care practitioner.

TABLE 3
Annual economic burden associated with spinal cord injury in Canada

	Injury occurring at age 35 years 2011 Canadian dollars, 2% Discount Rate					
	Tetraplegia		*Paraplegia*			
	Complete	Incomplete	Complete	Incomplete	Total	% of Total
Number of surviving incident cases[a]	106	651	163	469	1389	
Direct costs (in millions), $						
Health care						
Hospitalization	24.1	84.7	27.7	37.0	173.5	6.5
HCP	16.2	114.1	15.7	33.7	179.8	6.7
Prescription drugs	1.7	5.5	3.1	4.0	14.2	0.5
Subtotal health care	**41.9**	**204.3**	**46.5**	**74.7**	**367.4**	**13.7**
Equipment and modifications						
Non-prescription items	10.3	71.9	13.1	33.7	129.1	4.8
Adaptive equipment	10.9	57.3	8.8	16.5	93.5	3.5
Home modifications	4.3	24.7	5.6	16.5	51.1	1.9
Vehicle modifications	2.1	18.1	4.0	13.1	37.3	1.4
Subtotal equipment and modifications	**27.7**	**172.0**	**31.5**	**79.8**	**311.1**	**11.6**
Long-term care						
Institutional care	3.7	8.3	1.4	1.3	14.7	0.6
Attendant care	108.6	519.0	47.9	198.3	873.8	32.7
Subtotal long-term care	**112.3**	**527.3**	**49.2**	**199.6**	**888.5**	**33.2**
Total direct costs, $	**182.0**	**903.6**	**127.2**	**354.2**	**1567.0**	**58.6**
Indirect costs, $						
Morbidity	45.6	384.4	83.8	277.2	791.0	29.6
Premature mortality	94.3	82.2	79.0	59.3	314.8	11.8
Total indirect costs, $	**139.9**	**466.6**	**162.8**	**336.5**	**1105.8**	**41.4**
Overall total, $	**321.9**	**1370.3**	**290.0**	**690.7**	**2672.8**	**100.0**

Abbreviation: HCP, health care provider.

[a] 1389 patients per year survive to be discharged following their initial hospitalization.[23]

rate of 0%) increases the lifetime economic burden by 38% to 47%. Using a discount rate of 4% (compared to the base case discount rate of 2%) decreases the lifetime economic burden by 23% to 27%. The age at which the injury is sustained also has a significant effect. Using an average age of 25 years (compared to the base case assumption of 35 years) increases overall costs by 10% to 14% while using age 45 years decreases overall costs by 14% to 18%. Varying the disability weighting from 0.45 for all injuries to 0.45, 0.55, 0.65 and 0.75 for incomplete paraplegia, incomplete tetraplegia, complete paraplegia and complete tetraplegia, respectively, increases indirect costs by 18% to 23%.

Direct care costs are most sensitive to assumptions regarding the hours of attendant care received. Increasing the annual number of hours of care received per year or the average wage rate by 25% increases direct costs by 9% to 15%. If both the number of hours and the wage rate are increased by 25%, then direct costs would increase by 21% to 34%.

Discussion

To our knowledge, this is the first attempt to quantify the lifetime economic burden of tSCI in Canada. We have attempted to be as extensive as possible in the scope of the costs included.

The value of cost-of-illness studies has been questioned, particularly given the varied approaches and methodological limitations associated with this type of research.[24,25,26] However, Segui-Gomez and Mackenzie[27] note that a variety of metrics, including economic burden, are important when assessing the impact to society of injuries, particularly non-fatal injuries. Rice[28] notes that cost-of-illness studies ''translate the adverse effects of diseases and injuries into dollar terms, the universal language of decision makers and the policy arena. These estimates are used to: (1) define the magnitude of the disease or injury in dollar terms; (2) justify intervention programs; (3) assist in the allocation of research dollars on specific diseases; (4) provide a basis for policy and planning relative to prevention and control initiatives; and (5) provide an economic framework for program evaluation.''[28,p178]

Unfortunately, the application of these studies to the policy arena continues to be problematic. For example, in 1995 the

TABLE 4
Lifetime economic burden associated with spinal cord injury

	Sensitivity analysis 2011 Canadian Dollars							
	Tetraplegia				*Paraplegia*			
	Complete, $	% Change from Base	Incomplete, $	% Change from Base	Complete, $	% Change from Base	Incomplete, $	% Change from Base
Base case								
Direct costs	1 710 775		1 388 715		782 036		754 834	
Indirect costs	1 315 251		717 096		1 000 662		717 096	
Total costs	**3 026 027**		**2 105 811**		**1 782 698**		**1 471 930**	
Discount rate (0%)								
Direct costs	2 089 080	22.1	1 931 791	39.1	990 747	26.7	1 035 128	37.1
Indirect costs	2 093 169	59.1	1 126 491	57.1	1 596 826	59.6	1 126 491	57.1
Total costs	**4 182 249**	**38.2**	**3 058 282**	**45.2**	**2 587 573**	**45.1**	**2 161 619**	**46.9**
Discount rate (4%)								
Direct costs	1 437 892	(16.0)	1 056 393	(23.9)	643 468	(17.7)	583 277	(22.7)
Indirect costs	890 518	(32.3)	495 242	(30.9)	679 325	(32.1)	495 243	(30.9)
Total costs	**2 328 411**	**(23.1)**	**1 551 636**	**(26.3)**	**1 322 789**	**(25.8)**	**1 078 520**	**(26.7)**
Average age (25 years)								
Direct costs	2 049 089	19.8	1 569 131	13.0	896 299	14.6	847 909	12.3
Indirect costs	1 399 792	6.4	775 979	8.2	1 065 542	6.5	775 979	8.2
Total costs	**3 448 881**	**14.0**	**2 345 110**	**11.4**	**1 961 841**	**10.0**	**1 623 888**	**10.3**
Average age (45 years)								
Direct costs	1 314 480	(23.2)	1 172 657	(15.6)	661 964	(15.4)	643 373	(14.8)
Indirect costs	1 175 364	(10.6)	618 796	(13.7)	874 421	(12.6)	618 796	(13.7)
Total costs	**2 489 844**	**(17.7)**	**1 791 453**	**(14.9)**	**1 536 385**	**(13.8)**	**1 262 169**	**(14.3)**
Disability weighting[a]								
Direct costs	1 710 776	0.0	1 388 715	(0.0)	782 036	(0.0)	754 835	-
Indirect costs	1 601 022	21.7	848 373	18.3	1 229 675	22.9	717 096	-
Total costs	**3 311 798**	**9.4**	**2 237 088**	**6.2**	**2 011 711**	**12.8**	**1 471 931**	-
Attendant care hours *or* wage rate (+25%)								
Direct costs	1 966 131	14.9	1 588 113	14.4	855 641	9.4	860 472	14.0
Indirect costs	1 315 252	0.0	717 096	(0.0)	1 000 662	(0.0)	717 096	(0.0)
Total costs	**3 281 383**	**8.4**	**2 305 209**	**9.5**	**1 856 303**	**4.1**	**1 577 568**	**7.2**
Attendant care hours *or* wage rate (−25%)								
Direct costs	1 455 421	(14.9)	1 189 318	(14.4)	708 432	(9.4)	649 198	(14.0)
Indirect costs	1 315 252	0.0	717 096	(0.0)	1 000 662	(0.0)	717 096	(0.0)
Total costs	**2 770 673**	**(8.4)**	**1 906 414**	**(9.5)**	**1 709 094**	**(4.1)**	**1 366 294**	**(7.2)**
Attendant care hours *and* wage rate (+25%)								
Direct costs	2 285 324	33.6	1 837 360	32.3	947 646	21.2	992 518	31.5
Indirect costs	1 315 252	0.0	717 096	(0.0)	1 000 662	(0.0)	717 096	(0.0)
Total costs	**3 600 576**	**19.0**	**2 554 456**	**21.3**	**1 948 308**	**9.3**	**1 709 614**	**16.1**
Attendant care hours *and* wage rate (−25%)								
Direct costs	1 263 904	(26.1)	1 039 769	(25.1)	653 228	(16.5)	569 970	(24.5)
Indirect costs	1 315 252	0.0	717 096	(0.0)	1 000 662	(0.0)	717 096	(0.0)
Total costs	**2 579 156**	**(14.8)**	**1 756 865**	**(16.6)**	**1 653 890**	**(7.2)**	**1 287 066**	**(12.6)**
Annual number of hospital admissions *or* ALOS (+25%)								
Direct Costs	1 726 944	0.9	1 408 801	1.4	796 642	1.9	763 577	1.2

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TABLE 4 (continued)
Lifetime economic burden associated with spinal cord injury

	Sensitivity analysis 2011 Canadian Dollars							
	Tetraplegia				*Paraplegia*			
	Complete, $	% Change from Base	Incomplete, $	% Change from Base	Complete, $	% Change from Base	Incomplete, $	% Change from Base
Indirect Costs	1 315 252	0.0	717 096	(0.0)	1 000 662	(0.0)	717 096	(0.0)
Total Costs	**3 042 196**	**0.5**	**2 125 897**	**1.0**	**1 797 304**	**0.8**	**1 480 673**	**0.6**
Annual number of hospital admissions *or* ALOS (−25%)								
Direct Costs	1 693 754	(1.0)	1 367 870	(1.5)	766 795	(1.9)	745 762	(1.2)
Indirect Costs	1 315 252	0.0	717 096	(0.0)	1 000 662	(0.0)	717 096	(0.0)
Total Costs	**3 009 006**	**(0.6)**	**2 084 966**	**(1.0)**	**1 767 457**	**(0.9)**	**1 462 858**	**(0.6)**
Annual number of hospital admissions *and* ALOS (+25%)								
Direct Costs	1 749 076	2.2	1 435 616	3.4	816 330	4.4	775 248	2.7
Indirect Costs	1 315 252	0.0	717 096	(0.0)	1 000 662	(0.0)	717 096	(0.0)
Total Costs	**3 064 328**	**1.3**	**2 152 712**	**2.2**	**1 816 992**	**1.9**	**1 492 344**	**1.4**
Annual number of hospital admissions *and* ALOS (−25%)								
Direct Costs	1 680 987	(1.7)	1 352 237	(2.6)	755 363	(3.4)	738 957	(2.1)
Indirect Costs	1 315 252	0.0	717 096	(0.0)	1 000 662	(0.0)	717 096	(0.0)
Total Costs	**2 996 239**	**(1.0)**	**2 069 333**	**(1.7)**	**1 756 025**	**(1.5)**	**1 456 053**	**(1.1)**
Annual number of *or* average cost per HCP visits (+25%)								
Direct Costs	1 746 086	2.1	1 431 768	3.1	804 389	2.9	771 925	2.3
Indirect Costs	1 315 252	0.0	717 096	(0.0)	1 000 662	(0.0)	717 096	(0.0)
Total Costs	**3 061 338**	**1.2**	**2 148 864**	**2.0**	**1 805 051**	**1.3**	**1 489 021**	**1.2**
Annual number of *or* average cost per HCP visits (−25%)								
Direct Costs	1 675 465	(2.1)	1 345 662	(3.1)	759 683	(2.9)	737 744	(2.3)
Indirect Costs	1 315 252	0.0	717 096	(0.0)	1 000 662	(0.0)	717 096	(0.0)
Total Costs	**2 990 717**	**(1.2)**	**2 062 758**	**(2.0)**	**1 760 345**	**(1.3)**	**1 454 840**	**(1.2)**
Annual number of *and* average cost per HCP visits (+25%)								
Direct Costs	1 790 225	4.6	1 485 584	7.0	832 330	6.4	793 289	5.1
Indirect Costs	1 315 252	0.0	717 096	(0.0)	1 000 662	(0.0)	717 096	(0.0)
Total Costs	**3 105 477**	**2.6**	**2 202 680**	**4.6**	**1 832 992**	**2.8**	**1 510 385**	**2.6**
Annual number of *and* average cost per HCP visits (−25%)								
Direct Costs	1 648 982	(3.6)	1 313 372	(5.4)	742 918	(5.0)	724 926	(4.0)
Indirect Costs	1 315 252	0.0	717 096	(0.0)	1 000 662	(0.0)	717 096	(0.0)
Total Costs	**2 964 234**	**(2.0)**	**2 030 468**	**(3.6)**	**1 743 580**	**(2.2)**	**1 442 022**	**(2.0)**

Abbreviations: ALOS, average length of stay; HCP, health care practitioner.

[a] Complete tetraplegia = 0.75; complete paraplegia = 0.65; incomplete tetraplegia = 0.55; incomplete paraplagia = 0.45.

U.S. Senate Committee on Appropriations recommended that the National Institutes of Health (NIH) produce a report on the societal cost of the diseases for which the NIH conducts and funds research.[28] A 1998 review by the U.S. Institute of Medicine recommended that the NIH strengthen its use of data on ''disease burden and costs'' in setting research funding priorities.[29] Despite producing disease-specific cost-of-illness reports in 1995, 1997 and 2000,[28] this information does not appear to be used in current research funding allocations by the NIH.[30,31]

In an attempt to reduce the methodological heterogeneity of cost-of-illness studies while recognizing the ''strong continuing demand for economic impact studies,''[32,p2] associations such as the World Health Organization have proposed a framework for conducting cost-of-illness studies ''with a view to enhancing the consistency and coherence of economic impact studies in health.''[32,p3]

There are important limitations associated with this analysis. The analysis depends on published data from a variety of sources and timeframes rather than detailed costing of a patient cohort. Average costs also mask the wide varia-

tion in individual costs, even when accounting for the severity of the injury. As a result, these costs should not replace any professionally developed life care plan and the costs of implementing that care. In addition, no attempt was made to determine whether these costs are associated with optimal or even adequate care. In the U.S., Webster et al.[6] found that ''those with work-related tetraplegia may receive more injury-related paid medical benefits after the first year post-injury than cases who do not receive (workers compensation)-supported benefits.''[6,p240]

Estimating acute care costs is based on an aggregated disease-specific cost per patient day. An alternative approach would be to use Resource Intensity Weights assigned to each hospitalization together with an estimated cost per Resource Intensity Weight. The required information on specific hospitalizations, however, is currently unavailable but is something that the Rick Hansen Institute is in the process of addressing.

While an incidence-based approach to costing is nominally based on a trajectory of estimated life-time costs, in reality it requires an assumption (for this study) of functional status at a point in time. Actual changes in costs associated with changing functional status would only be possible given long-term, individual patient-level data.

The most commonly used method in valuing indirect costs is the human-capital approach. In this approach, gender- and age-specific average earnings are combined with productivity trends and years of life lost due to a specific disease/condition to estimate unrealized lifetime earnings. An important criticism of this method is that it places a higher value on the years of life lost for someone with higher earning potential (e.g. men aged 35–55 years) than someone with lower earning potential (e.g. women aged 75+ years).[33] In particular, unpaid work and leisure time are not explicitly accounted for in the human-capital approach.[34]

In calculating indirect costs, we used a modified human-capital approach in which unpaid time is explicitly valued. This approach involved assigning a value of $47 834 (the average annual Canadian wage rate in 2011) to every QALY lost. The inclusion of valuing unpaid time within the human capital approach has been suggested by a number of researchers[35,36] to address the inherent bias of the approach in undervaluing the impact of illness or injury in retired elderly people, the disabled and those who choose not to be gainfully employed.

Cao et al.[4] recently estimated the value of average lifetime direct costs (versus charges) in the U.S. for an injury sustained at age 25 years and using a 2% discount rate. The range was from $1.10 million (in 2009 U.S. dollars) for an American Spinal Injury Association (ASIA) Impairment Scale (AIS) D injury at any level to $3.41 million for a C1-4 AIS A, B or C injury.[4] Using the same major assumptions (injury at age 25 years, 2% discount rate), the present value of average lifetime direct costs derived from our analysis ranges from $0.85 million to $2.05 million, or approximately 23% to 40% lower than the U.S. estimate.

One possible reason for this difference is the higher overall cost of providing health care in the U.S. due to a combination of higher prices, administrative overhead costs, use of high-cost equipment and the practice of ''defensive medicine'' triggered by uniquely American tort laws. Excess costs in the U.S. are estimated to be approximately 40% over that of international comparators.[38]

A further possibility for the disparity is the way in which attendant care is determined. DeVivo et al.[5] estimated the annual hours of attendant care beginning in the second year following the injury to be from 1124 for an AIS D injury at any level to 5453 for a C1-4 A, B or C injury.[5] Each paid or unpaid hour was valued at $21.00 (in 2009 U.S. dollars). The annual number of hours appears to be derived ''based on self-report of all persons in the NSCISC database who completed an annual follow-up evaluation between 2000 and 2006 and had complete data on this item.''[5,p4] We used the considerably lower estimate (ranging from 702 to 2928 hours annually) from the Berkowitz et al.[14] population-based study and applied a value of $17.52 per hour for both paid and unpaid hours. Comprehensive estimates of attendant care costs in the Canadian SCI population are needed, particularly because these costs are the single largest driver of direct costs.

Finally, it is important to note the difference when institution-based prevalence rather than population-based prevalence is used. In both the Canadian and U.S. population-based studies, the proportion of the SCI population with complete tetraplegia or paraplegia is similar, at 7% to 8% and 10% to 12%, respectively, whereas the prevalence of complete tetraplegia or paraplegia based on persons with SCI receiving care in the U.S. Model System tends to be substantially higher at 24% and 27%, respectively.[10,12] This overweighting of more severe injuries is important to take into account, particularly when estimating the annual economic burden associated with tSCI.

To our knowledge, this is the first attempt to estimate the economic burden of tSCI in Canada. While the number of injuries per year is relatively small, the annual economic burden, at $2.67 billion, is substantial. This burden could be reduced if some of the new cases could be avoided or if function could be improved[39] or secondary complications prevented (either through functional improvements or better management) after the tSCI occurs.

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