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Cost Avoidance Associated With Optimal Stroke Care in Canada

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Background and Purpose—Evidence-based stroke care has been shown to improve patient outcomes and may reduce health system costs. Cost savings, however, are poorly quantified. This study assesses 4 aspects of stroke management (rapid assessment and treatment services, thrombolytic therapy, organized stroke units, and early home-supported discharge) and estimates the potential for cost avoidance in Canada if these services were provided in a comprehensive fashion.

Methods—Several independent data sources, including the Canadian Institute of Health Information Discharge Abstract Database, the 2008–2009 National Stroke Audit, and the Acute Cerebrovascular Syndrome Registry in the province of British Columbia, were used to assess the current status of stroke care in Canada. Evidence from the literature was used to estimate the effect of providing optimal stroke care on rates of acute care hospitalization, length of stay in hospital, discharge disposition (including death), changes in quality of life, and costs avoided.

Results—Comprehensive and optimal stroke care in Canada would decrease the number of annual hospital episodes by 1062 (3.3%), the number of acute care days by 166 000 (25.9%), and the number of residential care days by 573 000 (12.8%). The number of deaths in the hospital would be reduced by 1061 (14.9%). Total avoidance of costs was estimated at $682 million annually ($307.4 million in direct costs, $374.3 million in indirect costs).

Conclusions—The costs of stroke care in Canada can be substantially reduced, at the same time as improving patient outcomes, with the greater use of known effective treatment modalities. **(*Stroke*. 2012;43:00-00.)**

Key Words: cerebrovascular disease/stroke ■ health policy and outcome research ■ resource use

Optimal management of stroke and its sequelae has been shown to result in improved patient outcomes and significant cost savings, in large part because the treatment and care of people disabled by stroke are very costly. Over the past 5 years, the Canadian Stroke Strategy has implemented a multipronged approach to encourage and support all provinces and territories in Canada to develop and implement integrated systems of stroke care with the goal of improving quality of care and health outcomes of individuals with stroke. The Canadian Stroke Network encourages the use of the evidence-based Canadian Best Practice Recommendations for Stroke Care, which span the stroke care continuum, from primary prevention to rehabilitation and return to the community for ongoing recovery.[1]

A number of these recommendations, if routinely implemented, are expected to be cost-effective. Current evidence suggests that rapid assessment and treatment of patients who present with transient ischemic attack (TIA) or minor stroke reduces the risk of progression to or recurrence of a disabling stroke; moreover, this approach is cost-effective.[2–5] Similarly, thrombolytic therapy—through the administration of recombinant tissue-type plasminogen activator (tPA) within a 3-hour window from symptom onset—is effective for a subset of patients with stroke[6,7] and is cost-effective.[8–11] Providing acute care in organized stroke units is associated with a significant reduction in death, dependency, length of hospital stay,[12–15] and is also cost-effective.[16–18] Early home-supported discharge, in which patients are released from the hospital at an earlier point in recovery than would normally occur, and receive intensive rehabilitation in their home by a team of stroke rehabilitation specialists, is associated with a significant reduction in the length of hospital stay,

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lower incidence of death or dependency,[19] and may be cost-effective.[20–24]

The purpose of this study was to estimate the potential for cost avoidance in Canada from a societal perspective if these 4 aspects of stroke management were provided in a comprehensive and optimal fashion.

Methods

Current Stroke Care in Canada

The following 3 independent data sets were used to provide an overview of current stroke care in Canada, which in turn was used as the base model when assessing the effect of optimizing stroke care: (1) Canadian Institute of Health Information Discharge Abstract Database; (2) British Columbia Acute Cerebrovascular Syndrome Registry; and (3) 2008–2009 Canadian Stroke Audit.

Data from these sources were used to determine the annual number of hospital episodes for ischemic stroke, hemorrhagic stroke, and TIA in Canada, whether the hospital episode was associated with an incident or recurrent stroke or a readmission, average length of stay in the hospital, and hospital discharge disposition. We excluded venous sinus thrombosis. Additional estimates based on these data sources include the annual risk of stroke recurrence, progression after an incident TIA or nonhospitalized stroke to a hospitalized stroke, length of stay in a residential care facility, stroke severity, proportion of patients receiving tPA, and the proportion of patients receiving care in a stroke unit.

The cerebrovascular literature was used to estimate additional base model parameters including years of life lost[25] and quality of life for stroke survivors.[26] See Table 1 and the online-only Data Supplement (http://stroke.ahajournals.org) for additional details and references.

Optimal Stroke Care Model Assumptions

Optimal stroke care was modeled based on the assumption that 80% of patients with a TIA/nonhospitalized stroke would receive rapid assessment and treatment, 10% of hospitalized patients with ischemic stroke would receive tPA, 80% of hospitalized patients with stroke would be cared for in an organized stroke unit, and 37% of hospitalized patients would receive early home-supported discharge.

The major benefits of optimal stroke care include a 70% reduction in progression to a hospitalized stroke after a TIA/nonhospitalized stroke,[2–4] an 11% reduced risk of dependency after the administration of tPA,[7,27,28] a 21% reduction in average length of stay and 20% reduction in death and dependency associated with care in an organized stroke unit,[12] and a 27% reduction in average length of stay and 26% reduction in death and dependency associated with receiving early home-supported discharge.[19,29] See Table 2 and the online-only Data Supplement for additional benefits, details, and references.

Determining Unit Costs

The daily cost of residential care in Canada was calculated based on information from Statistics Canada.[30] The cost of an acute care day for patients with ischemic and hemorrhagic stroke was estimated based on data from 2006–2007 to 2008–2009 available from the Ontario Case Costing Initiative.[31] Due to higher unit costs in Ontario compared with other provinces (except Alberta), acute care costs from the Ontario Case Costing Initiative were adjusted for each province and a weighted average cost per day obtained.[32] All costs were adjusted to 2010 Canadian dollars using the health and personal care component of the consumer price index. A modified human-capital approach (in which unpaid time is explicitly valued) was used in calculating indirect costs; in this way, a quality-adjusted life-year (QALY) was valued at $42 275 (the average Canadian annual wage rate in 2010) regardless of the patient's age or work status. A weighted (based on the proportion of stroke hospitalizations in each province) average annual Canadian wage rate was calculated and assigned as the value for changes in the number of QALYs lost.[33] A 3% annual discount rate was applied to all future year costs.

Life-years lost were quality-adjusted based on utilities of 0.64, 0.45, and 0.28 for a minor (Rankin score of 0, 1, 2), moderate (Rankin score of 3), or major stroke (Rankin score of 4, 5), respectively.[26] Thus, 1 year of life with a minor stroke would receive a value of 0.64 QALYs.

Model Progression

In modeling the effect of optimizing stroke care in Canada, and the potential for cost avoidance, the initial focus was on enhancing the rapid assessment and treatment of patients with TIA or minor stroke followed by improving rates of thrombolytic therapy for patients with acute ischemic stroke, enhancing access to care in organized stroke units, and finally providing optimal early home-supported discharge services. The impact of each area of focus was built on the assumption that optimal care had been achieved at earlier points in the continuum.

Future Costs Avoided

In projecting costs avoided between 2010 and 2030 in Canada, current age-specific rates for ischemic and hemorrhagic hospital episodes were combined with age-specific population projections.[34] Age- and stroke type-specific average length of stay and pattern of discharge disposition were kept constant. Adjustments in life expectancy were made to take into account the increasing average age of the stroke population over time and an overall increase in life expectancy of the population aged ≥65 years. Costs were inflated by 3% per year. See the online-only Data Supplement for additional details.

Results

Current Stroke Care in Canada

Between 2004–2005 and 2008–2009, there were an estimated 32 081 hospital episodes for stroke care (excluding TIA) in Canada annually, 28 345 for incident stroke, 493 for readmissions, and 3243 for recurrence. There were 7111 deaths in hospital (annually) and approximately 286 000 QALYs lost annually. These stroke admissions used 639 000 acute care days and 4.5 million residential care days annually. In addition, there were approximately 29 300 incident TIA and nonhospitalized (minor) strokes in Canada per year. A total of 7.4% of patients with an ischemic stroke received tPA. The annual risk of recurrence in the 10 years after an incident stroke decreased from 3.64% in the year after an incident stroke to 0.27% after 10 years. A total of 4.14% of patients with an incident TIA or nonhospitalized stroke progressed to a hospitalized stroke within 365 days. The average length of stay in a residential care facility after an ischemic or hemorrhagic stroke was 525 and 570 days, respectively. Twenty-three percent of patients with a stroke received care in a stroke unit across Canada. The proportion of strokes categorized as minor/moderate/major was 54%/21%/25%.

Optimal Stroke Care Model Results

The potential impact of optimizing delivery of each intervention is outlined in Table 3. In each case, we assumed a range of magnitude of effect and conducted a sensitivity analysis to determine a "best-case" and "worst-case" scenario. We present estimates of both direct and indirect costs avoided.

Implementing stroke care in a comprehensive and optimal fashion in Canada would decrease the number of hospital episodes for stroke annually by 1062 (or 3.3% of the 32 081 annual hospital episodes). The number of acute care days

Table 1. Base Model Assumptions

Area of Focus	Values Type of Admission			Sensitivity Analysis	Source
	Incident	Readmission	Recurrence		
Acute care hospitalization					
Average length of acute hospital stay, d					Adjusted CIHI
Ischemic stroke	19.95	18.78	18.87		
Hemorrhagic stroke	20.68	18.02	18.60		
Discharge disposition					Adjusted CIHI
Ischemic stroke					
Died in the hospital	16.83%	14.94%	30.66%		
Discharged to home	40.93%	46.55%	28.68%		
Home with support services	12.16%	7.48%	10.20%		
Continuing care facility	28.02%	27.65%	23.49%		
Other	2.06%	3.38%	6.97%		
Hemorrhagic stroke					
Died in the hospital	40.38%	22.55%	40.50%		
Discharged to home	31.41%	48.26%	20.80%		
Home with support services	6.38%	4.59%	6.48%		
Continuing care facility	19.09%	20.80%	28.17%		
Other	2.74%	3.80%	4.05%		
Average length of residential care stay, d					B.C. estimates
Ischemic stroke		525		±25%	
Hemorrhagic stroke		570		±25%	
Life-years lost					
Ischemic stroke					
Per death		12.4			Hannerz and Nielsen, 2001[25]
Per survivor		4.9			
Hemorrhagic stroke					
Per death		17.2			Hannerz and Nielsen, 2001[25]
Per survivor		6.9			
QALYs					
Incident stroke survivors (percent by stroke severity)					CSN Audit
Minor stroke (Rankin score of 0, 1, 2)		54.2%			
Moderate stroke (Rankin score of 3)		20.5%			
Major stroke (Rankin score of 4, 5)		25.3%			
Utility (by stroke severity)					Tengs and Lin, 2003[26]
Minor stroke		0.64			
Moderate stroke		0.45			
Major stroke		0.28			
Cost estimates					
Per acute care day					
Ischemic stroke		$979			OCC and CIHI
Hemorrhagic stroke		$1807			OCC and CIHI
Residential care/bed day		$213			Stats Canada
Life-year lost		$42 275			Stats Canada
Discount rate		3%			

CIHI indicates Canadian Institute of Health Information; QALYs, quality-adjusted life-years; CSN, Canadian Stroke Network; OCC, Ontario Case Costing.

would decrease by 166 000 (or 25.9% of the 639 000 annual acute care days). The number of residential care days for patients admitted to such facilities after stroke would decrease by 573 000 (or 12.8% of the 4.5 million residential care days). The estimated change in use of acute and residential care translates to a reduction of 432 and 1553 beds, respectively. The number of deaths in hospital would be reduced by 1061 (or 14.9% of the 7111 annual deaths in

Table 2. Optimal Stroke Care Model Assumptions

Area of Focus	Values	Sensitivity Analysis	Source
TIA rapid assessment and treatment			
Percent of patients with TIA currently receiving optimal care	10%		Estimated
Percent of patients with TIA ultimately receiving optimal care	80%	70%–90%	Estimated
Change in Annual Progression Rate Associated with Optimal Care	−70%	−50% to −80%	Rothwell et al, 2007[2]; Lavalee et al, 2007[3]; Wu et al, 2009[4]
Increased use of tPA			
Percent of patients with ischemic stroke currently receiving tPA	7.4%		CSN Audit
Percent of patients with ischemic stroke ultimately receiving tPA	10.0%	15.0%	Barber et al, 2001[27]; Kleindorfer et al, 2004[28]
Reduction in acute care ALOS	12.3%		Fagan et al, 1998[8]
Net percent of patients receiving tPA who benefit	11.0%	9%–13%	Lees et al, 2010[7]
Reduced risk of readmission and recurrence for patients who benefit	50%		Estimated
Percent residential care avoided for patients who benefit	77%	55%–100%	Estimated
Stroke units			
Percent of patients with stroke currently receiving care in a stroke unit	23.0%		CSN Audit
Percent of patients with stroke ultimately receiving care in a stroke unit	80%	70%–90%	Estimated
Reduction in acute care ALOS with care in a stroke unit	20.7%		Govan et al, 2008[13]
Reduction in death with care in a stroke unit	15.0%		Govan et al, 2008[13]
Reduction in residential care with care in a stroke unit	5.0%		Govan et al, 2008[13]
Early supported discharge			
Percent of patients with stroke currently receiving early supported discharge	3.0%		Estimated
Percent of patients with Stroke ultimately receiving early supported discharge	37.0%	27 to 47%	Winkel et al, 2008[29]
Reduction in acute care ALOS with early supported discharge	26.7%		Hankey and Langhorne, 2005[19]
Reduction in death with early Supported Discharge	10.0%		Hankey and Langhorne, 2005[19]
Reduction in residential care with early supported discharge	16.0%		Hankey and Langhorne, 2005[19]

TIA indicates transient ischemic attack; tPA, tissue-type plasminogen activator; CSN, Canadian Stroke Network; ALOS, average length of stay.

hospital) and the number of lost QALYs by 10 568 (or 3.7% of the 286 000 QALYs).

Total avoidance of costs is estimated at $682 million annually with direct costs at $307 million and indirect costs at $374 million. The most significant contributions to the direct cost avoidance were generated by optimized access to early supported discharge services ($132.9 million) and organized stroke units ($116.8 million). Both of these areas reduce length of stay in the hospital and reduce the risk of admission to a residential care facility after a stroke. The most significant contribution to the indirect cost avoidance was optimized TIA rapid assessment and treatment (representing $269.2 million in avoided indirect costs). Preventing the risk of progression from a TIA/minor stroke to a major stroke requiring hospitalization has a significant impact on the number of QALYs lost. See the online-only Data Supplement for additional details.

For the average patient with stroke in Canada, implementing comprehensive and optimal care is expected to result in a 3.3% reduced risk of acute hospitalization. For hospitalized patients, we estimate reductions in length of stay by 23.4% (from 19.93–15.27 days), rates of death by 12.1% (from 22.5%–19.8%), and rates of discharge to residential care by 9.9% (from 26.2%–23.6%). For hospitalized patients with stroke, direct costs avoided due to reduced hospital and residential care services would be $8191 per patient, whereas the indirect costs avoided due to the reduced likelihood of early death and improved quality of life would be $3277 per patient. For patients with TIA and those not hospitalized with stroke, the direct and indirect costs avoided would be $1524 and $9187 per patient, respectively.

Sensitivity Analysis

The results of sensitivity analyses are summarized in Table 4. Most changes in individual assumptions modify the direct or indirect cost estimates by <10%. The 1 exception is the change in indirect costs associated with a reduction in the effectiveness of TIA rapid assessment and treatment services. The base case scenario assumes an effectiveness of 70%, whereas the sensitivity analysis uses a range from 50% to 80%. Using an effectiveness of 50% in terms of reducing the risk of progression to a hospitalized stroke after an incident TIA translates into a 20.3% decrease in the total indirect costs avoided. Of the 4 interventions considered in the model, a TIA rapid assessment and treatment service is the only 1 with the potential to avoid stroke (rather than improve treatment after a stroke); thus, it represents a substantial opportunity for indirect cost avoidance (ie, reductions in morbidity and mortality).

When all assumptions are modified simultaneously to create scenarios at the extremes of the sensitivity spectrum, the overall annual cost avoidance results would increase from

Table 3. Estimated Annual Benefits of Optimal Stroke Care in Canada by Area of Focus

	TIA Rapid Assessment and Treatment*	Increased Use of tPA†	Stroke Unit‡	Early Supported Discharge§	Total
Hospitalized stroke cases	(899)	(163)	0	0	(1062)
Acute care days	(17 821)	(4351)	(78 711)	(64 993)	(165 876)
Acute care costs ($ million)	($17.3)	($4.1)	($89.0)	($77.4)	($187.8)
Residential care days	(130 063)	(43 902)	(132 140)	(266 440)	(572 545)
Residential care costs ($ million)	($27.3)	($9.0)	($27.7)	($55.5)	($119.6)
Direct costs ($ million)	($44.6)	($13.1)	($116.8)	($132.9)	($307.4)
Deaths in the hospital	(164)	(46)	(638)	(213)	(1061)
QALYs lost	(7323)	(122)	(2341)	(782)	(10 568)
Indirect costs ($ million)	($269.2)	($4.7)	($75.3)	($25.1)	($374.3)
Total costs ($ million)	($313.8)	($17.8)	($192.0)	($158.0)	($681.7)
Percent of total					
Hospitalized stroke cases	84.7%	15.3%	0.0%	0.0%	100.0%
Acute care days	10.7%	2.6%	47.5%	39.2%	100.0%
Residential care days	22.7%	7.7%	23.1%	46.5%	100.0%
Direct costs	14.5%	4.3%	38.0%	43.2%	100.0%
Deaths in the hospital	15.4%	4.4%	60.1%	20.1%	100.0%
Life-years lost	69.3%	1.2%	22.2%	7.4%	100.0%
Indirect costs	71.9%	1.3%	20.1%	6.7%	100.0%

TIA indicates transient ischemic attack; tPA, tissue-type plasminogen activator; QALYs, quality-adjusted life-years.
*Eighty percent of patients not receiving optimal care will ultimately receive optimal care.
†tPA use will increase from 7.40% of hospitalized patients with ischemic stroke in 2008–2009 to 10%.
‡Eighty percent of patients not receiving optimal care will ultimately receive optimal care.
§Thirty-seven percent of patients will ultimately receive optimal care.

$682 to $892 (+30.9%) million in the best case and decrease to a cost avoidance of $488 (−28.5%) million in the worst-case scenario.

Future Costs Avoided

Between 2010 and 2031, achieving optimal care could reduce the number of hospital episodes for stroke by 35 500, whereas the number of acute and residential care days could decrease by 4.8 and 19.5 million, respectively. The reduction in the number of deaths in the hospital is estimated at 36 800 and the number of lost QALYs at 388 000. Total avoidance of costs is estimated at $32.1 billion with direct costs at $13.8 billion and indirect costs at $18.3 billion (Figure).

Discussion

Optimizing stroke care in Canada by improving TIA secondary prevention services, increasing administration of tPA, increasing the proportion of care provided in stroke units, and establishing early supported discharge programs is projected to reduce stroke hospitalization episodes by 1062 (3.3%), acute care days by 166 000 (25.9%), residential care days by 573 000 (12.8%), deaths in the hospital by 1061 (14.9%), and QALYs lost by 10 568 (3.7%). Acute and residential care costs would be reduced by $307 million annually, equivalent to an annual reduction or reallocation of 432 acute and 1553 residential care beds. In addition, the reduction in premature deaths and QALYs lost would be associated with an estimated economic cost avoided of $374 million annually. Between 2010 and 2031, total costs avoided could reach $32.1 billion.

The annual occurrence of a hospitalized stroke, after an incident TIA or nonhospitalized stroke, in this study (4.14%) differs from the 90-day recurrence rate of approximately 10% reported by Rothwell et al.[2] In an effort to capture all recurrent stroke events, the authors followed individual patients for 24 months after the initial visit to their clinic. This level of ascertainment is not possible using administrative data. Instead, the stroke rate was calculated based on patients with incident TIA/minor (nonhospitalized) stroke who were subsequently hospitalized for a stroke. While underestimating the true rate of early recurrence, this approach captures the majority of costs associated with resource use in treating this population. Likewise, changes in the stroke rate associated with provision of optimal care and consequent reductions in hospitalization would generate the majority of avoided costs.

The role of intravenous thrombolysis in an acute ischemic stroke is well established as a cost-effective treatment.[8–11] However, even with ideal systems of care, many patients with stroke may not be suitable candidates for thrombolysis either because their symptoms are so mild or because delays in presentation are unavoidable. Stroke is a condition that often renders the patient incapable of activating emergency response services in an urgent fashion, and the public is not aware of the necessity of rapid action; thus, patients living alone who have a stroke are rarely treated with thrombolysis because they cannot get to help in time, and witnessed stroke may not be responded to appropriately. Distance to treatment

Table 4. Estimated Annual Benefits of Optimal Stroke Care in Canada Sensitivity Analysis by Area of Focus ($ Million)

		TIA Rapid Assessment and Treatment	Increased Use of tPA	Stroke Unit	Early Home-Supported Discharge	Percent Change in Cost Avoidance
Base case						
Direct costs	($44.6)	($13.1)	($116.8)	($132.9)	($307.4)	
Indirect costs	($269.2)	($4.7)	($75.3)	($25.1)	($374.3)	
Total costs	($313.8)	($17.8)	($192.0)	($158.0)	($681.7)	
TIA rapid assessment and treatment assumptions						
Effectiveness of a TIA rapid assessment and treatment clinic						
50%						
Direct costs	($31.9)	($13.5)	($117.6)	($133.8)	($296.8)	−3.5%
Indirect costs	($192.3)	($4.9)	($75.7)	($25.3)	($298.2)	−20.3%
Total costs	($224.2)	($18.4)	($193.3)	($159.1)	($595.0)	−12.7%
80%						
Direct costs	($51.0)	($13.0)	($116.3)	($132.4)	($312.7)	1.7%
Indirect costs	($307.6)	($4.6)	($75.1)	($25.1)	($412.3)	10.2%
Total costs	($358.6)	($17.6)	($191.4)	($157.5)	($725.1)	6.4%
Percent of patients with stroke receiving optimal care						
70%						
Direct costs	($39.1)	($13.3)	($117.1)	($133.3)	($302.8)	−1.5%
Indirect costs	($235.5)	($4.8)	($75.5)	($25.2)	($341.0)	−8.9%
Total costs	($274.6)	($18.1)	($192.6)	($158.5)	($643.8)	−5.6%
90%						
Direct costs	($50.2)	($13.0)	($116.4)	($132.5)	($312.1)	1.5%
Indirect costs	($302.8)	($4.6)	($75.1)	($25.1)	($407.6)	8.9%
Total costs	($353.0)	($17.6)	($191.5)	($157.5)	($719.6)	5.6%
tPA assumptions						
Increase optimal care from 10% to 15%						
Direct costs	($44.6)	($26.4)	($116.1)	($132.1)	($319.2)	3.8%
Indirect costs	($269.2)	($14.8)	($75.5)	($25.2)	($384.6)	2.8%
Total costs	($313.8)	($41.1)	($191.6)	($157.3)	($703.8)	3.2%
9% benefit, only mRS 4 to residential care						
Direct costs	($44.6)	($11.0)	($116.8)	($133.0)	($305.5)	−0.6%
Indirect costs	($269.2)	($3.8)	($75.3)	($25.1)	($373.4)	−0.2%
Total Costs	($313.8)	($14.9)	($192.1)	($158.1)	($678.9)	−0.4%
13% benefit, mRS 3 and 4 to residential care						
Direct costs	($44.6)	($15.7)	($116.7)	($132.7)	($309.8)	0.8%
Indirect costs	($269.2)	($5.6)	($75.3)	($25.1)	($375.2)	0.2%
Total costs	($313.8)	($21.3)	($192.0)	($157.9)	($685.0)	0.5%
Coordinated stroke units						
Percent of patients with stroke receiving optimal care						
70%						
Direct costs	($44.6)	($13.1)	($102.2)	($138.5)	($298.5)	−2.9%
Indirect costs	($269.2)	($4.7)	($65.9)	($25.5)	($365.2)	−2.4%
Total costs	($313.8)	($17.8)	($168.0)	($164.0)	($663.7)	−2.6%
90%						
Direct costs	($44.6)	($13.1)	($131.4)	($127.2)	($316.3)	2.9%
Indirect costs	($269.2)	($4.7)	($84.7)	($24.8)	($383.4)	2.4%
Total costs	($313.8)	($17.8)	($216.0)	($152.0)	($699.7)	2.6%

(*Continued*)

Table 4. Continued

		TIA Rapid Assessment and Treatment	Increased Use of tPA	Stroke Unit	Early Home-Supported Discharge	Percent Change in Cost Avoidance
Early home-supported discharge						
Percent of patients with stroke receiving optimal care						
27%						
Direct costs	($44.6)	($13.1)	($116.8)	($104.5)	($279.0)	−9.2%
Indirect costs	($269.2)	($4.7)	($75.3)	($17.7)	($366.9)	−2.0%
Total costs	($313.8)	($17.8)	($192.0)	($122.3)	($645.9)	−5.2%
47%						
Direct costs	($44.6)	($13.1)	($116.8)	($161.2)	($335.8)	9.2%
Indirect costs	($269.2)	($4.7)	($75.3)	($32.5)	($381.7)	2.0%
Total costs	($313.8)	($17.8)	($192.0)	($193.8)	($717.5)	5.2%
Length of stay in residential care						
−25%						
Direct costs	($37.9)	($10.9)	($110.0)	($119.2)	($278.0)	−9.6%
Indirect costs	($269.2)	($4.7)	($75.3)	($25.1)	($374.3)	0.0%
Total costs	($307.1)	($15.6)	($185.2)	($144.4)	($652.3)	−4.3%
+25%						
Direct costs	($51.3)	($15.4)	($123.6)	($146.5)	($336.8)	9.6%
Indirect costs	($269.2)	($4.7)	($75.3)	($25.1)	($374.3)	0.0%
Total costs	($320.5)	($20.1)	($198.8)	($171.7)	($711.1)	4.3%
Better case						
Direct costs	($66.0)	($40.6)	($136.8)	($168.9)	($412.4)	34.2%
Indirect costs	($346.1)	($17.1)	($84.4)	($32.0)	($479.6)	28.1%
Total costs	($412.1)	($57.7)	($221.2)	($201.0)	($892.0)	30.9%
Length of stay in residential care—+25%; TIA rapid assessment and treatment—effectiveness 80%, optimal care 90%; tPA—optimal care 15%, 13% benefit, mRS 3 and 4 to residential care; coordinated stroke units—90%; early home-supported discharge—47%						
Worse case						
Direct costs	($23.7)	($9.6)	($97.2)	($100.3)	($230.8)	−24.9%
Indirect costs	($168.2)	($4.1)	($66.4)	($18.1)	($256.8)	−31.4%
Total costs	($191.9)	($13.7)	($163.5)	($118.4)	($487.6)	−28.5%
Length of stay in residential care—−25%; TIA rapid assessment and treatment—effectiveness 50%, optimal care 70%; tPA—optimal care 10%, 9% benefit, only mRS 4 to residential care; coordinated stroke units—70%; Early home-supported discharge—27%						

TIA indicates transient ischemic attack; tPA, tissue-type plasminogen activator; mRS, modified Rankin Scale.

in Canada where geography has a direct impact on access to care may be an important limiting factor for a minority of the population.

Randomized controlled clinical trials and observational studies of stroke units in their "natural" environment have demonstrated that stroke unit care is highly effective, whether based in large tertiary referral centers or smaller referral hospitals.[12,14,15,35] However, because it is a system or model of care with multiple components, it is often difficult to implement. There are relatively few cost-effectiveness studies relevant to this area, but modeling has suggested that stroke unit care approach is cost-effective.[16–18] Recent Canadian data suggest that cost avoidance would mostly be generated from reducing the length of stay of hospitalized patients.[15]

Because all patients with stroke, including those with hemorrhagic stroke and selected patients with TIA, can benefit from stroke unit care, the greatest cost avoidance would be achieved with the widespread availability of stroke units. In practice, this would mean centralizing stroke care in stroke centers and establishing stroke units in smaller nonreferral institutions, particularly in remote regions where transfer to a specialized stroke center would not be feasible. This effort has begun in hospitals throughout Canada but could be accelerated. Recently published data suggest that the volume of treated patients with stroke and adherence to quality-of-care criteria through certification can improve stroke care.[36,37] In this way, stroke care is much like trauma in which the concentration of care in designated hospitals can result in substantial cost avoidance and better outcomes for patients. Cost avoidance benefits will depend on the local medical system such that in other jurisdictions where acute hospitals stays are much shorter than in Canada, stroke unit care may have less of an economic impact.

The implementation of an early supported discharge approach to stroke care is less well studied in the economic literature.[20–23] Because bed days are a major driver of acute

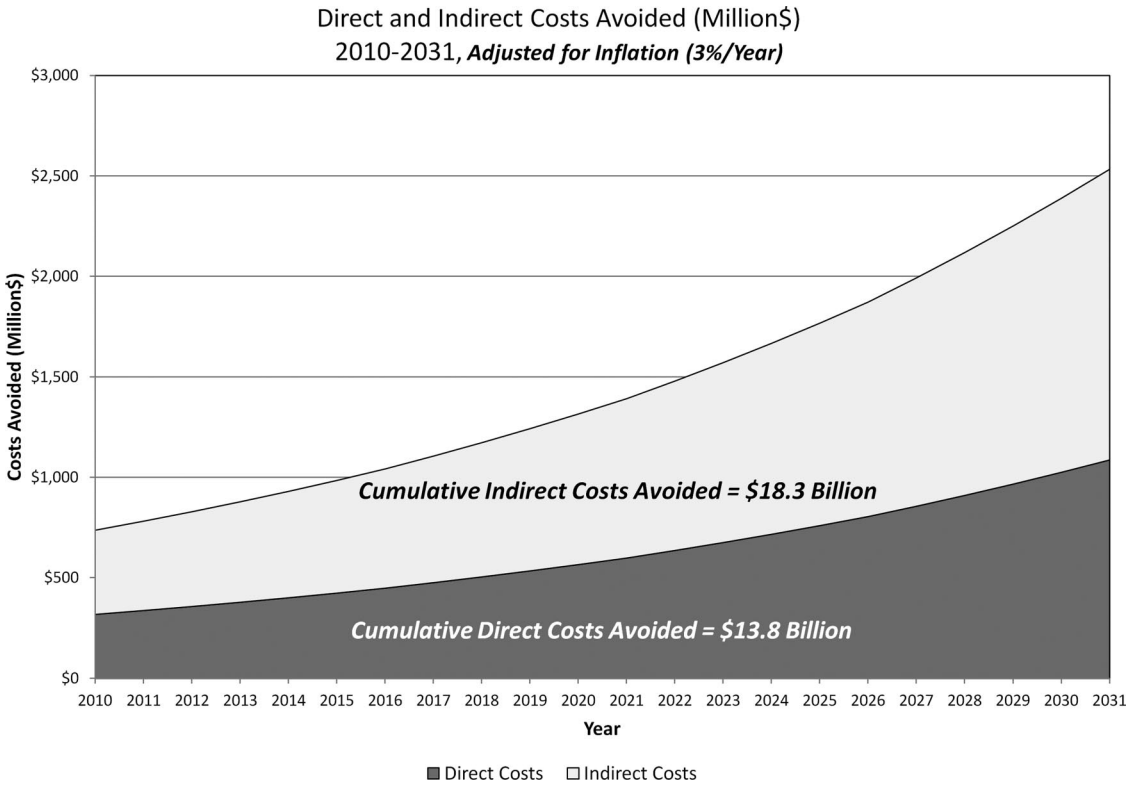

Figure. Estimated benefits of optimal stroke care in Canada: direct and indirect costs avoided 2010 to 2031.

care costs, and early supported discharge is associated with a reduction in length of stay, the economic benefits may be unique to health systems with longer acute or rehabilitation lengths of stay. Research from Canada does suggest further benefits associated with a reduction in readmissions.[21]

Our study is limited in that it is not based on a cost-effectiveness approach. That is, the estimated costs of implementing these changes in stroke care in Canada were not calculated or included in a full cost-effectiveness framework. Indeed, to include an estimate of indirect costs, we have placed a value on QALYs lost, a usual output measure in most cost-effectiveness analyses. However, our modeling exercise is based on multiple current and accurate sources of data, which provides an estimate of cost avoidance when applying optimal stroke care in 4 key areas in Canada. By their very nature, these types of studies are limited by the appropriateness of the assumptions made. Sensitivity analyses show a range of benefit and that even using a worst-case scenario, there is still likely to be significant cost avoidance.

Furthermore, primary prevention is a key component of any integrated stroke strategy and, if successful, would result in the avoidance of all resources associated with stroke care identified in our model. Our analysis begins with the assumption that primary prevention has been unsuccessful.

In summary, these analyses suggest that costs of stroke care might be substantially attenuated in Canada and elsewhere with the greater application of known effective treatment modalities focusing on different components of the stroke continuum. The magnitude of potential cost savings over 2 decades could be substantial. Healthcare decision-makers could use these data to better plan investment in stroke systems of care over the next decade.

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