The economic burden of prostate cancer in Canada: forecasts from the Montreal Prostate Cancer Model

Research

Recherche

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Abstract

Background: We developed an economic model of prostate cancer management from diagnosis until death. We have used the Montreal Prostate Cancer Model to estimate the total economic burden of the disease in a cohort of Canadian men.

Methods: Using this Markov state-transition simulation model, we estimated the probability of prostate cancer, annual prostate cancer progression rates and associated direct medical costs according to patient age, tumour stage and grade, and treatment modalities in a 1997 cohort of Canadian men. The estimated lifetime costs of prostate cancer included the costs of clinical staging, initial treatments and complications, follow-up cancer therapies, routine outpatient care, and palliative care following metastatic disease.

Results: The clinical burden of prostate cancer forecasted using the model was similar to the projections of the National Cancer Institute. In the 1997 cohort of 5.8 million Canadian men between 40 and 80 years old, prostate cancer would be diagnosed in an estimated 701 491 men (12.1%) over their lifetime. Direct medical costs would total $9.76 billion, or $3.89 billion when discounted 5% annually.

Interpretation: The Montreal Prostate Cancer Model indicates that the economic burden of prostate cancer to Canada's health care system will be substantial. Further analyses are needed to identify the most efficient means of treating this disease.

Prostate cancer is the second most commonly diagnosed type of cancer in Canada, with the number of newly diagnosed cases estimated at 19 800 in 1997.[1] Tumour incidence has been steadily increasing at a mean annual rate of 5.3% since 1985, but mortality rates have been relatively stable. Accordingly, the prevalence of this slow-growing tumour is expected to increase in the coming years. Several therapeutic options are available to prostate cancer patients, but considerable controversy exists surrounding the appropriate choice of therapy. This controversy stems from the lack of large randomized clinical trials comparing the benefits of therapeutic alternatives.

Given the increasing prevalence of prostate cancer and the uncertainty surrounding its treatment, there is growing concern that the future burden of disease may be substantial.[2] To address these questions, we developed the Montreal Prostate Cancer Model (page 977).[3] With this Markov state-transition model we were able to estimate the annual probabilities of prostate cancer being diagnosed, the distribution of the initial therapeutic alternatives and their associated complications, annual progression rates of prostate cancer, choices of follow-up therapies and palliative care. We have used the model to estimate the direct medical costs associated with each treatment modality as a means of forecasting the total lifetime clinical and economic burden of the disease among a cohort of Canadian men aged 40 to 80 years in 1997.

Methods

The Montreal Prostate Cancer Model is a validated Markov simulation model that describes the natural history of the disease.[3] For a cohort of men initially free of a prostate cancer, the model estimates the expected age at diagnosis of prostate cancer and the probability of progression to metastatic disease. It estimates overall life expectancy as well as metastasis-free and disease-specific survival. The model has been validated using population cancer statistics and survival data specific to tumour stage and grade.[3] The resulting forecasts have been shown to approximate closely the observed outcomes in different patient cohorts followed for up to 15 years.

Estimation of clinical burden

We used Canadian age-specific incidence data to estimate the probabilities of prostate cancer diagnoses.[4] We then distributed cases by tumour stage and grade using data from the National Cancer Data Base.[5] The model uses the tumour–node–metastasis (TNM) classification for the staging of prostate cancer.[6] The model also considers 3 tumour histologic grades, as defined by the Gleason scoring system:[7] well-differentiated tumours (Gleason score of 2–4), moderately differentiated (Gleason score of 5–7) and poorly differentiated (Gleason score of 8–10).

The choice of initial treatment was derived from the National Cancer Data Base.[5] Therapies include radical prostatectomy, radiation therapy, hormonal therapies (including orchiectomy or drug treatment, or both), combination therapies and watchful waiting. Radiation therapy refers to external-beam therapy because 94% of patients receiving radiation therapy undergo this procedure.[8]

The complications associated with radical prostatectomy were determined from a sample of Medicare beneficiaries and included age-specific 30-day hospital mortality, cardiopulmonary complications, vascular complications and surgical complications.[9–12] Complications following external-beam radiation were taken from the results of 2 radiation therapy trials.[13] The complication rates for combination therapies were estimated as the weighted sum of treatment-specific rates.[14] No major complications were considered for hormonal therapies.

We considered treatment options following radical prostatectomy to include radiation therapy and hormonal therapies. We assumed that patients initially followed conservatively (watchful waiting) or undergoing radiation therapy could only receive hormonal therapies as follow-up care. Stage- and grade-specific progression rates were used to derive the annual probabilities of additional curative therapies following prostatectomy.[15] The relative frequency of specific follow-up therapies was derived from data for Medicare patients.[12,16] Following watchful waiting, we assumed that either orchiectomy or pharmacologically induced hormone blockade would occur upon disease progression. Progression rates from localized prostate cancer (T1 or T2) to T3 were taken from published data.[17]

Stage- and grade-specific probabilities of progression to metastatic disease following radical prostatectomy, radiation therapy and watchful waiting were estimated from the results of published cohorts.[18–21]

Three types of death were considered by the model: death without prostate cancer, death with but not resulting from prostate cancer and death from prostate cancer. Adjusted Canadian life tables[22] were used to estimate the risk of death from causes other than prostate cancer. We estimated the annual probability of death from prostate cancer following progression to metastatic disease using 15-year observed survival data.[17]

Estimation of economic burden

The costs of initial and follow-up cancer therapies and complications included the costs of initial hospital services, physician fees and outpatient services. Annual outpatient costs included disease monitoring and palliative care expenditures. All costs were expressed in 1996 Canadian dollars. Because health care costs can be incurred at different times, we weighted each by an annual discount rate of 5% to value them at the same point of time.[23]

The utilization rates of diagnostic tests and procedures for staging were taken from US data.[8,24] The unit costs of diagnostic tests, procedures and physicians fees were estimated from the mean of the Quebec and Ontario reimbursement schedules.[25–27] We considered this choice representative of Canada because health care expenditures per capita are relatively low in Quebec and relatively

Table 1: Mean hospital costs and length of stay for patients with prostate cancer (in 1996 Canadian dollars)

Type of hospital care	Mean length of stay, d	Costs, $		
		Hospital charges	Physician fees	Total
Initial therapy*				
Radical prostatectomy	7.7	6 825	1 442	8 267
External-beam radiotherapy	–†	4 860	400	5 260
Orchiectomy	1.0	1 105	585	1 689
Treatment of complications after initial therapy*				
Bowel or rectal surgical injury	12.2	10 030	758	10 788
Urethral stricture	1.0	512	329	842
Implantation of urinary sphincter	1.0	4 649	530	5 179
Penile prosthesis	1.0	4 649	391	5 041
Cardiopulmonary complications	7.4	5 565	376	5 941
Vascular complications	7.4	4 079	317	4 396
Radiation-related complications				
Cystitis	5.4	3 098	246	3 345
Hematuria	3.3	2 018	178	2 196
Proctitis or rectal stricture	1.0	695	271	966
Diarrhea	4.0	2 627	200	2 827
Follow-up cancer therapy				
Radiation therapy	–†	4 860	400	5 260
Orchiectomy	1.0	1 105	585	1 689
Palliative care				
Palliative radiation	–†	1 468	285	1 753
Chemotherapy	–†	1 903	322	2 224
Terminal care in hospital	14.2	8 085	706	8 791

*These data were used in Grover et al[2] to exemplify the economic burden of prostate cancer in Canada.
†This type of therapy is provided mainly on an outpatient basis in hospital clinics.

high in Ontario. Moreover, over 60% of Canada's total health care dollars are spent in Quebec and Ontario.[28] We also used the fully allocated 1994/95 unit costs from the Montreal General Hospital (unpublished data) and translated them into Ontario cost equivalents using the ratios of per-diem hospital costs or laboratory unit charges between Quebec and Ontario.[29]

We estimated inpatient costs associated with prostate cancer (Table 1) using the methodology of the Canadian Institute for Health Information (CIHI).[30] The costs associated with external-beam radiation therapy were taken from estimates provided by the Royal Victoria Hospital, Montreal.[31] For inpatient physician fees we included anticipated charges for surgeons, assistants, anesthetists, urologists, medical oncologists and radiation oncologists in addition to fees for regular care and the care provided by other specialists.

We identified the costs of various outpatient procedures performed in hospital. These interventions included orchiectomy and the management of complications from initial treatments, such as treatment of urethral strictures, penile prosthesis implantation to treat impotence, urinary sphincter implantation to treat incontinence and treatment of rectal strictures. We calculated the costs of outpatient hospital care using CIHI methodology by assigning each diagnosis to a Day Procedure Group.

We assumed palliative care would be required for men whose prostate cancer progressed to metastatic disease and that it would include more frequent visits to the urologist, routine laboratory tests and radiographic examinations. The mean number of chemotherapy sessions per patient with metastatic disease was taken from published Canadian data.[32] The cost of palliative radiation was estimated and updated to current (1996) costs using the relative cost difference between radiation for palliative and curative purposes[33] and recent estimates from the Royal Victoria Hospital.[31] The frequency and duration of various palliative treatments were estimated from the literature.[34–37] We also estimated the number of urinary procedures that would be required to alleviate urinary tract obstruction.[34,38]

Utilization rates of hormone-blocking drug therapy and orchiectomy were derived from data for 23 214 patients in the United States with newly diagnosed prostate cancer.[8] We assumed that these rates applied to both initial and follow-up hormonal therapies and that drug therapy would be initiated according to specified indications.[39] The selection of hormone-blocking drugs was derived using data from the Ontario Drug Benefit plan.[40]

Drug costs were provided by IMS Canada.[41] Monthly costs were based on the average retail prescription price, including dispensing fees, calculated by the IMS. The proportion of opiates, analgesics and steroids used in palliative care were estimated from the literature.[34–37]

The lifetime costs of caring for Canadians with prostate cancer were estimated for the male population between 40 and 80 years of age based on 1997 population projection data.[42] A cohort representing the number of 40-year-old Canadian men was first entered into the model, and the annual and lifetime prostate-cancer–specific costs were estimated for them. Next, a cohort of 41-year-old men was entered into the model and the lifetime costs were estimated. This process was repeated until the estimated lifetime costs of every cohort of men aged less than 81 years of age were derived.

Results

Validation of the model is described in detail in the accompanying article (page 977).[3] In brief, we compared long-term survival rates among 59 876 men with clinically localized prostate cancer enrolled in a population-based study[43] with survival estimates forecasted by the model. For example, the 10-year disease-specific survival rates following prostatectomy for tumour grades 1, 2 and 3 were 98%, 91% and 76% in the study, as compared with the model's estimates of 96%, 92% and 84%, respectively.[3] We also compared the model's estimates with observed survival rates from the Connecticut Tumor Registry for patients with conservatively treated localized prostate cancer.[44] For example, the registry data showed that 65-year-old men with clinically localized grade 1, 2 and 3 tumours had on average 16.1, 11.3 and 7.9 remaining years of life respectively, as compared with 14.2, 11.5 and 7.4 years estimated by the model.[3]

We compared National Cancer Institute of Canada (NCIC) prostate cancer projections[45] with those generated using the Montreal Prostate Cancer Model (Tables 2 and 3). The lifetime probability of prostate cancer was determined to be 12.4% by the NCIC and 12.2% by the model; the lifetime probability of death from prostate cancer was 3.8% according to the NCIC and 3.3% according to the model. The model estimated that 15 248 new cases of prostate cancer would be diagnosed in Canada in 1997, as

Table 2: Risk of prostate cancer and death from the disease: estimates from the Montreal Prostate Cancer Model and the National Cancer Institute of Canada (NCIC)[45]

	Risk of prostate cancer, %		Risk of death from prostate cancer, %	
By age	Model	NCIC	Model	NCIC
50	0.1	–	0.0	–
60	1.0	0.7	0.1	–
70	4.2	4.2	0.6	–
80	8.9	9.5	1.7	–
90	11.7	12.0	2.9	–
Lifetime	12.2	12.4	3.3	3.8

Table 3: Incidence of prostate cancer and potential years of life lost from the disease: estimates from the Montreal Prostate Cancer Model and the NCIC[45]

	No. of new cases		Potential years of life lost	
Age group, yr	Model	NCIC	Model	NCIC
40–49	181	90	498	–
50–59	1 373	1 300	3 025	–
60–69	4 508	6 000	9 765	–
70–79	5 963	8 400	13 190	–
≥ 80	3 223	3 900	6 552	–
Total	15 248	19 690	33 030	33 000

compared with 19 690 estimated by the NCIC; the potential years of life lost were estimated at 33 030 and 33 000 years respectively.

Using the model, we estimated that, among the 5.8 million Canadian men 40 to 80 years of age in 1997 without a diagnosis of prostate cancer, the disease will eventually be diagnosed in 701 491 (12.1%) and that the lifetime costs of care will be $9.76 billion, or $3.89 billion when discounted at 5% annually) (Table 4). The model estimated that disease staging, prostatectomy, external-beam radiation therapy and hormonal therapies will account for 10.2%, 12.9%, 11.9% and 2.7% of the total lifetime costs of care respectively (Table 5).

The annual costs associated with treating prostate cancer in the 1997 cohort of Canadian men were also estimated for the years 1997 through 2060 (Fig. 1). The number of Canadian men with a diagnosis of prostate cancer in 1997 was estimated to be 15 248 and would incur $111 million in direct medical costs in that year. The model projected a peak in annual treatment costs of $286 million in 2022.

Interpretation

Prostate cancer is a slowly evolving disease, which makes it difficult to demonstrate the efficacy of alternative treatments on clinically important outcomes such as tumour progression or cancer-related mortality.[46,47] The high costs of completing such trials often limits the opportunity to follow patients over the long term. Randomized clinical trials are essential to prove short-term efficacy for a specific therapy but may be inadequate to estimate the long-term impact over a patient's lifetime.[48,49] We therefore developed and validated the Montreal Prostate Cancer Model to forecast the long-term clinical burden of prostate cancer and to estimate the economic burden of this disease on the Canadian health care system.

Similar models have been published by others.[50–54] Cowen and colleagues[50] developed a Markov model of the natural history of prostate cancer; however, the model did not include disease progression rates according to tumour grade and did not consider the direct health care costs associated with specific treatments. Fleming and coworkers[51] developed a detailed decision-analysis model that included grade-specific disease progression; however, the direct

Table 5: Costs associated with the treatment of prostate cancer: estimates from the Montreal Prostate Cancer Model

Type of care	Cost, $ millions (and % of total)
Staging	994 (10.2)
Initial therapy	
Prostatectomy	1257 (12.9)
Radiation therapy	1159 (11.9)
Hormonal therapies	
Orchiectomy	123 (1.3)
Hormonal blockade*	136 (1.4)
Combination therapies	480 (4.9)
Watchful waiting	115 (1.2)
Treatment of complications after initial therapy	186 (1.9)
Follow-up cancer therapy	
Radiation therapy	130 (1.3)
Orchiectomy	188 (1.9)
Hormonal blockade	751 (7.7)
Outpatient care	
After prostatectomy	150 (1.5)
After radiation therapy	689 (7.1)
After hormonal therapies	163 (1.7)
After combination therapies	108 (1.1)
After watchful waiting	425 (4.4)
Palliative care	1117 (11.4)
Terminal care in hospital	1588 (16.3)
Total	9760 (100.0)

*Costs incurred in the first year.

Table 4: Clinical and economic burden of prostate cancer in Canada: estimates from the Montreal Prostate Cancer Model

Age group yr	Total population*	Lifetime incidence of prostate cancer, no. (and %) of cases†	Lifetime costs, $ millions	
			Undiscounted	Discounted‡
40–44	1 220 400	149 234 (12.2)	2 151	492
45–49	1 086 400	134 242 (12.4)	1 932	559
50–54	894 700	112 252 (12.5)	1 611	586
55–59	683 700	86 284 (12.6)	1 223	543
60–64	590 700	74 131 (12.5)	1 025	537
65–69	543 500	65 741 (12.1)	873	527
70–74	437 100	47 638 (10.9)	587	389
75–80	338 780	31 969 (9.4)	357	260
Total	5 795 280	701 491 (12.1)	9 760	3 894

*Projected Canadian population, July 1997. Source: Statistics Canada.[42]
†Percentages are based on total population in each age group.
‡Costs are discounted 5% annually.

health care costs associated with these treatments were not considered. An extensive cost-effectiveness analysis was completed by the US Office of Technology Assessment.[54] This analysis included a comprehensive literature review on prostate cancer management and included grade-specific disease progression rates and an analysis of direct health care costs. However, the costs of managing recurrent cancer beyond hormonal therapies, including palliative care, were not considered because the primary focus of the analysis was the cost-effectiveness of screening and early detection.

We have tried to build on these earlier disease-simulation models to capture the most important clinical and economic consequences of prostate cancer over the entire course of the disease. We have paid particular attention to studies presenting data stratified by tumour grade because tumour grade has been shown to be one of the strongest predictors of disease progression and survival.[18,20,43,44] We have also validated our model against studies in which data were stratified by patient age, tumour stage and grade, and treatment modalities.[43,44,55]

The main limitation of our model is that, because of the paucity of Canadian population-based data, we had to rely often on US data. Moreover, because of the model's complexity we are unable at present to provide the confidence intervals around our estimates using techniques such as Monte Carlo simulations. Despite these limitations, the model has a number of potential uses including forecasting the impact of changes in management on disease progression, life expectancy and health care costs. However, it is impossible to use the model to compare alternative treatment strategies in the absence of data from randomized clinical trials demonstrating clinical efficacy.

The clinical burden of prostate cancer in Canada is substantial and appears to be rising.[1,2] Projections from the National Cancer Institute[45] and our model suggest that prostate cancer will develop in over 12% of Canadian men over their lifetime and will be fatal in 3% to 4% of cases.

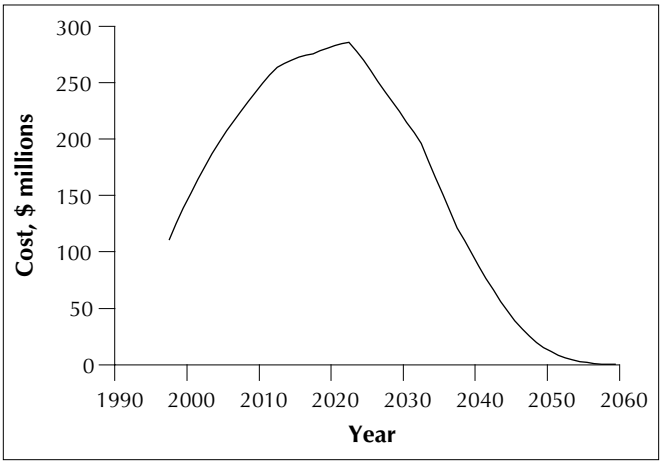

Fig. 1: Projected costs of managing prostate cancer in a cohort of Canadian men aged 40–80 years in 1997.

The economic burden of this disease also appears to be substantial.[2,56] Our model estimates that the direct health care costs of treating over 700 000 cases of prostate cancer among Canadian men currently aged 40 to 80 will be $9.76 billion over their lifetime. The present value of these expenditures when discounted 5% annually is $3.89 billion, or about 5% of the $77 billion spent on health care in 1997.[57] A detailed analysis of these costs indicates that initial therapy, including disease staging, prostatectomy and radiation therapy, accounts for over one-third of these health care costs. Palliative care, including the final hospital admission for terminal care, will acount for a quarter of the costs.

These data underscore the need to define which treatment is the most effective in reducing the morbidity and mortality associated with this common cancer.[58–61] The costs of treatment per patient are relatively modest, ranging from $16 000 to $23 000 depending on the age of the patient, the tumour stage and selected treatments. These expenditures represent good value for the money, provided we can show that the treatments significantly affect the clinical course of this important disease.

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