Five-year relative survival from prostate, breast, colorectal and lung cancer

*Larry F. Ellison, Laurie Gibbons, and the Canadian Cancer Survival Analysis Group**

Abstract

Objectives

This article presents five-year relative survival rates for prostate, breast, colorectal and lung cancer diagnosed in 1992. Provincial variations are also examined.

Data sources

Data are from the Canadian Cancer Registry, the National Cancer Incidence Reporting System, the Canadian Mortality Data Base, and life tables.

Analytical techniques

Analysis was conducted using the maximum likelihood method of Estève. Provincial rates were standardized to the age distribution of patients diagnosed with the specific cancer. Statistical tests were conducted to determine if the site-specific age-standardized provincial relative survival rates should be regarded as heterogeneous. (National estimates exclude Québec.)

Main results

Five-year relative survival rates for ages 15 to 99 were highest for prostate cancer (88%) and lowest for lung cancer (17%, women; 14%, men). Relative survival rates for prostate, breast and male lung cancer differ among provinces. There was little inter-provincial variation in relative survival rates for colorectal cancer.

Key words

survival analysis, survival rate

Authors

Larry F. Ellison (613-951-5244; larry.ellison@statcan.ca) and Laurie Gibbons (613-951-4426; laurie.gibbons @statcan.ca) are with the Health Statistics Division at Statistics Canada, Ottawa, Ontario, K1A 0T6. Canadian Cancer Survival Analysis Group members are with various government departments and provincial cancer registries.

The burden of cancer in a population is generally measured by three main indicators: incidence (the number of new cases diagnosed in a year); mortality (the number of deaths attributed to cancer); and five-year survival after diagnosis. While cancer incidence and mortality can reflect how effective public health strategies have been in reducing the burden of the disease, survival time after diagnosis is typically used to evaluate treatments in clinical trials of selected cancer patients. But cancer survival rates can also be compared across large population groups, and this may provide some insight into changing diagnostic patterns, the use of early-detection strategies, and the availability of effective treatments for the general population.[1,2]

Relative survival is the preferred method for analyzing the survival of cancer patients in population studies. It compares the observed survival for a group of cancer patients to the survival that would have been expected for

** Contributing members of the Canadian Cancer Survival Analysis Group are: Ron Dewar, Douglas Dover, Juanita Hatcher, Eric Holowaty, Erich Kliewer, Loraine Marrett, Diane Nishri, Norm Phillips, Donna Turner, Anne-Marie Ugnat and Ghislaine Villeneuve.*

Analytical techniques

All invasive cancer cases diagnosed in 1992 and reported to the Canadian Cancer Registry (CCR) as of December 20, 1999 were included in the analysis file. An internal record linkage identified and deleted duplicates. Vital status during the first five years was then determined through record linkage to the Canadian Mortality Data Base, or from information reported to the CCR by provincial/territorial cancer registries. Although computerized record linkage for follow-up precludes a definitive answer about completeness of mortality tracing, a previous study that used both active follow-up and the computerized record linkage system employed in this analysis concluded that the latter was comparable with, or even superior to, active follow-up.[3]

If a patient was diagnosed with more than one invasive tumour in 1992, only the record with the earliest date of diagnosis was retained. Records for individuals who had been diagnosed with a primary invasive cancer before 1992 were excluded. Historic information covering 1969 to 1992 was obtained by linking the 1992 CCR data with the National Cancer Incidence and Reporting System on a regional basis (British Columbia and the North; Alberta and Saskatchewan; Manitoba; and the Atlantic). For Ontario, the provincial tumour sequence number was used to determine if an individual had been diagnosed with a primary invasive tumour before 1992.

The analysis was restricted to prostate, female breast, colorectal, and lung cancer cases. Records were excluded when: the year of birth or death was unknown; individuals were younger than 15 or older than 99 when diagnosed; diagnosis was established either through autopsy or death certificate only (DCO); the date of cancer diagnosis was after the date of death. The majority of exclusions were autopsy or DCO cases (see Appendix A, Tables A and B). Québec data were excluded from national estimates and are presented separately (see *Limitations* and Appendix B).

In general, survival time was calculated as the difference in days between the date of diagnosis and the date of last observation (date of death or December 31, 1997, whichever was earliest) to a maximum of five years. For a small percentage of subjects (2.6%) with missing information on day/month of diagnosis (Event 1) and/or day/month of death (Event 2), survival time was estimated (see Appendix A,Table C). For deaths reported by a provincial registry but not confirmed by record linkage with the Canadian Mortality Data Base, it was assumed that the individual died on the date submitted by the reporting province. These represent 0.7% of the total number of deaths, with the following provincial breakdown: Newfoundland (7), Nova Scotia (1), New Brunswick (10), Ontario (69), Manitoba (9), Saskatchewan (11), Alberta (10), and British Columbia (33).

The analysis was conducted in STATA 6.0 using the strel module,[4,5] a user-written module that follows Estève's maximum likelihood method.[6] Because the program automatically excludes cases with zero days of survival, one day of survival was added to cases with the same date of diagnosis and death (not including those cases previously excluded because they were diagnosed through autopsy or DCO). Excluding subjects whose true recorded survival was zero would have tended to inflate estimates of relative survival.[5] In addition to point estimates for relative survival, 95% confidence intervals are given to provide an estimate of the stability, or lack thereof, in point estimates.

To estimate relative survival, observed and expected survival rates must be compared. The expected survival rates used to calculate national and provincial relative survival estimates were derived, by single year of age up to 85, from sex-specific provincial life tables (1990 to 1992) provided by Statistics Canada.[7] Using the method suggested by Dickman et al.,[8] each life table was extended to age 99.

Deaths were grouped into intervals of arbitrary length, following the actuarial method for survival analysis: 3 months for the first year of follow-up, then 6 months for the remaining 4 years for a total of 12 intervals. Because the strel module does not produce survival estimates when the number of intervals exceeds the number of incident cases, it was sometimes necessary to reduce the number of intervals.

Age-standardized rates for a given cancer were calculated by weighting age-specific rates to the age distribution of eligible patients diagnosed with that cancer (see Appendix A, Table D for standard population figures). For example, the standard cancer population for any analysis (national or provincial) of the survival of lung cancer patients would be formed by the eligible lung cancer patients included in the study. Another option for a standard cancer population would be to use the age distribution of all eligible cancer patients diagnosed in 1992, regardless of site. While this would permit direct comparisons of standardized survival rates across cancer sites, it leads to age-standardized survival rates that differ widely from the non-standardized rates because the age distribution of patients can vary widely between cancers.[5] In two circumstances—prostate cancer in 15- to 54-year-olds in Newfoundland and Manitoba—there were no deaths in the first five years of follow-up, so to calculate age-standardized rates, the 15-to-54 and 55-to-64 age groups were collapsed into one group. Confidence intervals for age-standardized rates were based on the log (–log) transformation.

Tests of heterogeneity were used to determine whether age-standardized provincial relative survival rates, as a group, could be regarded as homogeneous, in that they could differ from each other by random variation, or whether they should be regarded as heterogeneous, in that random variation is unlikely to explain the differences. Testing was performed using the method of weighting[9] for each of the six cancer site–sex combinations. This test assumes that the log (–log) transformation of the age-standardized relative survival rates is normally distributed with a known variance estimated by the variance of the log (–log) transformation of the age-standardized relative survival rates. In each case, the chi-square test statistic was compared with a critical value of 14.07, based on a one-sided test with alpha set at 0.05 and 7 degrees of freedom.

members of the general population who have the same characteristics—such as sex, age and province of residence—as the cancer patients. Relative survival allows for the measurement of the extra risk of death due to cancer, as does cause-specific survival, but without the need for information on specific causes of death.

This article presents five-year relative survival rates, by age and sex, for each of the four most common cancers diagnosed in Canada in 1992: prostate, breast, colorectal and lung. Relative survival by province is also presented; analyses have been performed to determine statistically significant variations among provincial rates (see *Analytical techniques*, *Data sources*, and *Limitations*).

Rates highest for prostate, breast cancer

Five-year relative survival rates were highest for prostate and breast cancer (Table 1). Men diagnosed with prostate cancer in 1992 were 88% as likely to

Data sources

Cancer incidence data are from the Canadian Cancer Registry (CCR), a database that has information based on reports from every provincial/territorial cancer registry since 1992. This database is maintained by Statistics Canada, and it succeeds the National Cancer Incidence and Reporting System (1969 through 1991). Mortality data are from the Canadian Mortality Data Base (also maintained by Statistics Canada), which is based on information provided by the vital statistics registrars in each province and territory. Canadian and provincial life tables from Statistics Canada were also used.

Table 1
Five-year relative survival rates for prostate, breast, colorectal and lung cancer cases diagnosed in 1992, by sex and age group, Canada†

	Men					Women			
Cancer site/ Age group	Relative survival rate	95% confidence interval	Number of cases	Number of deaths‡	Cancer site/ Age group	Relative survival rate	95% confidence interval	Number of cases	Number of deaths‡
	%					%			
Prostate					**Breast**				
15-54	81	75, 85	242	53	15-39	73	70, 77	663	178
55-64	89	87, 91	1,947	363	40-49	83	81, 85	1,947	345
65-74	89	88, 91	4,752	1,273	50-59	83	81, 84	2,107	410
75-84	86	83, 88	3,585	1,663	60-69	83	81, 84	2,749	620
85-99	67	58, 75	763	577	70-79	86	83, 88	2,405	674
15-99	88	87, 89	11,289	3,929	80-99	78	72, 82	1,137	623
					15-99	82	81, 83	11,008	2,850
Colorectal					**Colorectal**				
15-49	58	53, 63	424	182	15-49	64	58, 68	362	134
50-59	59	56, 63	828	361	50-59	64	59, 68	551	210
60-69	56	54, 59	1,647	827	60-69	62	59, 65	1,127	477
70-79	56	53, 60	1,673	976	70-79	59	56, 62	1,389	703
80-99	50	44, 56	786	594	80-99	52	47, 56	1,076	752
15-99	56	55, 58	5,358	2,940	15-99	59	57, 61	4,505	2,276
Lung					**Lung**				
15-49	17	14, 21	409	340	15-49	24	20, 29	402	305
50-59	16	14, 18	1,041	881	50-59	20	17, 23	684	549
60-69	15	13, 16	2,464	2,147	60-69	17	15, 20	1,291	1,081
70-79	13	12, 15	2,196	1,980	70-79	15	13, 17	1,142	995
80-99	8	5, 11	743	713	80-99	10	7, 14	410	384
15-99	14	13, 15	6,853	6,061	15-99	17	16, 19	3,929	3,314

Data source: *Canadian Cancer Registry*
† Excluding Québec
‡ Within first five years of follow-up

live another five years as were men of the same age and in the same province. Women diagnosed with breast cancer in 1992 had 82% the chance of living another five years as did women with similar characteristics. Men with colorectal cancer had a relative survival rate of 56%, and for women the rate was 59%. By contrast, relative survival rates for lung cancer were low: 14% for men and 17% for women.

Limitations

Some provincial cancer registries differ with respect to methods of data collection and registration of multiple primaries (more than one diagnosis of a primary cancer). There are also variations in the percentage of "death certificate only" (DCO) cases, and the aggressiveness of follow-up. For example, there is an under-registration of cancer cases in Newfoundland; Alberta aggressively follows-up DCO cases; Ontario's registration process is passive, relying almost completely on records collected for other purposes; and Newfoundland does not use information from their vital statistics registries to update their cancer registry database.

Québec data were not included in the national estimates of five-year relative survival because their method of ascertaining the date of diagnosis of cancer cases differs substantially from that of other provincial cancer registries. While other provinces use a variety of sources (pathology reports, laboratory test results, etc.) to ascertain the date of diagnosis of new cancer cases, the Québec cancer registry relies solely on hospital discharge records. Any patient originally diagnosed outside the hospital, and in fact, even patients diagnosed in the hospital, would have their survival time underestimated because their date of diagnosis is registered as the date of discharge. (Five-year relative survival rates for Québec are presented separately in Appendix B).

Cases diagnosed outside Québec, but who died in that province, could not be identified through national death linkage given the absence of signed legal agreements allowing for the exchange of information between Québec and the other provinces/territories. This may result in slightly increased survival estimates for the affected provinces.

Results for Prince Edward Island, the Yukon, and the Northwest Territories are not shown because of an insufficient number of cases for analysis. Cases from these areas are, however, included in the national estimates. Expected survival rates for Prince Edward Island, the Yukon and the Northwest Territories were derived from the Canadian life tables, as stable estimates for single ages could not be produced because of small populations. This substitution should not introduce bias in national estimates, as these three areas combined accounted for just 0.9% of all eligible cases.

While a few provinces collect information on stage of disease at diagnosis, this is not available in the Canadian Cancer Registry. If such information were available, it would be possible to learn more about the effectiveness and use of early cancer detection from stage-specific survival rates. Until staging information is available at a national level, inferences can be made only about the possible effects of diagnosis and treatment together.

Because the diagnosis of cancer in the sites studied in this report is a rare occurrence in very young adults, it is important to consider the possibility of a miscoded primary cancer for these patients. However, less than 0.1% of the breast, colorectal, and lung cancer cases, and none of the prostate cancer cases, were aged 15 to 24. The extremely small case contribution of this group meant that diagnostic miscoding in very young adults, if present at all, had a negligible impact on the results.

Unless they have been age-standardized to the same population (see Appendix A, Table D), relative survival rates from other sources should not be compared with those presented in this analysis.

DCO cases were excluded from estimates of relative survival because the date of diagnosis, and hence survival time, was unknown. The "true" survival of cases registered by DCO is generally poorer than that of those in the registry population.[10] The necessity of excluding DCO cases may have led to increases in observed survival rates, particularly in provinces with proportionately more DCO cases. However, the magnitude is generally minor.[10]

Tests to determine if the difference between two relative survival rates is statistically significant were not conducted for several reasons. Comparing a province's age-standardized relative survival rate for a given cancer site/sex combination to the corresponding rate for Canada would not test two independent groups. Such tests could also involve a very large number of multiple comparisons; for example, nearly 300 site-specific pairwise comparisons could be made between provinces alone. And finally, highlighting small differences that may be statistically significant but not practically meaningful, while ignoring larger, potentially more meaningful differences simply because they approach but do not achieve statistical significance, did not seem appropriate.

Age patterns vary

Age-related patterns of relative survival varied by cancer site. At ages 55 to 64 and 65 to 74, the relative survival rate for men with prostate cancer was 89%. Prostate cancer prognoses were poorer at younger and older ages. For patients aged 15 to 54, the five-year relative survival rate was 81%, and at ages 85 to 99, 67% (Table 1). Findings from other studies inicate that younger men with prostate cancer have poorer survival,[11,12] perhaps because of biological features of prostate tumours presenting in younger men.[12] Studies have also found that older men with prostate cancer are less likely to receive aggressive therapy,[11,13] even when co-morbidity is taken into account.[13]

Similarly, breast cancer survival was considerably less favourable among women diagnosed at very young or very old ages. Patients aged 15 to 39 had a five-year relative survival rate of 73%, even less than the 78% rate among their counterparts aged 80 to 99. By contrast, for women in the 40-to-79 age range, relative breast cancer survival rates were at least 83%. It is thought that women diagnosed with breast cancer when they are relatively young have a poorer prognosis because of certain genetic and biological characteristics.[11,14-17] Women who are older may be diagnosed at more advanced stages of the disease,[18] when treatment is often less effective. Physicians may also be reluctant to initiate aggressive treatment in elderly patients, who may have frail health and other medical conditions.[13,18,19]

Among patients of both sexes, colorectal cancer relative survival rates varied little by age. From the 15-to-49 to the 70-to-79 age groups, rates ranged between 56% and 59% for men, and declined slightly, from 64% to 59%, for women. Relative survival rates dropped to about 50% in the oldest age group (80 to 99) for both sexes.

Relative survival rates for lung cancer decreased with age for both sexes, but were consistently higher for women. For male and female lung cancer patients, survival rates at ages 80 to 99 were less than half those for patients aged 15 to 49. These findings are similar to those from a recent US study,[11] which also found that older lung cancer patients were less likely than their younger counterparts to undergo surgical treatment.

Provincial variations in prostate, breast and lung cancer

Statistical tests of heterogeneity revealed that age-standardized relative survival rates for prostate, breast and male lung cancer varied by province (chi-squares = 36.77, 18.83, and 21.37, respectively).

For prostate cancer, age-standardized relative survival rates stood out in British Columbia and Newfoundland. In British Columbia, men diagnosed with prostate cancer in 1992 had 91% the chance of surviving five years as did men of the same age and province (Table 2). The corresponding figure for men in Newfoundland was 67%. In other provinces, prostate cancer survival rates ranged from 82% to 86%.

While interprovincial variation in prostate cancer survival rates is likely influenced by many factors, the use of prostate-specific antigen (PSA) screening for prostate cancer has led to dramatic increases in prostate cancer incidence in Canada[20] and the United States.[21,22] This has led in turn to increases in prostate cancer survival rates.[2,23] In Saskatchewan, from 1990 to 1994, rates of PSA screening and prostate cancer incidence both rose dramatically, and the five-year relative survival rate increased from 69% in the 1985-to-1989 period to 83% in 1990-to-1994.[23] In the absence of information on PSA testing from other provinces, 1992 provincial prostate cancer incidence rates may provide an indication of rates of screening and thus a possible explanation for the variation in observed relative survival rates. In 1992, prostate cancer incidence rates were highest in Manitoba and British Columbia and lowest in Newfoundland.[24]

Similar to prostate cancer, age-standardized relative survival rates for breast cancer were highest in British Columbia (85%) and lowest in Newfoundland (76%). Differing use of mammography for early diagnosis may explain some of the provincial variation in survival rates for breast cancer. According to the 1994/95 National Population Health Survey,[25] the proportion of women aged 40 or older who reported ever having had a mammogram was highest in British Columbia (69%) and lowest in Newfoundland (43%).

Because of the lack of national data on the stage of cancer at diagnosis, it is not possible to truly ascertain the impact of screening and early diagnosis on survival rates.

For men with lung cancer, five-year age-standardized relative survival rates ranged from 12% to 15%, except in Saskatchewan (8%) and Alberta (10%). Survival rates for women with lung cancer ranged from 11% in New Brunswick to 20% in Newfoundland; however, as a group, variations among the provinces were not statistically significant (chi square = 12.62). Except in New Brunswick, rates were equal or slightly higher for women than men in each province. The male–female difference was greatest in Newfoundland and Saskatchewan.

Colorectal cancer rates vary little by province

There was little interprovincial variation in relative survival rates for colorectal cancer (chi squares = 7.23, males; 8.39, females). The lowest age-standardized relative survival rates for this cancer

Table 2
Age-standardized† five-year relative survival rates for prostate, breast, colorectal and lung cancer cases diagnosed in 1992, ages 15 to 99, by sex and province

	Men					Women			
Cancer site	Relative survival rate	95% confidence interval	Number of cases	Number of deaths§	Cancer site	Relative survival rate	95% confidence interval	Number of cases	Number of deaths§
	%					%			
Prostate					**Breast**				
Canada‡	**87**	**85, 88**	**11,289**	**3,929**	**Canada‡**	**82**	**81, 83**	**11,008**	**2,850**
Newfoundland	67	55, 77	133	65	Newfoundland	76	68, 82	217	64
Nova Scotia	82	75, 87	445	172	Nova Scotia	84	79, 88	456	110
New Brunswick	83	76, 89	408	145	New Brunswick	77	71, 82	345	102
Ontario	86	84, 88	5,363	1,889	Ontario	82	81, 83	5,688	1,468
Manitoba	85	80, 89	842	314	Manitoba	79	74, 83	580	176
Saskatchewan	83	77, 87	621	230	Saskatchewan	83	78, 86	550	147
Alberta	82	78, 85	1,084	405	Alberta	81	78, 84	1,203	307
British Columbia	91	88, 93	2,304	669	British Columbia	85	83, 87	1,884	447
Colorectal					**Colorectal**				
Canada‡	**56**	**54, 58**	**5,358**	**2,940**	**Canada‡**	**59**	**58, 61**	**4,505**	**2,276**
Newfoundland	56	46, 66	145	75	Newfoundland	56	46, 65	135	66
Nova Scotia	54	45, 62	237	135	Nova Scotia	56	49, 63	243	128
New Brunswick	47	39, 55	192	111	New Brunswick	52	43, 60	178	99
Ontario	55	53, 58	2,831	1,564	Ontario	59	57, 61	2,339	1,191
Manitoba	53	46, 60	303	170	Manitoba	60	53, 66	284	139
Saskatchewan	54	46, 61	256	144	Saskatchewan	65	56, 72	190	87
Alberta	54	48, 59	503	283	Alberta	55	49, 60	379	204
British Columbia	59	54, 63	842	426	British Columbia	61	56, 65	705	335
Lung					**Lung**				
Canada‡	**14**	**13, 15**	**6,853**	**6,061**	**Canada‡**	**17**	**16, 18**	**3,929**	**3,314**
Newfoundland	13	8, 20	136	121	Newfoundland	20	10, 33	50	42
Nova Scotia	13	10, 17	334	297	Nova Scotia	16	11, 23	169	143
New Brunswick	15	11, 20	296	259	New Brunswick	11	6, 17	143	129
Ontario	15	14, 16	3,765	3,290	Ontario	18	17, 20	2,065	1,714
Manitoba	15	11, 20	371	325	Manitoba	15	10, 20	217	187
Saskatchewan	8	6, 12	320	297	Saskatchewan	17	12, 23	174	146
Alberta	10	7, 13	607	557	Alberta	13	10, 17	374	323
British Columbia	12	10, 15	967	862	British Columbia	15	12, 18	699	598

Data source: *Canadian Cancer Registry*
Notes: *Tests of heterogeneity for prostate, breast and male lung cancer show statistically significant differences in age-standardized survival rates among provinces as a group. Results for Prince Edward Island, the Yukon and the Northwest Territories not shown because of insufficient number of cases, but cases from these areas are included in national totals.*
† Age-standardized to the 1992 Canadian case distribution of the cancer site under study (see Appendix A, Table D).
‡ Excluding Québec
§ Within first five years of follow-up

were in New Brunswick: 47% for men and 52% for women. It is possible that diagnostic practices and/or delivery of treatment may differ in New Brunswick to the extent that they affect five-year relative survival from colorectal cancer. Among men with colorectal cancer, British Columbia's relative survival rate was highest (59%). For women, the highest rate was in Saskatchewan (65%). The largest male–female difference between colorectal cancer survival rates was in Saskatchewan.

Because reporting procedures vary across the country, provincial differences in survival rates should be interpreted with caution (see *Limitations*). (Non-standardized provincial rates are presented in Appendix A, Table E.)

Concluding remarks

Five-year relative survival rates decline dramatically with age among lung cancer patients. This may reflect a reluctance to use aggressive therapy for older patients. Comparatively low rates were also observed among the youngest and oldest age groups with prostate and breast cancer.

When new screening techniques enable physicians to detect cancers earlier, then survival rates for these cancers should increase.[1,2] If, however, cancers are detected early, but treatment is no more effective at early than at later stages, survival rates will increase with no decrease in mortality. Patients diagnosed early will appear to live longer with their disease, thus increasing their survival time, but will not actually benefit from this early diagnosis; this is often referred to as lead-time bias. Indeed it has been argued that new diagnostic techniques may be responsible for much of the recent change in cancer incidence and survival.[2]

Although techniques are available to detect prostate, colorectal and breast cancer at early stages, not all have proven effective in reducing mortality from these diseases. While PSA testing leads to an earlier diagnosis of prostate cancer and thus increases survival rates, it has not yet been shown to effectively reduce mortality. On the other hand, mortality from colorectal cancer can be reduced if the disease is detected early,[26-28] either before the benign polyp becomes cancerous, or while the tumour remains localized in the colon. But screening for colorectal cancer in the Canadian population was not widespread in 1992.

Some studies have argued that mammography screening in women aged 50 to 69 has reduced breast cancer mortality by detecting tumours at earlier, more treatable stages.[29-32] Varying use of mammography screening may explain some of the provincial differences in breast cancer relative survival rates.

The extent to which differences in the use and diffusion of screening, diagnostic and/or treatment practices have affected differences in five-year relative survival rates across the provinces is not known. In fact, the reasons behind the provincial variations are not evident, nor is there any discernible pattern behind the differences. Although they may partly reflect the availability and level of screening being used across the country, the results of this analysis cannot be considered a reflection of the effectiveness of screening tests.

Acknowledgements

The authors thank Rebecca Filyer for her work in extending provincial life tables and Ingrid Friesen for her help in resolving data quality issues.

References

1 Gatta G, Capocaccia R, Coleman M, et al. Toward a comparison of survival in American and European cancer patients. *Cancer* 2000; 89(4): 893-900.

2 Welch HG, Schwartz LM, Woloshin S. Are increasing 5-year survival rates evidence of success against cancer? *Journal of the American Medical Association* 2000; 283: 2975-8.

3 Shannon HS, Jamieson E, Walsh C, et al. Comparison of individual follow-up and computerized linkage using the Canadian Mortality Data Base. *Canadian Journal of Public Health* 1989; 80: 54-7.

4 Sloggett A, Hills M, de Stavola, et al. *Strel: Estimation of relative survival* [computer program], 2000. Available at Andy.Slogett@lshtm.ac.uk.

5 Coleman MP, Babb P, Damiecki P, et al. *Cancer Survival Trends in England and Wales 1971-1995: Deprivation and NHS Region. Series SMPS No. 61*. London: The Stationery Office, 1999.

6 Estève J, Benhamou E, Croasdale M, et al. Relative survival and the estimation of net survival: elements for further discussion. *Statistics in Medicine* 1990; 9: 529-38.

7 Millar WJ, David P. *Life Tables, Canada and Provinces, 1990-1992* (Statistics Canada, Catalogue 84-537) Ottawa: Minister of Industry, 1995.

8 Dickman PW, Auvinen A, Voutilainen ET, et al. Measuring social class differences in cancer patient survival: Is it necessary to control for social class differences in general population mortality? A Finnish population-based study. *Journal of Epidemiology and Community Health* 1998; 52: 727-34.

9 Armitage P, Berry G. *Statistical Methods in Medical Research, Third edition.* Oxford: Blackwell Science Ltd., 1994.

10 Berrino F, Estève J, Coleman MP. Basic issue in estimating and comparing the survival of cancer patients. In: Berrino F, Dante M, Verdecchia A, et al. *Survival of Cancer Patients in Europe. The Eurocare Study*. IARC Scientific Publication No. 132. Lyon: International Agency for Research on Cancer, 1995: 1-14.

11 Wingo PA, Gloeckler Ries LA, Parker SL, et al. Long-term cancer patient survival in the United States. *Cancer Epidemiology, Biomarkers & Prevention* 1998; 7: 271-82.

12 Robbins AS, Whittemore AS, Thom DH. Differences in socioeconomic status and survival among white and black men with prostate cancer. *American Journal of Epidemiology* 2000; 151(4): 409-16.

13 Goodwin JS, Samet JM, Hunt WC. Determinants of survival in older cancer patients. *Journal of the National Cancer Institute* 1996; 88(15): 1031-7.

14 de la Rochfordière A, Asselain B, Campana F, et al. Age as a prognostic factor in premenopausal breast carcinoma. *Lancet* 1993; 341: 1039-43.

15 Adami H-O, Malker B, Holmberg L, et al. The relation between survival and age at diagnosis in breast cancer. *New England Journal of Medicine* 1996; 315: 559-63.

16 Marcus JN, Watson P, Page DL, et al. Pathology and heredity of breast cancer in younger women. *Monograph of the National Cancer Institute* 1994; 16: 23-34.

17 Yildirim E, Dalgiç T, Berberoglu U. Prognostic significance of young age in breast cancer. *Journal of Surgical Oncology* 2000; 74: 267-72.

18 Yancik R, Ries LG. Cancer in the aged: An epidemiologic perspective on treatment issues. *Cancer* 1991; 68: 2502-10.

19 Lazovich D, White E, Thomas DB, et al. Underutilization of breast-conserving surgery and radiation therapy among women with stage I or II breast cancer. *Journal of the American Medical Association* 1991; 266: 3433-8.

20 National Cancer Institute of Canada. *Canadian Cancer Statistics 2001*. Toronto: National Cancer Institute of Canada, 2001.

21 Potosky AL, Miller BA, Albertsen PC, et al. The role of increasing detection in the rising incidence of prostate cancer. *Journal of the American Medical Association* 1995; 273: 548-52.

22 Jacobsen SJ, Katusic SK, Bergstralh EJ, et al. Incidence of prostate cancer diagnosis in the eras before and after serum prostate-specific antigen testing. *Journal of the American Medical Association* 1995; 274: 1445-9.

23 Skarsgard D, Tonita J. Prostate cancer in Saskatchewan, before and during the PSA era. *Cancer Causes and Control* 2000; 11: 79-88.

24 Statistics Canada. *Canadian Cancer Registry,* unpublished data, 2001.

25 Gaudette LA, Altmayer CA, Nobrega KMP, et al. Trends in mammography utilization, 1981 to 1994. *Health Reports* (Statistics Canada, Catalogue 82-003), 1996; 8(3): 17-27.

26 Mandel JS, Church TR, Ederer F, et al. Colorectal cancer mortality: effectiveness of biennial screening for faecal occult blood. *Journal of the National Cancer Institute* 1999; 91: 434-7.

27 Hardcastle JD, Chamberlain JO, Robinson MH, et al. Randomised controlled trial of faecal-occult-blood screening for colorectal cancer. *Lancet* 1996; 348: 1472-7.

28 Kronberg O, Fenger C, Olsen J, et al. Randomised study of screening for colorectal cancer with faecal-occult-blood test. *Lancet* 1996; 348: 1467-71.

29 Shapiro S, Venet W, Strax, P, et al. Ten-to-fourteen year effect of screening on breast cancer mortality. *Journal of the National Cancer Institute* 1982; 69: 349-55.

30 Shapiro S, Venet W, Strax, P, et al. *Periodic screening for breast cancer; the Health Insurance Plan project and its sequelae, 1963-1986*. Baltimore, Maryland: Johns Hopkins University Press, 1988.

31 Miller AB, Baines CJ, To T, et al. Canadian National Breast Screening Study, 2: breast detection and death rates among women 50-59 year. *Canadian Medical Association Journal* 1992; 147: 1477-88.

32 Moody-Ayers SY, Wells CK, Feinstein AR. Benign tumors and early detection in mammography-screened patients of a natural cohort with breast cancer. *Archives of Internal Medicine* 2000; 160: 1109-15.

Appendix A

Table A
Records remaining after exclusions,† prostate, breast, colorectal and lung cancer cases diagnosed in 1992, by province

Restricted to ...	Canada‡	NFLD	PEI	NS	NB	ONT	MAN	SASK	ALTA	BC
Prostate cancer										
First tumour only	11,413	137	83	463	410	5,407	848	628	1,090	2,339
Year of birth and/or death available	11,399	133	83	462	410	5,398	848	628	1,090	2,339
Age at diagnosis ≥ 15 and ≤ 99	11,394	133	83	462	410	5,394	848	628	1,089	2,339
Cancer not diagnosed by autopsy or by DCO	11,289	133	82	445	408	5,363	842	621	1,084	2,304
Breast cancer										
First tumour only	11,095	219	66	468	346	5,730	583	551	1,203	1,910
Year of birth and/or death available	11,089	217	66	467	346	5,727	583	551	1,203	1,910
Age at diagnosis ≥ 15 and ≤ 99	11,087	217	66	466	346	5,726	583	551	1,203	1,910
Cancer not diagnosed by autopsy or by DCO	11,008	217	66	456	345	5,688	580	550	1,203	1,884
Colorectal cancer										
First tumour only	10,073	285	91	514	376	5,252	601	461	888	1,592
Year of birth and/or death available	10,067	282	91	513	376	5,250	601	461	888	1,592
Age at diagnosis ≥ 15 and ≤ 99	10,060	281	91	511	376	5,246	601	461	888	1,592
Cancer not diagnosed by autopsy or by DCO	9,863	280	88	480	370	5,170	587	446	882	1,547
Lung cancer										
First tumour only	11,355	195	70	600	449	6,012	618	529	991	1,858
Year of birth and/or death available	11,345	190	70	600	449	6,008	618	528	991	1,858
Age at diagnosis ≥ 15 and ≤ 99	11,339	189	70	599	449	6,005	618	528	991	1,857
Cancer not diagnosed by autopsy or by DCO	10,782	186	63	503	439	5,830	588	494	981	1,666

Data source: *Canadian Cancer Registry*
Note: *Yukon and Northwest Territories not displayed because of small numbers.*
† There were no exclusions resulting from date of diagnosis after date of death.
‡ Excluding Québec

Table B
Percentage of death certificate only (DCO) cases,† prostate, breast, colorectal and lung cancer diagnosed in 1992, by province

	Canada‡	NFLD§	PEI	NS	NB	ONT	MAN	SASK	ALTA	BC
Prostate cancer										
Eligible cases + DCOs	11,367	133	83	459	409	5,389	848	625	1,085	2,328
DCOs	78	...	1	14	1	26	6	4	1	24
% of otherwise eligible cases	0.7	...	1.2	3.1	0.2	0.5	0.7	0.6	0.1	1.0
Breast cancer										
Eligible cases + DCOs	11,086	217	66	466	346	5,726	583	551	1,203	1,909
DCOs	78	...	0	10	1	38	3	1	0	25
% of otherwise eligible cases	0.7	...	0.0	2.1	0.3	0.7	0.5	0.2	0.0	1.3
Colorectal cancer										
Eligible cases + DCOs	10,017	280	89	508	372	5,234	599	454	883	1,585
DCOs	154	...	1	28	2	64	12	8	1	38
% of otherwise eligible cases	1.5	...	1.1	5.5	0.5	1.2	2.0	1.8	0.1	2.4
Lung cancer										
Eligible cases + DCOs	11,235	186	65	590	441	5,990	617	517	983	1,813
DCOs	453	...	2	87	2	160	29	23	2	147
% of otherwise eligible cases	4.0	...	3.1	14.7	0.5	2.7	4.7	4.4	0.2	8.1

Data source: *Canadian Cancer Registry*
Note: *Yukon and Northwest Territories not displayed because of small numbers.*
*† Calculated as death certificate only cases (DCOs) * 100 / (eligible cases + DCOs)*
‡ Excluding Québec
§ Could not have any DCO cases as the province did not use information from their vital statistics registries to update their data.
... Not applicable

Table C
Estimating intervals

	Interval between Event 2 and Event 1
Date event 1 **Date event 2**	**d1/m1/y1** **d2/m2/y2**
If both dates complete:	Interval = d2/m2/y2 – d1/m1/y1
If d1 missing, all others complete:	
If m1 = m2 and y1 = y2	Interval = ½ (d2/m2/y2 – 1/m1/y1)
Else	Interval = d2/m2/y2 – z/m1/y1
If d1 and d2 missing:	
If m1 = m2 and y1 = y2	Interval = 8
Else	Interval = z/m2/y2 – z/m1/y1
If d2 missing:	
If m1 = m2 and y1 = y2	Interval = ½ (x/m2/y2 – d1/m1/y1)
Else	Interval = z/m2/y2 – d1/m1/y1
If d1 and m1 missing:	
y1 = y2	Interval = ½ (d2/m2/y2 – 1/1/y1)
y1 < y2	Interval = d2/m2/y2 – 2/7/y1
If d2 and m2 missing:	
y1 = y2	Interval = ½ (31/12/y2 – d1/m1/y1)
y1 < y2	Interval = 2/7/y2 – d1/m1/y1
If m1, d1, and d2 missing:	
y1 = y2	Interval = ½ (z/m2/y2 - 1/1/y1)
y1 < y2	Interval = z/m2/y2 - 2/7/y1
If m2, d2, and d1 missing:	
y1 = y2	Interval = ½ (31/12/y2 - z/m1/y1)
y1 < y2	Interval = 2/7/y2 - z/m1/y1
If m1, d1, m2, d2 missing:	
y1 = y2	Interval = 91
y1 < y2	Interval = 365*(y2-y1)

Notes: *Calculated survival time should be rounded to the nearest integer value where applicable. Where x = 28, 29, 30, or 31 depending on the month and z = 16 (or 15 if February).*

Table D
Standard age populations

Cancer site	**Number of cases**
Prostate	
15-54	242
55-64	1,947
65-74	4,752
75-84	3,585
85-99	763
Breast	
15-39	663
40-49	1,947
50-59	2,107
60-69	2,749
70-79	2,405
80-99	1,137
Colorectal	
15-49	786
50-59	1,379
60-69	2,774
70-79	3,062
80-99	1,862
Lung	
15-49	811
50-59	1,725
60-69	3,755
70-79	3,338
80-99	1,153

Data source: *Canadian Cancer Registry (after exclusions)*

Table E

Non-standardized five-year relative survival rates for prostate, breast, colorectal and lung cancer cases diagnosed in 1992, ages 15 to 99, by sex and province

Cancer site	Men: Relative survival rate	Men: 95% confidence interval	Men: Number of cases	Men: Number of deaths†
	%			
Prostate				
Newfoundland	72	58, 81	133	65
Nova Scotia	84	77, 89	445	172
New Brunswick	87	80, 92	408	145
Ontario	87	85, 88	5,363	1,889
Manitoba	86	82, 90	842	314
Saskatchewan	85	80, 89	621	230
Alberta	84	80, 87	1,084	405
British Columbia	93	91, 95	2,304	669
Colorectal				
Newfoundland	60	50, 69	145	75
Nova Scotia	56	48, 64	237	135
New Brunswick	52	43, 60	192	111
Ontario	56	53, 58	2,831	1,564
Manitoba	55	48, 62	303	170
Saskatchewan	55	47, 62	256	144
Alberta	54	49, 59	503	283
British Columbia	61	57, 65	842	426
Lung				
Newfoundland	14	8, 22	136	121
Nova Scotia	14	10, 19	334	297
New Brunswick	15	11, 20	296	259
Ontario	15	14, 16	3,765	3,290
Manitoba	16	12, 20	371	325
Saskatchewan	9	6, 13	320	297
Alberta	10	8, 13	607	557
British Columbia	13	11, 16	967	862

Cancer site	Women: Relative survival rate	Women: 95% confidence interval	Women: Number of cases	Women: Number of deaths†
	%			
Breast				
Newfoundland	78	71, 84	217	64
Nova Scotia	86	81, 89	456	110
New Brunswick	78	73, 83	345	102
Ontario	82	81, 83	5,688	1,468
Manitoba	80	76, 84	580	176
Saskatchewan	84	79, 87	550	147
Alberta	81	78, 83	1,203	307
British Columbia	85	83, 87	1,884	447
Colorectal				
Newfoundland	58	49, 67	135	66
Nova Scotia	58	50, 65	243	128
New Brunswick	56	46, 64	178	99
Ontario	58	56, 61	2,339	1,191
Manitoba	60	53, 67	284	139
Saskatchewan	67	58, 75	190	87
Alberta	55	49, 61	379	204
British Columbia	62	58, 66	705	335
Lung				
Newfoundland	17	8, 29	50	42
Nova Scotia	17	11, 23	169	143
New Brunswick	11	6, 17	143	129
Ontario	19	17, 21	2,065	1,714
Manitoba	15	11, 21	217	187
Saskatchewan	18	12, 24	174	146
Alberta	15	11, 19	374	323
British Columbia	16	13, 19	699	598

Data source: *Canadian Cancer Registry*
† Within first five years of follow-up

Appendix B

Five-year relative survival rates, Québec

Five-year relative survival rates for Québec are presented separately because the province's method of ascertaining the date of diagnosis of cancer cases differs sufficiently from that of the other provinces to render Québec data not comparable with those from the other provinces (see *Limitations*).

Non-standardized five-year relative survival rates for prostate, breast, colorectal and lung cancer cases diagnosed in 1992, ages 15 to 99, by sex, Québec

Cancer site	Relative survival rate	95% confidence interval	Number of cases	Number of deaths
	%			
Prostate	88	85, 90	2,702	953
Breast	82	80, 83	3,579	931
Colorectal				
Men	61	58, 63	1,698	869
Women	61	58, 64	1,619	782
Lung				
Men	23	22, 25	2,545	2,050
Women	26	23, 29	1,203	919

Data source: *Canadian Cancer Registry*

The same exclusion criteria employed in this report (see *Analytical techniques*) were also used for Québec. Information about whether a patient had been diagnosed with a primary invasive tumour before 1992 was obtained directly from the Québec cancer registry. All cases had both the birth and death year recorded; one colorectal cancer case whose age at diagnosis was outside the 15-to-99 age parameters was excluded; and no cases were identified through autopsy. Because Québec does not use information from their vital statistics data base to update their cancer registry, there were no exclusions based on cases diagnosed by DCO. There were, however, 2 cases of colorectal cancer and 11 of lung cancer excluded because the date of cancer diagnosis was after the date of death.

The Québec cancer registry relies solely on hospital discharge records to identify new cancer cases. Thus, a patient diagnosed with cancer outside of a hospital will not be registered as a new cancer case unless he or she enters a hospital and is discharged with a diagnosis of cancer. It is not possible to determine whether the missed cases differ from those who are registered in terms of their survival, so it is unclear what effect this under-registration of cases has on survival estimates.

One consequence of relying solely on hospital discharge records is that if a patient is admitted to a hospital in Québec, diagnosed with cancer, and dies while still in the hospital, the date of diagnosis is reported as the day of death (date of discharge). Restricting to cases otherwise eligible for the current study, Québec reported 1,357 non-autopsy, non-DCO cancer cases with identical dates of diagnosis and death (94 prostate, 93 breast, 296 colorectal, and 874 lung). Because the dates of diagnosis of these cases were based exclusively on hospital discharge records, the "true" dates of diagnosis were not known. As such, these records were excluded from the analysis. In all other regards, the methods of analysis employed for Québec were the same as those used for the rest of the country (see *Analytical techniques*).