Survival from cancer—up-to-date predictions using period analysis

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Abstract

Objectives

This period analysis provides Canadian predictions of the short- and long-term relative survival of people recently diagnosed with cancer. Long-term period and cohort-based estimates are also compared.

Data sources

Data are from the Canadian Cancer Registry, the Canadian Mortality Data Base, and Statistics Canada life tables.

Analytical techniques

Relative survival analyses were conducted using the life-table method; expected survival proportions were derived using the Ederer II approach. Period analysis estimates were based on the survival experience of cancer cases followed up in 2002. The cohort analyses involved people diagnosed in 1997 (5-year survival) or 1992 (10-year survival). National estimates exclude Québec.

Main results

Relative survival ratios were highest for thyroid (5-year, 97.7%) and prostate (95.2%) cancer and lowest for pancreatic cancer. Survival for many forms of cancer is higher than previously estimated by cohort-based analysis. The largest increases in 10-year relative survival were predicted for cancers of the prostate (13.0%) and rectum (9.7%). The largest predicted increases for 5-year survival were for cancers of the cervix uteri (5.4%) and rectum (4.5%), and for leukemia (3.7%).

Keywords

epidemiological methods, neoplasms, prognosis, registries

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Long-term survival rates are important outcome measures for people with cancer. Survival rates are widely used to monitor progress in cancer care,[1,2] or to compare quality of care between different populations.[3,4] Cancer survival statistics can also have a strong impact on a clinician's management of the disease, as well as on a patient's coping strategies.[5]

The traditional way of estimating cancer survival has been to use a cohort-based method in which only people diagnosed within defined calendar years and with the potential to be followed over the full duration of interest are included in the analysis. Long-term survival estimates derived using this approach pertain to the survival experience of people diagnosed many years ago. Since most cancer deaths occur during the first few years after diagnosis, cohort survival estimates essentially reflect the clinical outcomes achieved at that time. When there has been a subsequent change in prognosis, these estimates will not reflect the long-term survival experience expected for newly diagnosed individuals. Consequently, both patients and their physicians may be unduly discouraged.[6]

Data sources and Limitations

Data sources

Cancer incidence data are from the Canadian Cancer Registry (CCR). The CCR is a dynamic, person-oriented, population-based database maintained by Statistics Canada. It contains cases diagnosed from 1992 onward. The information comprising the CCR is based on reports from every provincial/territorial cancer registry.[7] A detailed description of the CCR, including data sources, methodology and accuracy, is available on Statistics Canada's Web site.[8] Mortality data are from the Canadian Mortality Data Base, also maintained by Statistics Canada. These data are 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 for this analysis.

Limitations

In the context of cancer, relative survival is defined as the ratio of the observed survival for a group of people with cancer to the survival that would have been expected for members of the general population who are assumed to be free of cancer and otherwise have the same characteristics affecting survival as those with cancer.[9]

This analysis used the common matching variables of age, sex, and calendar time, and also considered province of residence at diagnosis. Other potential factors were not matched, because the CCR does not contain the information and/or because population life tables were not available. Ideally, people diagnosed with lung cancer (or another smoking-related cancer) would also be matched by smoking status to members of the general population, because most people diagnosed with lung cancer are smokers or ex-smokers and smoking is known to reduce life expectancy. While the relative survival ratio (RSR) for lung cancer would likely have been higher if such data were available, a previous study found that adjusting the expected survival for the excess mortality related to smoking increased estimates of relative survival by 1% or less.[9]

An empirical evaluation of the period method for 5-year survival using data from the CCR concluded that the method provides more up-to-date estimates than traditional cohort-based methods.[10] Although a similar evaluation for 10-year survival will not be possible until over 20 years of case registration and mortality follow-up have been completed for the CCR, empirical evaluations of longer term survival conducted elsewhere have found period analysis estimates to be more up-to-date than those produced using traditional methods.[5,6,11-14] In one study, period analysis was reported to advance the detection of progress in 10-, 15-, and 20-year survival rates of newly diagnosed cancer cases by 5 to 10, 10 to 15, and 15 to 20 years, respectively.[12]

A very small percentage of cases diagnosed in 2002 may not relate to an individual's first primary invasive tumour because the record linkage of the historical National Cancer Incidence Reporting System (1969 to 1991) to the CCR did not extend past 2001 (see *Analytical techniques*). Based on an analysis of 2001 data, this means that approximately 1% of the cases in 2002 would otherwise have been omitted from the study. This would likely have reduced the overall 10-year period RSR by about 0.3%.

All expected survival proportions for Prince Edward Island and the territories were derived from Canadian life tables. Stable estimates for single ages could not be produced for these areas because of small population counts. This substitution should not introduce bias in national estimates as these areas combined accounted for 0.9% of all eligible cases from 1992 to 2002.

Another traditional cohort-based method of survival analysis, known as complete analysis,[15] is not discussed in this article for the sake of brevity. Complete analysis includes only people diagnosed within a defined calendar period. However, unlike cohort analysis, it includes people who do not have the potential to be followed over the full duration of interest. While complete analysis provides more up-to-date long-term survival estimates than cohort analysis, the estimates are still not as up-to-date as those produced using period analysis.[6,10,13,14]

Stage of disease at diagnosis and information about treatment received are not available in the CCR.

A new method of survival analysis, known as period analysis, was introduced to derive more up-to-date estimates of long-term survival.[15,16] The results from period analysis exclusively reflect the survival experience in the most recent period for which data are available (see *Analytical techniques*). The rationale for this approach is analogous to that of using period life tables to estimate current life expectancy. Empirical evaluations of period analysis have shown that the method does indeed provide better predictions of survival for the recently diagnosed[5,6,10-14,17] than does cohort analysis.

This article presents predictions of the short- and long-term relative survival of Canadians recently diagnosed with cancer (see *Data sources and Limitations*). Predictions are based on period analysis, and are shown by sex and by age group for all cancer sites combined, as well as by sex for 20 selected cancer sites. Long-term period estimates are compared with the latest available cohort-based estimates. A brief discussion of international period analysis predictions is also included (see *The international picture*).

Predicting long-term survival

The period analysis estimate of the 5-year relative survival ratio (RSR) for all invasive cancers combined was 62.3%. This is based on the follow-up experience of cancer cases in 2002, the latest year for which follow-up data were available (Table 1). This means that people recently diagnosed with invasive cancer will be, on average, 62.3% as likely to be alive five years after diagnosis as members of the general population who have the same main characteristics affecting survival as the people with cancer. The corresponding 1-, 3- and 10-year period survival estimates were 76.2%, 66.2% and 57.7%, respectively.

The assumption underlying period analysis is that the cross-sectional follow-up experience of cases in 2002 will provide a good approximation of the longitudinal survival to be experienced by recently diagnosed persons. Period estimates may be overly optimistic if advances in early detection or therapy do not increase the chance of cure, but merely postpone death due to cancer.[5] But this theoretical concern has been found to be irrelevant in practice.[5,6,10-14,17] In fact, period estimates have often been shown to be slightly pessimistic, albeit more up-to-date, than estimates from traditional cohort methods. This observation has been attributed to ongoing improvements in conditional survival probabilities resulting from advances in early detection or therapy, or both.[5]

Sex, age and cancer site

For all invasive cancers combined, RSRs from period analysis were generally slightly higher among females than among males. Period RSRs were also inversely related to age; that is, the best prognoses, or the highest estimates, were in the youngest age group. Breast cancer is a noteworthy exception: the five-year RSR was lowest in the youngest (15-to-39) and oldest (80-to-99) age groups; otherwise, it

Table 1
Period analysis, relative survival ratios for all cancer sites combined, by sex and by age group, based on follow-up in 2002, Canada†

	Survival							
	1-year		3-year		5-year		10-year	
	Relative survival ratio	95% confidence interval	Relative survival ratio	95% confidence interval	Relative survival ratio	95% confidence interval	Relative survival ratio	95% confidence interval
	%		%		%		%	
Overall	**76.2**	**75.9, 76.4**	**66.2**	**65.9, 66.5**	**62.3**	**62.0, 62.6**	**57.7**	**57.3, 58.0**
Sex								
Male	75.1	74.8, 75.5	65.2	64.8, 65.7	61.7	61.2, 62.1	57.8	57.3, 58.3
Female	77.3	77.0, 77.7	67.2	66.8, 67.6	63.1	62.7, 63.5	57.7	57.3, 58.2
Age group								
15 to 44	91.2	90.7, 91.8	83.1	82.5, 83.8	79.6	78.9, 80.3	74.9	74.1, 75.6
45 to 54	85.1	84.6, 85.7	74.7	74.0, 75.3	70.6	69.9, 71.3	64.4	63.7, 65.2
55 to 64	80.7	80.2, 81.2	70.0	69.4, 70.5	65.5	64.9, 66.1	59.0	58.3, 59.7
65 to 74	75.5	75.1, 76.0	65.3	64.7, 65.8	61.1	60.5, 61.7	56.4	55.7, 57.1
75 to 99	63.5	62.9, 64.0	53.9	53.2, 54.5	51.0	50.2, 51.7	50.3	49.3, 51.3

***Data source**: Canadian Cancer Registry*
† Excluding Québec

Analytical techniques

Incident cancer case data for this study were obtained from the Canadian Cancer Registry (CCR) database as of December 2004. Cancer cases were defined based on the *International Classification of Diseases for Oncology, Third Edition*.[18] Analyses were restricted to records of first primary invasive tumours. The pre-1992 tumour history of individuals on the CCR from 1992 to 2001, if any, was obtained by linking the CCR data with its predecessor, the National Cancer Incidence Reporting System, a fixed, tumour-oriented database containing cases as far back as 1969. Supplementary information available for 1992 to 2002 Ontario data was also used.

Cancer cases diagnosed in Québec were not included in this analysis, partly because the method of ascertaining the date of diagnosis in this province clearly differed from that of the other provincial cancer registries.[19] For the remaining provinces and territories, records were excluded when the year of birth was unknown (0.02%). A total of 958,520 people aged 15 to 99 (20 to 99 for cancer of the bones and joints) were diagnosed with a first primary invasive tumour in Canada (excluding Québec) from 1992 to 2002. People identified as having died but whose year of death was not recorded (n=96) were excluded, as were those whose diagnosis was established either through autopsy only (n=2,187) or death certificate only (n=17,526). For a small percentage of subjects with missing information on day/month of diagnosis and/or day/month of death, the survival time was estimated. The algorithm used has been described elsewhere.[19] Mortality follow-up was determined through record linkage to the Canadian Mortality Data Base, and from information reported by provincial/territorial cancer registries.[20] For deaths reported by a provincial registry but not confirmed by record linkage, it was assumed that the individual died on the date submitted by the reporting province. At the time of the analysis, registration of new cases and mortality follow-up were complete through December 31, 2002.

Using period analysis, short- and long-term predictions of relative survival of individuals recently diagnosed with cancer were derived for all cancers combined and for 20 selected cancer sites. A period analysis is defined by the survival experience of people in a recent time interval. Estimates are obtained by left truncation of observations at the beginning of that period and right censoring at the end of the period. In this study, the period method used follow-up in 2002 exclusively. The survival probability during the first year after diagnosis was estimated from the person-time at risk and events (death or censoring) of individuals diagnosed in 2001 and 2002 whose first year after diagnosis included some part of 2002. Similarly, the conditional probability in the 2nd, 3rd, and up to the 10th year after diagnosis was estimated from the survival experience of persons diagnosed in, respectively, 2000 and 2001, 1999 and 2000, and so on, to 1992 and 1993.

For context, the period estimates of survival were compared with estimates derived using cohort analysis. A cohort-based analysis is defined by the time interval in which people are diagnosed. Depending on the analysis, the cohort method in this study involved people diagnosed in 1997 (5-year survival) or 1992 (10-year survival) and potentially followed to the end of 2002. For background, the number of diagnosed cases eligible for survival analysis, the percentage that were male, and the median age at diagnosis were calculated by cancer site for diagnosis years 1992, 1997 and 2002 (Appendix Table A).

Cancer registries prefer to use relative survival for reporting because it provides a measure of survival corrected for the effect of other independent causes of death.[21,22] Relative survival analyses

Data used to calculate cohort and period 10-year relative survival estimates

	Year of diagnosis	Follow-up year										
		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Cohort analysis	1992	1	1,2	2,3	3,4	4,5	5,6	6,7	7,8	8,9	9,10	10
Period analysis	1992											10
	1993											9,10
	1994											8,9
	1995											7,8
	1996											6,7
	1997											5,6
	1998											4,5
	1999											3,4
	2000											2,3
	2001											1,2
	2002											1

Years of follow-up since diagnosis

... continued

Analytical techniques - concluded

were based on algorithms (i.e., survival.sas, survival_period.sas) written in SAS by Paul Dickman,[23] with some minor adaptations. The algorithms use a life table (actuarial) approach: relative survival ratios (RSRs) are calculated at discrete points during the follow-up, generally by taking the product of interval-specific (conditional) estimates over sub-intervals of the follow-up. Observation time for each individual is split into multiple observations, one for each sub-interval of follow-up time. Attained age and attained period are monitored by the algorithm so that the appropriate expected probabilities of death, estimated by the Ederer II approach,[24] are used. Observations are collapsed over calendar year(s) at time of diagnosis (cohort) or calendar year(s) of follow-up (period) depending on the desired method of analysis.

For this analysis, three-month sub-intervals were used for the first year of follow-up, six-month sub-intervals up to the fifth year of follow-up, and one-year sub-intervals for the 6th through 10th years. More intervals were used in the first year of follow-up because the actuarial method assumes an approximately even distribution of deaths within each interval, and mortality is often highest during the first year. Expected survival proportions were derived from sex-specific complete and abridged provincial life tables produced by Statistics Canada. Data from the 1990-1992 complete life tables[25] were used for patient follow-up in 1992 and 1993, and data from 1995-1997 complete life tables[26] were used for follow-up from 1994 to 1998. Because the 2000-2002 complete life tables had not been published when this analysis was conducted, expected survival for follow-up from 1999 to 2002 was derived from 1995-1997 and 2000-2002 abridged life tables and the 1995-1997 complete life tables using a method suggested by Dickman et al.[27] This method was also used to extend the 1990-1992 set of complete provincial life tables from age 85 to age 99. Cases with the same date of diagnosis and death (not including those previously excluded because they were diagnosed through autopsy only or death certificate only) were assigned one day of survival, as the program automatically excludes cases with zero days of survival. Asymmetric observed survival confidence intervals were formed from standard errors estimated using Greenwood's method[28] and the log (-log) transformation. Confidence intervals for RSRs were derived by dividing the observed survival limits by the corresponding expected survival proportion. This general approach has previously been used to publish Canadian national and provincial cohort survival estimates for 49 cancer sites.[29]

was quite similar across the remaining groups (data not shown).

Among the sites analyzed, five-year period RSRs were highest for thyroid (97.7%) and prostate cancer (95.2%), followed by skin melanoma (89.5%) and cancers of the breast (87.5%) and corpus uterus (86.2%) (Table 2). The five-year prognosis was poorest for pancreatic cancer (6.6%), then cancers of the esophagus (13.2%), lung and bronchus (15.5%), brain (23.4%) and stomach (24.0%). When other survival durations (1-, 3- and 10-year) were considered, the relative ranking of the cancer sites remained quite similar. Only modest absolute differences were observed between the 1- and 10-year rates for cancers of the thyroid (1.2%) and prostate (6.5%). But the differences were quite large for multiple myeloma (51.2%) and ovarian cancer (39.6%). For the 20 sites studied, the average site-specific difference between the 1- and 10-year rates was 20.9%.

Period–Cohort differences

Before period analysis was introduced to cancer survival research, predictions of the survival experience of recently diagnosed patients were necessarily derived using a cohort-based analysis. For this study, the most up-to-date cohort analysis estimates of long-term survival available were based on the experience of cases diagnosed in 1992 (10-year) and 1997 (5-year). For all invasive cancers combined, the 5-year cohort-based RSR was 60.3%; the 10-year ratio was 52.1% (Table 3). These estimates are about 2 and 6 percentage points lower, respectively, than the most recent period-based estimates. Similar differences have been reported elsewhere. One study found period estimates to be 1% and 7% higher than cohort estimates for 5- and 10-year survival,[30] while another reported increases of 4% and 7%.[31]

Table 2
Period analysis, relative survival ratios, by cancer site and sex, based on follow-up in 2002, Canada†

	Survival duration							
	1-year		3-year		5-year		10-year	
	Relative survival ratio	95% confidence interval	Relative survival ratio	95% confidence interval	Relative survival ratio	95% confidence interval	Relative survival ratio	95% confidence interval
	%		%		%		%	
Oral (buccal cavity and pharynx)	**80.5**	**78.9, 82.1**	**67.4**	**65.5, 69.2**	**63.4**	**61.3, 65.4**	**55.5**	**53.4, 57.7**
Male	79.5	77.4, 81.4	66.8	64.4, 69.0	62.7	60.2, 65.1	54.6	51.9, 57.3
Female	82.5	79.7, 85.1	68.5	65.2, 71.6	64.6	61.1, 68.0	57.3	53.5, 61.0
Esophagus	**37.4**	**34.4, 40.3**	**15.2**	**13.2, 17.3**	**13.2**	**11.3, 15.3**	**11.5**	**9.6, 13.7**
Male	39.7	36.3, 43.2	15.6	13.2, 18.2	13.5	11.2, 16.1	12.4	9.9, 15.2
Female	31.3	26.0, 36.6	13.7	10.4, 17.5	12.1	8.9, 15.8	9.6	6.7, 13.2
Stomach	**44.8**	**42.7, 46.9**	**27.4**	**25.6, 29.2**	**24.0**	**22.2, 25.8**	**22.5**	**20.6, 24.5**
Male	44.7	42.0, 47.3	26.7	24.5, 29.0	22.2	20.0, 24.4	21.1	18.7, 23.5
Female	45.1	41.7, 48.5	28.6	25.6, 31.8	27.2	24.1, 30.4	25.0	21.8, 28.5
Colon	**78.6**	**77.7, 79.4**	**65.6**	**64.6, 66.6**	**61.3**	**60.2, 62.4**	**58.7**	**57.4, 60.1**
Male	78.6	77.4, 79.8	65.9	64.4, 67.3	60.9	59.3, 62.5	58.8	56.9, 60.7
Female	78.5	77.3, 79.7	65.3	63.9, 66.7	61.7	60.1, 63.2	58.7	56.9, 60.6
Rectum	**85.9**	**84.8, 87.0**	**71.1**	**69.6, 72.5**	**65.0**	**63.4, 66.6**	**60.4**	**58.5, 62.3**
Male	86.9	85.5, 88.2	71.6	69.7, 73.4	64.7	62.6, 66.7	60.0	57.5, 62.5
Female	84.3	82.5, 86.0	70.2	67.9, 72.4	65.4	62.9, 67.9	60.9	58.0, 63.8
Pancreas	**20.5**	**18.9, 22.2**	**7.9**	**6.9, 9.0**	**6.6**	**5.6, 7.6**	**6.0**	**5.0, 7.0**
Male	21.2	18.9, 23.6	9.0	7.4, 10.7	7.0	5.6, 8.6	7.2	5.6, 9.0
Female	20.0	17.8, 22.3	6.9	5.7, 8.4	6.1	4.9, 7.5	4.9	3.7, 6.3
Lung and bronchus	**37.3**	**36.5, 38.1**	**19.3**	**18.7, 19.9**	**15.5**	**15.0, 16.1**	**12.4**	**11.9, 13.0**
Male	34.7	33.6, 35.7	16.6	15.8, 17.4	13.3	12.6, 14.0	10.9	10.2, 11.6
Female	40.6	39.4, 41.8	22.9	21.9, 23.9	18.5	17.5, 19.4	14.2	13.4, 15.1
Skin melanoma	**97.0**	**96.3, 97.7**	**92.3**	**91.2, 93.3**	**89.5**	**88.2, 90.8**	**87.6**	**86.0, 89.2**
Male	96.1	94.9, 97.1	90.6	88.9, 92.1	86.8	84.7, 88.7	84.7	82.2, 87.1
Female	98.0	97.0, 98.8	94.1	92.7, 95.4	92.4	90.7, 93.9	90.7	88.6, 92.6
Breast	**97.2**	**96.9, 97.5**	**91.9**	**91.4, 92.4**	**87.5**	**86.9, 88.1**	**79.6**	**78.8, 80.4**
Female	97.2	96.9, 97.5	91.9	91.4, 92.4	87.5	86.9, 88.2	79.7	78.9, 80.5
Cervix uteri	**88.7**	**86.8, 90.4**	**79.1**	**76.8, 81.2**	**75.7**	**73.2, 78.0**	**71.6**	**69.0, 74.0**
Corpus uteri	**94.1**	**93.1, 95.0**	**88.8**	**87.4, 90.0**	**86.2**	**84.6, 87.6**	**84.5**	**82.6, 86.3**
Ovary	**73.2**	**71.2, 75.2**	**51.0**	**48.8, 53.2**	**40.5**	**38.3, 42.7**	**33.6**	**31.5, 35.8**
Prostate	**98.4**	**98.1, 98.7**	**96.5**	**96.0, 97.0**	**95.2**	**94.5, 95.9**	**91.9**	**90.9, 93.0**
Bladder (including in situ)	**86.3**	**85.1, 87.4**	**78.4**	**76.9, 79.8**	**75.0**	**73.4, 76.7**	**71.6**	**69.6, 73.5**
Male	86.8	85.4, 88.1	79.2	77.5, 80.9	76.1	74.1, 78.0	73.3	70.9, 75.6
Female	85.0	82.5, 87.2	76.0	73.0, 78.7	72.2	68.9, 75.2	66.9	63.3, 70.5
Kidney and renal pelvis	**78.3**	**76.7, 79.8**	**70.6**	**68.8, 72.4**	**65.8**	**63.8, 67.7**	**61.2**	**59.0, 63.4**
Male	77.4	75.3, 79.4	70.4	68.0, 72.6	64.4	61.9, 66.9	59.5	56.6, 62.3
Female	79.7	77.2, 82.0	71.0	68.2, 73.7	67.8	64.7, 70.8	63.7	60.3, 67.0
Brain	**45.6**	**43.1, 48.0**	**27.0**	**25.0, 29.1**	**23.4**	**21.4, 25.4**	**18.9**	**17.1, 20.7**
Male	44.7	41.4, 47.9	25.0	22.4, 27.7	20.6	18.2, 23.1	16.8	14.6, 19.1
Female	46.7	42.9, 50.4	29.7	26.4, 33.1	27.1	23.9, 30.4	21.7	18.8, 24.7
Thyroid	**98.7**	**98.1, 99.2**	**97.8**	**96.9, 98.5**	**97.7**	**96.7, 98.7**	**97.5**	**96.1, 98.7**
Male	96.3	94.1, 97.8	95.5	92.9, 97.5	93.6	90.3, 96.3	91.2	87.0, 94.8
Female	99.3	98.8, 99.7	98.4	97.5, 99.1	98.9	97.9, 99.8	99.3	97.9,100.5
Non-Hodgkin's lymphoma	**77.0**	**75.7, 78.2**	**67.5**	**66.0, 68.9**	**61.5**	**60.0, 63.1**	**52.0**	**50.3, 53.6**
Male	76.5	74.7, 78.2	65.5	63.5, 67.4	59.1	57.0, 61.2	50.2	47.9, 52.5
Female	77.6	75.7, 79.3	69.7	67.6, 71.7	64.2	62.0, 66.4	54.0	51.6, 56.4
Multiple myeloma	**72.3**	**69.7, 74.6**	**48.7**	**46.0, 51.4**	**33.9**	**31.3, 36.6**	**21.1**	**18.7, 23.6**
Male	72.0	68.5, 75.2	50.0	46.3, 53.7	36.9	33.2, 40.7	24.9	21.2, 28.8
Female	72.6	68.8, 75.9	47.2	43.3, 51.0	30.9	27.3, 34.6	17.6	14.7, 20.8
Leukemias	**65.7**	**63.9, 67.5**	**54.5**	**52.6, 56.4**	**49.3**	**47.3, 51.3**	**41.2**	**39.1, 43.3**
Male	66.3	63.8, 68.6	54.7	52.2, 57.2	48.0	45.4, 50.6	40.1	37.4, 42.8
Female	64.9	61.9, 67.7	54.2	51.2, 57.2	51.0	47.9, 54.1	42.7	39.5, 46.0

***Data source**: Canadian Cancer Registry*
† Excluding Québec

A comparison of sex-specific differences in survival using both cohort and period analyses indicated that previously observed differences in overall relative survival between the sexes are likely to be diminished among recently diagnosed cases. Sex-specific *cohort* estimates of the RSR for all invasive cancers combined were lower among males for both 5- (3.9% difference) and 10-year (5.6% difference) survival. But differences in sex-specific *period* estimates were much smaller for 5-year (1.5% difference), and virtually non-existent for 10-year, survival. This may be partly due to the large predicted increase in prostate cancer survival. When sex-specific cancers including breast cancer were omitted from the period analysis, RSRs were approximately 3% lower among males for both survival lengths studied (data not shown).

An age gradient for 5- and 10-year relative survival was observed for both cohort and period analyses. RSRs for all cancer sites combined were highest for people who were aged 15 to 44 when diagnosed, and lowest for those aged 75 to 99. The fact that

Table 3
Comparison of most recent period and cohort analysis estimates† of 5- and 10-year relative survival, by sex, by age group, and by cancer site, Canada‡

	5-year survival					10-year survival				
	Period analysis		Cohort analysis			Period analysis		Cohort analysis		
	Relative survival ratio	95% confidence interval	Relative survival ratio	95% confidence interval	Period-cohort difference§	Relative survival ratio	95% confidence interval	Relative survival ratio	95% confidence interval	Period-cohort difference§
	%		%			%		%		
Overall	**62.3**	**62.0, 62.6**	**60.3**	**59.9, 60.6**	**2.1**	**57.7**	**57.3, 58.0**	**52.1**	**51.6, 52.5**	**5.6**
Sex										
Male	61.7	61.2, 62.1	58.4	57.8, 58.9	3.3	57.8	57.3, 58.3	49.4	48.7, 50.1	8.4
Female	63.1	62.7, 63.5	62.3	61.7, 62.8	0.8	57.7	57.3, 58.2	55.0	54.4, 55.7	2.7
Age group										
15 to 44	79.6	78.9, 80.3	75.8	74.8, 76.7	3.8	74.9	74.1, 75.6	67.6	66.6, 68.7	7.2
45 to 54	70.6	69.9, 71.3	68.1	67.2, 69.0	2.5	64.4	63.7, 65.2	56.4	55.3, 57.5	8.1
55 to 64	65.5	64.9, 66.1	62.2	61.4, 63.0	3.3	59.0	58.3, 59.7	50.5	49.6, 51.4	8.5
65 to 74	61.1	60.5, 61.7	58.5	57.8, 59.3	2.5	56.4	55.7, 57.1	49.6	48.8, 50.5	6.8
75 to 99	51.0	50.2, 51.7	51.2	50.3, 52.1	-0.2	50.3	49.3, 51.3	49.1	47.6, 50.6	1.2
Cancer site										
Oral (buccal cavity and pharynx)	63.4	61.3, 65.4	62.0	59.5, 64.5	1.4	55.5	53.4, 57.7	54.5	51.7, 57.3	1.0
Esophagus	13.2	11.3, 15.3	12.7	10.4, 15.3	0.5	11.5	9.6, 13.7	9.6	7.1, 12.6	1.9
Stomach	24.0	22.2, 25.8	23.0	20.9, 25.2	1.0	22.5	20.6, 24.5	17.3	15.2, 19.6	5.2
Colon	61.3	60.2, 62.4	60.0	58.6, 61.4	1.3	58.7	57.4, 60.1	55.3	53.5, 57.1	3.5
Rectum	65.0	63.4, 66.6	60.6	58.5, 62.6	4.5	60.4	58.5, 62.3	50.7	48.2, 53.2	9.7
Pancreas	6.6	5.6, 7.6	6.4	5.3, 7.7	0.1	6.0	5.0, 7.0	5.5	4.3, 6.9	0.5
Lung and bronchus	15.5	15.0, 16.1	15.4	14.7, 16.2	0.1	12.4	11.9, 13.0	11.7	11.0, 12.4	0.7
Skin melanoma	89.5	88.2, 90.8	90.1	88.4, 91.6	-0.6	87.6	86.0, 89.2	85.1	82.7, 87.3	2.6
Breast (male and female)	87.5	86.9, 88.1	86.5	85.7, 87.3	1.0	79.6	78.8, 80.4	74.7	73.6, 75.9	4.9
Cervix uteri	75.7	73.2, 78.0	70.3	67.3, 73.1	5.4	71.6	69.0, 74.0	67.1	63.8, 70.2	4.5
Corpus uteri	86.2	84.6, 87.6	86.3	84.4, 88.1	-0.1	84.5	82.6, 86.3	83.8	81.2, 86.3	0.6
Ovary	40.5	38.3, 42.7	38.9	36.1, 41.6	1.7	33.6	31.5, 35.8	32.7	29.8, 35.6	0.9
Prostate	95.2	94.5, 95.9	92.5	91.5, 93.5	2.7	91.9	90.9, 93.0	79.0	77.3, 80.6	13.0
Bladder (including in situ)	75.0	73.4, 76.7	76.4	74.4, 78.4	-1.4	71.6	69.6, 73.5	71.6	68.7, 74.4	0.0
Kidney and renal pelvis	65.8	63.8, 67.7	63.5	61.0, 65.9	2.3	61.2	59.0, 63.4	57.1	54.0, 60.1	4.1
Brain	23.4	21.4, 25.4	22.8	20.4, 25.2	0.6	18.9	17.1, 20.7	17.6	15.3, 20.0	1.3
Thyroid	97.7	96.7, 98.7	95.8	94.1, 97.3	1.9	97.5	96.1, 98.7	93.3	90.8, 95.6	4.2
Non-Hodgkin's lymphoma	61.5	60.0, 63.1	58.7	56.8, 60.6	2.8	52.0	50.3, 53.6	44.5	42.2, 46.8	7.5
Multiple myeloma	33.9	31.3, 36.6	32.5	29.3, 35.7	1.5	21.1	18.7, 23.6	18.1	15.0, 21.5	3.0
Leukemias	49.3	47.3, 51.3	45.6	43.2, 48.0	3.7	41.2	39.1, 43.3	38.6	35.9, 41.4	2.6

***Data source**: Canadian Cancer Registry*
†The cohort analysis relative survival ratios and 95% confidence intervals were based on follow-up to 2002 of cases diagnosed in 1997 (5-year) or 1992 (10-year). The period method involved the survival experience in 2002 only of cases diagnosed from 1997 to 2002 (5-year) or cases diagnosed from 1992 to 2002 (10-year).
‡ Excluding Québec
§ Absolute difference between period and cohort analysis relative survival ratios. Positive values indicate that the period estimate was higher.

The international picture

Period analysis predictions of relative survival for people newly diagnosed with cancer have only been published for a small number of countries.[30-33] Although these studies covered different periods, included different age ranges, and used site groupings that were not necessarily uniform, some general comparisons with the results of this new period analysis can be made.

Period estimates for the United States, based on data collected by the Surveillance, Epidemiology, and End Results (SEER) program of the National Cancer Institute, were published for 1998.[30] While the SEER program is not a nationwide cancer registry (data were collected from nine population-based cancer registries), it is the most comprehensive source of information on cancer incidence and survival in the United States.[30] In general, Canada appears to have slightly higher relative survival ratios (RSRs) than the SEER registries, although it should be noted that the Canadian results are based on more recent data. The RSR estimates for Canada were much higher than the US ratios for multiple myeloma (5-year: 33.9% versus 29.5% and 10-year: 21.1% versus 12.7%), but were considerably lower for ovarian cancer (40.5% versus 55.0%, and 33.6% versus 49.3%).

Canadian RSRs compare even more favourably with those derived from Swedish cancer registry data.[31] In particular, relative survival for prostate cancer is vastly higher in Canada than in Sweden (5-year: 95.2% versus 79.5%; 10-year: 91.9% versus 59.3%). Similar differences in prostate cancer RSRs exist between Sweden and the United States and have been attributed to earlier and more extensive use of prostate-specific antigen testing in the United States.[31]

relative survival is poorer, for many forms of cancer, among those diagnosed at an older age has previously been noted.[34,35] Potential explanations include less therapy as a result of a higher level of co-morbidity, a less favourable stage distribution, and less aggressive treatment (independent of co-morbidity) among older patients.[34]

Ten-year age-specific period RSRs were higher than corresponding estimates derived using the cohort method. Period estimates were 6.8% to 8.5% higher in the first four age groups, but only 1.2% higher for the 75-to-99 age group. A similar pattern was seen for 5-year survival: RSRs were virtually identical for the elderly, but 2.5% to 3.8% higher in the first four age groups using the period method. This indicates that the disparity in long-term cancer survival between those younger than 75 at diagnosis and those at or over this age has widened. The same conclusion was reached in a recent study based on data collected by the Surveillance, Epidemiology, and End Results (SEER) program of the National Cancer Institute in the United States.[34] This study also reported that the proportion of cancer patients receiving surgery increased from 70% in 1986-1990 to 75% in 1996-2000 in the youngest age group, but actually dropped from 55% to 49% among those aged 75 or older. It may be that differences in therapy by age have become more divergent.

Site-specific, period versus cohort

Period estimates of 5- and 10-year relative survival were similar to or greater than the corresponding cohort estimates for every cancer site studied, though differences between period and cohort estimates were less pronounced for 5-year survival (Table 3). Predicted increases in survival varied by cancer site. In some cases, the reasons for these increases were not apparent, but likely reflected several factors, including improvements in treatment and earlier or increased diagnosis. As previously suggested,[31] it is also possible that, with certain forms of cancer, a diagnostic shift towards more favourable histopathological subtypes could have played a role.

For eight of the sites studied, the period estimate for 10-year survival was at least 4% higher and did not fall within the 95% confidence interval of the cohort estimate. However, for seven sites (bladder, pancreas, corpus uteri, lung, ovary, oral cavity, and brain), there was little to no difference between the estimates (1% or less). The largest increases in 10-year survival were predicted for prostate cancer (13.0%), rectal cancer (9.7%) and non-Hodgkin's lymphoma (7.5%); the next largest were for stomach (5.2%), breast (4.9%) and cervical cancer (4.5%). The largest predicted increases for 5-year relative survival were for cancers of the cervix uteri (5.4%) and rectum (4.5%), and for leukemia (3.7%). When period analysis suggests little or no change in survival, simply knowing that the survival rates are unlikely to change is worthwhile information.

It is likely that the predicted increase in 10-year prostate cancer survival is due to the continued effect of prostate specific antigen (PSA) testing. Widespread use of this test has led to increased incidence and survival rates for prostate cancer in Canada[36,37] and elsewhere.[38-40] Results from ongoing clinical trials of the PSA test[41] should determine whether its use as a screening tool has resulted in a true decrease in mortality from prostate cancer.

The anticipated increase in the long-term relative survival of those diagnosed with non-Hodgkin's lymphoma may partly result from improved treatment. Specifically, the use of autologous stem cell transplantation and, more recently, the addition of monoclonal antibodies to the standard chemotherapy regimen, have been shown to improve survival in patients with various forms of the disease.[42-44] It is likely that survival from non-Hodgkin's lymphoma will continue to increase as ongoing research into monoclonal antibodies results in the development and implementation of new treatment protocols. Expected gains in rectal cancer survival may be due in part to the increased use of radiotherapy and general improvements in surgical technique.

Five-year RSRs for breast cancer have been steadily increasing among women since at least the mid-1980s.[29,45] A concurrent steady decrease in breast cancer mortality[46] suggests that there has been a tangible improvement in prognosis. The increase predicted in this study probably reflects a continuation of this trend. A combination of early diagnosis from mammography screening and improved treatment is likely behind the positive change, although the relative impacts of each have yet to be quantified. Data from organized breast screening programs have shown steady increases in participation throughout the 1990s.[47]

Recent advances in the treatment of cervical cancer have likely contributed to the increase in long-term survival predicted using period analysis. In particular, the administration of cisplatin-based chemotherapy during radiotherapy began to be offered as a treatment for women who received radiotherapy for locally advanced cervical cancer after it was shown to improve overall survival.[48-50] While the continued widespread use of the Pap test as a screening tool[46] has resulted in decreased mortality rates for cervical cancer, most cancers detected by this test are in the pre-invasive stage and thus would not be reflected in these survival estimates.

Concluding remarks

Estimates of long-term survival for cancer are strongly affected by the survival in the first few years after diagnosis because this is when most cancer deaths occur. Period estimates of survival during the first few years after diagnosis are exclusively based on the survival of individuals diagnosed in recent years. By contrast, the calculation of survival during the first few years after diagnosis for long-term cohort estimates is based on the survival of persons diagnosed many years ago. This is the main reason why period estimates of long-term survival are more up-to-date than cohort estimates.

Using the cross-sectional experience of cases followed-up in 2002 results in more up-to-date predictions of long-term relative survival ratios (RSRs) for recently diagnosed people than would relying solely on the survival experience of a cohort of cases diagnosed in 1997 (5-year) or 1992 (10-year). When survival has improved, period estimates will be higher than cohort estimates. And when survival rates have remained constant, period and cohort survival rates will be similar.

The period analysis conducted in this study suggests that the long-term survival of Canadians recently diagnosed with cancer will be higher—for many forms of cancer—than previously estimated by cohort analysis. The 5- and 10-year RSRs for all invasive cancer sites combined were predicted to be 62.3% and 57.7%, respectively; about 2 and 6 percentage points higher than previously determined.

Predicted increases in survival varied greatly by cancer site. The largest predicted increases in 10-year relative survival were for prostate (13.0%) and rectal (9.7%) cancer. Differences between period and cohort estimates were less pronounced for 5-year survival. The largest increases for 5-year RSRs were for cancers of the cervix uteri (5.4%)

and rectum (4.5%), and for leukemia (3.7%). For sites such as the esophagus and pancreas, RSRs are expected to remain virtually constant.

How well the period analysis estimates obtained in this study actually predict the long-term survival of people recently diagnosed with cancer will remain unknown for quite some time. Estimates of survival may be even higher than reported here if improvement in survival continues. The up-to-date estimates do, however, provide a more realistic outlook of long-term cancer survival. ●

Acknowledgements

The Canadian Cancer Registry is maintained by Statistics Canada. It is comprised of data supplied by the provincial and territorial cancer registries whose cooperation is gratefully acknowledged.

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Appendix

Table A

Number of cases, percentage male and median age at diagnosis, by cancer site and year of diagnosis, Canada,‡ 1992, 1997 and 2002

	Year of diagnosis								
	1992			1997			2002		
	Number of cases	% male	Median age at diagnosis	Number of cases	% male	Median age at diagnosis	Number of cases	% male	Median age at diagnosis
All cancers	**76,946**	**53**	**68**	**84,493**	**52**	**68**	**95,299**	**52**	**67**
Oral (buccal cavity and pharynx)	2,128	71	64	1,975	69	65	2,109	66	63
Esophagus	712	72	68	839	70	69	902	72	70
Stomach	1,808	64	70	1,804	65	71	1,775	62	71
Colon	6,789	51	71	7,247	50	72	8,265	50	72
Rectum	3,037	62	69	3,265	60	69	3,931	60	68
Pancreas	1,696	50	70	1,861	48	72	1,963	47	72
Lung and bronchus	10,782	64	68	11,226	59	69	12,161	55	70
Skin melanoma	2,161	52	54	2,605	51	55	3,016	52	57
Breast (male and female)	11,227	1	63	12,666	1	61	13,981	1	60
Cervix uteri	1,053	0	46	1,043	0	45	1,011	0	46
Corpus uteri	1,975	0	66	2,239	0	65	2,564	0	64
Ovary	1,278	0	63	1,360	0	65	1,590	0	63
Prostate	11,368	100	72	12,456	100	71	14,900	100	69
Bladder (including in situ)	3,087	76	71	3,499	74	71	3,515	75	72
Kidney and renal pelvis	1,755	62	65	1,990	63	66	2,362	61	64
Brain	1,094	60	59	1,245	56	58	1,303	57	60
Thyroid	956	22	44	1,215	23	46	2,153	22	46
Non-Hodgkin's lymphoma	2,749	53	64	3,414	53	64	3,763	54	65
Multiple myeloma	874	54	70	1,047	54	71	1,097	54	71
Leukemias	1,931	59	68	2,074	58	68	2,281	58	68

***Data source**: Canadian Cancer Registry*
† After survival analysis exclusions
‡ Excluding Québec