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Childhood and adolescent cancer survival: A period analysis of data from the Canadian Cancer Registry

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ABSTRACT

This study provides up-to-date estimates of childhood and adolescent (ages 0–19) cancer survival in Canada using data from the Canadian Cancer Registry (CCR). Cases were classified according to the third edition of the International Classification of Childhood Cancer classification scheme. Follow-up for vital status was determined through record linkage to the Canadian Mortality Data Base, and from information reported by provincial/territorial cancer registries. Observed survival proportions (OSPs) were based on period analysis (1999–2003). The 1-, 3- and 5-year OSPs for all cancers combined were 92%, 85% and 82%, respectively. Among diagnostic groups, five-year survival estimates were highest for retinoblastoma (99%), carcinomas and other malignant epithelial neoplasms and malignant melanomas (91%) and for renal tumours (91%); they were poorest for hepatic tumours (68%) and for malignant bone tumours (68%). Survival for childhood and adolescent cancer in Canada has improved substantially since last reported.

1. Introduction

At just over 160 cases per million, cancer in children and adolescents is rare in Canada—accounting for about 1% of all newly diagnosed neoplasms.[1] Nonetheless, cancer is the fourth leading cause of death among Canadians less than 20 years of age, and second only to injuries when the first 28 days of life is excluded.[2]

Population-based survival studies are essential in evaluating the effectiveness of healthcare provision and the availability of effective treatments for patients with malignant disease.[3] While cancer survival among adults in Canada has been well documented,[4,5] estimates of survival among children and adolescents are presently outdated; the most recent figures available were based on cases diagnosed from 1985 to 1988.[6] The deficiency of more recent cancer survival data for children and adolescents has led the Canadian Cancer Society/National Cancer Institute of Canada to use the death to case ratio as an indicator of disease prognosis for this population[1] and compelled other investigators to draw inferences from survival data from the United States.[1,7] Up-to-date survival estimates for this population are therefore of great interest, especially considering that recent reports from Europe and the United States indicate that the considerable improvement in childhood cancer survival witnessed over the last several decades is ongoing.[8,9] In addition, a new method of

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survival analysis, known as period analysis, has been introduced to derive more up-to-date estimates of long-term survival than were previously possible using traditional cohort methods.[10]

The traditional method of estimating cancer survival has been to use a cohort-based method. Only people diagnosed within defined calendar years are included in cohort analyses. Long-term survival estimates derived using the cohort approach pertain to the survival experience of people diagnosed many years ago. Where there has been a subsequent change in prognosis, these estimates will not reflect the long-term survival experience to be expected by newly diagnosed persons.[10] Conversely, period analysis results exclusively reflect the survival experience of cases followed up in the most recent period for which data are available; they are, by definition, not based upon a specified diagnostic period. The rationale for this approach is analogous to that of the use of period life tables to estimate current life expectancy.

This paper provides up-to-date estimates of survival for those diagnosed with cancer before age 20 in Canada (excluding Quebec), using period analysis on data from the Canadian Cancer Registry (CCR) as of June 2006. Age-specific survival and survival for different durations of follow-up are presented by diagnostic group and selected subgroups. Five-year period estimates are compared with the latest available estimates based on the traditional cohort method.

2. Patients and methods

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 in Canada. However, because data from the province of Quebec are not entirely comparable with those from the other jurisdictions, they were excluded from this report.[1,11] A detailed description of the CCR, including data sources, methodology and accuracy, is available on Statistics Canada's Web site.[12] Cancer cases diagnosed from 1994 to 2003 were classified according to the third edition of the International Classification of Childhood Cancer which combines morphology and the tumour location to group similar diagnoses into categories.[13] Non-malignant intracranial and intraspinal tumours were included when reported. Such cases constituted 12% of the central nervous system neoplasms and 0.3% of the germ cell tumours, trophoblastic tumours and neoplasms of gonads diagnostic group.

Analyses were restricted to first primary tumours only. In order to identify persons in the CCR who had been diagnosed with cancer prior to 1992, the CCR was linked with its predecessor, the National Cancer Incidence Reporting System, a fixed, tumour-oriented database containing cases diagnosed as far back as 1969. Supplementary information available on the CCR for the data from the province of Ontario was also used. Persons whose diagnosis was established through either death certificate only ($n = 19$) or autopsy only ($n = 19$) were excluded as was one person who was identified as having died but whose year of death was not recorded. Remaining persons with the same date of diagnosis and death ($n = 15$) were assigned one day of survival.

Follow-up for vital status was determined through record linkage to the Canadian Mortality Data Base, and from information reported by provincial/territorial cancer registries.[14] For deaths reported by a registry but not confirmed by record linkage with the national database (1% of deaths), it was assumed that the individual died on the date submitted by the reporting province/territory. At the time of the analysis, registration of new cases and follow-up for vital status were complete through 31st December 2003.

Survival analyses were conducted using period analysis.[10] A period analysis is defined by the survival experience of people in a recent time interval, in this case 1999–2003. Estimates

	Diagnosis Year	Follow-up Year									
		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Period	1994						5				
	1995						4–5	5			
	1996						3–4	4–5	5		
	1997						2–3	3–4	4–5	5	
	1998						1–2	2–3	3–4	4–5	5
	1999						1	1–2	2–3	3–4	4–5
	2000							1	1–2	2–3	3–4
	2001								1	1–2	2–3
	2002									1	1–2
	2003										1
Cohort	1994	1	1–2	2–3	3–4	4–5	5				
	1995		1	1–2	2–3	3–4	4–5	5			
	1996			1	1–2	2–3	3–4	4–5	5		
	1997				1	1–2	2–3	3–4	4–5	5	
	1998					1	1–2	2–3	3–4	4–5	5

Fig. 1 – Data used to calculate the most up-to-date five-year survival estimates by period and cohort analysis methods. *NOTE:* The numbers within the cells represent year(s) of follow-up since diagnosis. For example, those diagnosed in 2000 and alive at the conclusion of 2003 would have contributed follow-time to both the third and fourth years of follow-up in 2003.

were obtained by left truncation of follow-up for vital status on 1 January 1999 and right censoring on the fifth anniversary of the date of diagnosis or 31 December 2003—whichever came first. The survival probability during the first year after diagnosis was estimated from the person-time at risk and events (death or censoring) of persons diagnosed from 1998 to 2003 only, whose first year after diagnosis included some part of the period from 1999 to 2003. Similarly, the conditional probability in the second, third, fourth and fifth year after diagnosis was estimated from the survival experience in 1999–2003 only, of persons diagnosed from 1997 to 2002, 1996 to 2001, 1995 to 2000 and 1994 to 1999, respectively (Fig. 1). Cases diagnosed from 1994 to 1998 that died before 1st January 1999 did not experience follow-up in the 1999–2003 period of interest and therefore did not contribute data to the period analysis.

Period estimates of five-year survival were compared to the most recent estimates available using the traditional cohort-based approach. With the cohort method, only cases diagnosed within defined calendar periods that have the potential to be followed over the full follow-up time of interest are included in the analysis. Presently, the cohort method analysis involved cases diagnosed from 1994 to 1998 that were followed up for vital status to a maximum of five years (Fig. 1).

Both the period and cohort survival analyses were based on algorithms written in SAS by Paul Dickman[15] with some minor adaptations. The algorithms use a life table (actuarial) approach in which survival estimates are calculated at discrete points in the follow-up, generally by taking the product of interval-specific (conditional) estimates over subintervals of the follow-up. Further detail on the algorithm and the subintervals employed in the analysis is available elsewhere.[4] Relative survival ratios, which provide a measure of survival corrected for other independent causes of death,[16] are not presented as they were determined to be virtually the same as observed (absolute) survival proportions (OSPs) for those under the age of 20 years (data not shown). Asymmetric survival confidence intervals were formed from standard errors estimated using Greenwood's method[17] and the log (–log) transformation.[15]

3. Results

Just over one-quarter of all childhood and adolescent cancer cases diagnosed before the age of 20 in Canada (excluding Quebec) from 1994 to 2003 were leukaemias (Table 1). Three-quarters of the leukaemias, and one-fifth of the overall total number of cases were lymphoid leukaemias. The next most common diagnostic groups during this time period were neoplasms of the central nervous system (19%) and lymphomas and reticuloendothelial neoplasms (16%). The percentage of cases in the remaining specified diagnostic groups ranged from 9% for other malignant epithelial neoplasms and malignant melanomas to 1% for hepatic tumours. While the method of diagnosis was unknown for 8% of the cases overall, this figure was only 0.3% outside of the province of Ontario as opposed to 15.6% within (data not shown). Diagnoses were microscopically verified for 89% of the cases overall (95% outside of Ontario) and 97% of the cases where the method of diagnosis was known. These percentages were somewhat lower for retinoblastoma and for neoplasms of the central nervous system. Almost one-third of all eligible cases were diagnosed among adolescents (ages 15–19); among children (ages younger than 15), most cases were diagnosed in those aged 1–4 years. More boys (54%) than girls were diagnosed.

The period analysis estimate of the five-year OSP for children and adolescents aged 0–19 years at diagnosis was 82% (Table 2). The corresponding 1- and 3-year survival proportions were 92% and 85%, respectively. Regardless of duration of follow-up time studied, main diagnostic group estimates were highest for retinoblastoma (five-year OSP 99%), other malignant epithelial neoplasms and malignant melanomas (five-year OSP 91%) and for renal tumours (five-year OSP 91%). One-, three- and five-year prognoses were poorest for those diagnosed with hepatic tumours (80%, 70% and 68%, respectively); the five-year prognosis was equally poor for malignant bone tumours.

Survival for those diagnosed with acute myeloid leukaemia (five-year OSP 60%) was considerably less than for those diagnosed with a lymphoid leukaemia (five-year OSP 87%). The outlook for those diagnosed with Hodgkin lymphoma (94% five-year OSP) was better than those diagnosed with non-Hodgkin lymphoma (81% five-year OSP). Similarly, the five-year prognosis for astrocytoma (83%) was found to be superior to that of intracranial and intraspinal embryonal tumours (60%). Thyroid carcinomas (99% five-year OSP) and malignant melanomas (96% five-year OSP), the two most common subgroups of the other malignant epithelial neoplasms and malignant melanomas diagnostic group, had better survival than the diagnostic group as a whole. Survival for osteosarcoma (malignant bone tumours) or rhabdomyosarcoma (soft-tissue and other extraosseous sarcomas) was worse than for other subgroups combined within their main diagnostic groups, while survival for malignant gonadal germ cell tumour cases (germ cell tumours, trophoblastic tumours and neoplasms of gonads) was better than within the diagnostic group as a whole.

The five-year OSP for those diagnosed with leukaemia before their first birthday (57%) or in their mid to late teens (59%) was considerably poorer than for children diagnosed in the intervening years, in whom survival ranged from 82% to 90% (Table 3). Those diagnosed with a neoplasm of the central nervous system also fared relatively poorly when diagnosed before the age of 1 (55% five-year OSP) as opposed to after this age (five-year OSP ranged from 72% to 81% for the respective age groups). In contrast, among those diagnosed with a neuroblastoma or other peripheral nervous cell tumour, five-year survival was highest for infants (94%), compared to other age groups.

The five-year period survival estimate for all diagnostic groups combined was determined to be about 3% higher than the most up-to-date estimate possible based on a cohort analysis (Table 4, Fig. 1). Period estimates of five-year survival were similar to (<1.0 difference) or greater than the corresponding cohort estimates for all diagnostic groups and subgroups analysed; differences were greatest for acute myeloid leukaemias (5.3%), non-Hodgkin lymphomas (4.8%), nephroblastoma and other non-epithelial renal tumours (4.5%) and malignant bone tumours (4.5%).

Table 1 – Counts of childhood and adolescent cancer cases eligible for survival analysis and method of diagnosis, sex and age distribution of cases, by diagnostic group and selected subgroups, Canada (excluding Quebec), Canadian Cancer Registry, 1994–2003

Diagnostic group (subgroup)	Cases	% Method of diagnosis		% Male	% in Age group				
		MV	Unknown		<1	1–4	5–9	10–14	15–19
All groups	9753	89	8	54	6	24	18	20	32
I. Leukaemias, myeloproliferative diseases and myelodysplastic diseases	2511	87	11	55	5	41	23	16	15
a. Lymphoid leukaemias	1883	89	10	57	3	46	26	15	10
b. Acute myeloid leukaemias	420	86	12	49	10	27	14	24	25
II. Lymphomas and reticuloendothelial neoplasms	1581	95	5	59	1	7	14	24	54
a. Hodgkin lymphomas	876	99	1	51	0	2	6	24	68
b. Non-Hodgkin lymphomas (except Burkitt lymphoma)	390	97	3	64	1	9	21	27	43
III. CNS and miscellaneous intracranial and intraspinal neoplasms	1826	81	9	53	4	23	29	25	19
b. Astrocytomas	754	92	3	50	3	21	30	28	18
c. Intracranial and intraspinal embryonal tumours	373	96	3	61	6	28	36	19	10
IV. Neuroblastoma and other peripheral nervous cell tumours	438	95	2	54	28	55	11	3	3
V. Retinoblastoma	165	73	13	57	35	59	5	1	0
VI. Renal tumours	411	95	4	45	11	56	23	4	6
a. Nephroblastoma and other non-epithelial renal tumours	429	98	2	44	11	60	25	3	2
VII. Hepatic tumours	129	90	8	61	26	45	12	5	12
VIII. Malignant bone tumours	510	92	7	58	0	5	17	36	42
a. Osteosarcomas	270	96	3	58	0	3	14	40	44
c. Ewing's tumour and related sarcomas of bone	176	97	2	59	1	7	23	32	36
IX. Soft-tissue and other extraosseous sarcomas	576	97	3	54	6	16	19	25	33
a. Rhabdomyosarcomas	247	98	2	55	5	29	28	21	17
X. Germ cell tumours, trophoblastic tumours and neoplasms of gonads	613	90	7	67	6	8	5	17	64
c. Malignant gonadal germ cell tumours	397	98	1	73	3	4	4	11	79
XI. Other malignant epithelial neoplasms and malignant melanomas	867	97	2	36	2	2	5	19	72
b. Thyroid carcinomas	358	98	2	23	0	1	6	17	76
d. Malignant melanomas	248	97	3	45	2	1	3	16	78
XII. Other and unspecified malignant neoplasms	126	17	79	44	23	19	14	16	28

Cases diagnosed through autopsy only, death certificate only, or that were not the first primary cancer for an individual were not eligible to be included in survival analyses.
MV = microscopically verified.
CNS = central nervous system.
Cases with a known method of diagnosis other than MV were diagnosed through radiology or laboratory diagnosis (other than MV), or surgery (without histology), or clinical diagnosis.
Age-specific percentages may not add to 100 due to rounding.

Table 2 – Period analysis estimates for 1999–2003 of observed survival proportions (%) and 95% confidence intervals by diagnostic group (subgroup) and length of follow-up, ages 0–19 years, Canada (excluding Quebec), Canadian Cancer Registry

Diagnostic group (subgroup)	Survival duration, OSP (95% CI)		
	1-year	3-year	5-year
All groups	92 (91–93)	85 (84–85)	82 (81–83)
I. Leukaemias, myeloproliferative diseases and myelodysplastic diseases	91 (89–92)	84 (82–86)	81 (79–83)
a. Lymphoid leukaemias	95 (94–96)	91 (89–92)	87 (85–89)
b. Acute myeloid leukaemias	76 (70–81)	62 (56–68)	60 (54–67)
II. Lymphomas and reticuloendothelial neoplasms	94 (92–95)	90 (88–92)	88 (86–90)
a. Hodgkin lymphomas	99 (98–100)	96 (94–97)	94 (91–95)
b. Non-Hodgkin lymphomas (except Burkitt lymphoma)	89 (84–93)	82 (76–86)	81 (75–85)
III. CNS and miscellaneous intracranial and intraspinal neoplasms	88 (86–90)	79 (76–81)	75 (73–78)
b. Astrocytomas	92 (89–95)	85 (81–88)	83 (79–86)
c. Intracranial and intraspinal embryonal tumours	83 (77–87)	68 (61–74)	60 (52–66)
IV. Neuroblastoma and other peripheral nervous cell tumours	92 (88–95)	77 (72–82)	70 (64–76)
V. Retinoblastoma	100 (.–.)	99 (92–100)	99 (92–100)
VI. Renal tumours	96 (93–98)	92 (88–95)	91 (86–94)
a. Nephroblastoma and other non-epithelial renal tumours	98 (95–99)	93 (89–96)	92 (87–95)
VII. Hepatic tumours	80 (68–88)	70 (57–79)	68 (55–78)
VIII. Malignant bone tumours	92 (88–95)	74 (69–79)	68 (62–73)
a. Osteosarcomas	92 (86–96)	71 (63–78)	62 (54–70)
c. Ewing's tumour and related sarcomas of bone	90 (82–94)	73 (64–81)	67 (57–75)
IX. Soft–tissue and other extraosseous sarcomas	93 (90–96)	80 (75–84)	77 (71–81)
a. Rhabdomyosarcomas	92 (86–95)	76 (68–83)	72 (63–79)
X. Germ cell tumours, trophoblastic tumours and neoplasms of gonads	96 (93–98)	89 (85–92)	88 (84–91)
c. Malignant gonadal germ cell tumours	98 (95–99)	93 (88–95)	92 (88–95)
XI. Other malignant epithelial neoplasms and malignant melanomas	97 (95–98)	92 (89–94)	91 (88–93)
b. Thyroid carcinomas	100 (.–.)	99 (96–100)	99 (96–100)
d. Malignant melanomas	99 (95–100)	98 (93–99)	96 (91–98)
XII. Other and unspecified malignant neoplasms	92 (83–96)	92 (83–96)	87 (77–93)

OSP = observed survival proportion; CNS = central nervous system; 95% CI = 95% confidence interval; (.–.) = confidence interval is undefined.

4. Discussion

Using data from the CCR and the period survival analysis method, the 5-year observed survival estimate for all childhood and adolescent cancers combined in Canada (excluding Quebec) was determined to be 82%. Comparing diagnostic groups, five-year OSPs were highest for retinoblastoma (99%), carcinomas and other malignant epithelial neoplasms and malignant melanomas (91%) and for renal tumours (91%); they were poorest for hepatic tumours (68%) and for malignant bone tumours (68%).

This study provides up-to-date estimates of childhood and adolescent cancer survival from a large population-based registry. Within Canada, the results fill a large void as survival estimates for this subset of the population have been outdated for some time. Though the CCR is a national registry, data from the province of Quebec were excluded from the analysis, in part, because the method of ascertaining the date of diagnosis in this province clearly differed from that of the other provincial cancer registries[11] and because of issues in correctly ascertaining the vital status of cases. However, there is no reason to expect that the childhood and adolescent cancer survival in this province differs from that of the rest of the country.

While the method of diagnosis was unknown for a relatively high percentage of the cases in this study (8%), this figure was considerably lower outside Ontario (0.3%)—a province that contributed half of the total caseload. The high percentage of childhood and adolescent cancer cases with an unknown method of diagnosis in Ontario (15.6%) is due to incomplete reporting of existing pathology results to the Ontario Cancer Registry during the time period under consideration. It has been estimated that for all ages combined, the Ontario registry received only 75–80% of the required pathology reports, although such reports were completed for about 94% of registered cases.[18]

Period analysis was introduced as a new method in cancer survival analysis in order to generate more up-to-date estimates of long-term survival than traditional cohort-based methods. It has been empirically evaluated favourably in this context in several studies,[19–22] including one which was restricted to childhood cancer cases[19] and one using data from the CCR.[22] In this study, the five-year overall period survival estimate of 82% was determined to be about 3% higher than

Table 3 – Period analysis estimates for 1999–2003 of five-year observed survival proportions (%) and 95% confidence intervals by diagnostic group (subgroup) and age group at diagnosis, Canada (excluding Quebec), Canadian Cancer Registry

Diagnostic group (subgroup)	Age group at diagnosis, OSP (95% CI)					
	<1	1–4	5–9	10–14	<15	15–19
All groups	78 (73–82)	83 (81–85)	82 (79–84)	82 (80–84)	82 (81–83)	81 (79–83)
I. Leukaemias, myeloproliferative diseases and myelodysplastic diseases	57 (45–67)	90 (87–92)	85 (80–88)	82 (76–87)	85 (83–87)	59 (52–66)
a. Lymphoid leukaemias	58 (38–73)	93 (91–95)	89 (85–93)	84 (77–89)	90 (88–91)	69 (59–77)
b. Acute myeloid leukaemias	52 (32–69)	67 (53–78)	59 (38–76)	76 (61–86)	67 (59–74)	41 (28–53)
II. Lymphomas and reticuloendothelial neoplasms	–	88 (76–94)	91 (85–95)	88 (83–92)	89 (85–92)	87 (84–90)
a. Hodgkin lymphomas	–	–	100 (.–.)	91 (85–95)	93 (88–96)	94 (90–96)
b. Non-Hodgkin lymphomas (except Burkitt lymphoma)	–	80 (56–92)	91 (78–96)	82 (70–90)	84 (77–90)	76 (66–83)
III. CNS and miscellaneous intracranial and intraspinal neoplasms	55 (38–68)	72 (66–77)	74 (68–79)	81 (76–86)	75 (72–78)	77 (71–83)
b. Astrocytomas	–	93 (85–96)	86 (78–91)	83 (74–89)	87 (82–90)	69 (57–78)
c. Intracranial and intraspinal embryonal tumours	–	46 (33–58)	65 (52–75)	75 (58–86)	60 (52–67)	53 (28–73)
IV. Neuroblastoma and other peripheral nervous cell tumours	94 (85–97)	60 (51–68)	55 (36–70)	–	70 (64–75)	–
V. Retinoblastoma	100 (.–.)	98 (87–100)	–	–	99 (92–100)	–
VI. Renal tumours	95 (70–99)	93 (86–96)	93 (83–97)	–	92 (87–95)	–
a. Nephroblastoma and other non-epithelial renal tumours	100 (.–.)	93 (86–96)	92 (82–97)	–	92 (88–95)	–
VII. Hepatic tumours	–	71 (50–84)	–	–	76 (62–85)	–
VIII. Malignant bone tumours	–	–	70 (56–81)	71 (61–78)	72 (65–78)	61 (51–69)
a. Osteosarcomas	–	–	–	67 (54–77)	70 (59–79)	53 (39–64)
c. Ewing's tumour and related sarcomas of bone	–	–	60 (39–75)	77 (58–88)	71 (59–81)	58 (40–73)
IX. Soft-tissue and other extraosseous sarcomas	–	69 (54–80)	89 (78–95)	72 (60–81)	77 (71–83)	75 (66–82)
a. Rhabdomyosarcomas	–	71 (53–83)	95 (81–99)	58 (37–75)	77 (68–84)	42 (20–62)
X. Germ cell tumours, trophoblastic tumours and neoplasms of gonads	–	96 (77–99)	83 (57–94)	90 (79–96)	89 (81–93)	88 (83–91)
c. Malignant gonadal germ cell tumours	–	–	–	95 (73–99)	95 (83–99)	91 (86–95)
XI. Other malignant epithelial neoplasms and malignant melanomas	–	–	85 (62–95)	87 (77–93)	86 (79–91)	93 (89–95)
b. Thyroid carcinomas	–	–	–	96 (76–99)	98 (84–100)	–
d. Malignant melanomas	–	–	–	–	92 (72–98)	97 (91–99)
XII. Other and unspecified malignant neoplasms	–	–	–	–	90 (79–96)	80 (55–92)

OSP = observed survival proportion; CNS = central nervous system; 95% CI = 95% confidence interval; (.–.) = confidence interval is undefined. Results were suppressed if there were less than 20 cases in the first interval of the period analysis. Suppression is indicated by a endash.

Table 4 – Comparison of the most recent period and cohort analysis five-year observed survival proportion estimates, by selected diagnostic group (subgroup), ages 0–19 years, Canada (excluding Quebec), Canadian Cancer Registry

Diagnostic group (subgroup)	Analysis method, OSP (95% CI)		Difference (period – cohort)
	Period	Cohort	
All groups	82 (81–83)	79 (78–80)	2.9
I. Leukaemias, myeloproliferative diseases and myelodysplastic diseases	81 (79–83)	77 (75–80)	3.9
a. Lymphoid leukaemias	87 (85–89)	84 (82–86)	3.2
b. Acute myeloid leukaemias	60 (54–67)	55 (48–61)	5.3
II. Lymphomas and reticuloendothelial neoplasms	88 (86–90)	86 (83–88)	1.9
a. Hodgkin lymphomas	94 (91–95)	93 (90–95)	0.5
b. Non-Hodgkin lymphomas (except Burkitt lymphoma)	81 (75–85)	76 (69–82)	4.8
III. CNS and miscellaneous intracranial and intraspinal neoplasms	75 (73–78)	72 (69–75)	3.6
b. Astrocytomas	83 (79–86)	81 (77–85)	1.6
c. Intracranial and intraspinal embryonal tumours	60 (52–66)	57 (50–64)	2.6
IV. Neuroblastoma and other peripheral nervous cell tumours	70 (64-76)	67 (61–73)	3.0
VI. Renal tumours	91 (86–94)	87 (82–91)	3.2
a. Nephroblastoma and other non-epithelial renal tumours	92 (87–95)	87 (82–91)	4.5
VIII. Malignant bone tumours	68 (62–73)	63 (57–69)	4.5
IX. Soft-tissue and other extraosseous sarcomas	77 (71–81)	74 (68–78)	2.8
X. Germ cell tumours, trophoblastic tumours and neoplasms of gonads	88 (84–91)	88 (84–91)	0.0
c. Malignant gonadal germ cell tumours	92 (88–95)	93 (88–96)	–0.9
XI. Other malignant epithelial neoplasms and malignant melanomas	91 (88–93)	92 (89–94)	–0.7
b. Thyroid carcinomas	99 (96–100)	99 (96–100)	0.0

OSP = observed survival proportion; CNS = central nervous system; 95% CI = 95% confidence interval. The data used to calculate the five-year period and cohort survival estimates are depicted in Fig. 1.
Difference refers to the absolute difference between period and cohort analysis observed survival proportions–positive values indicate that the period estimate was higher. Survival estimates were calculated to two decimal places before the difference was calculated and rounded to one decimal place.

the most up-to-date cohort analysis estimate. Period estimates have often been shown to be slightly pessimistic in estimating the long-term survival of recently diagnosed cancer cases, but still more up-to-date than estimates from traditional cohort methods.[19–22] This is particularly so for cancers with recent rapid improvement in survival over time such as childhood cancers.[19]

The analyses in this study were conducted using a five-year follow-up period (i.e., 1999–2003) in order to enhance the precision of estimates. In some instances (e.g., all cancer cases combined), it was realistic to use a shorter and hence more recent period; however, this was not done for reasons of uniformity in the presentation of results. Conversely, despite the use of a five-year follow-up period some point estimates are accompanied by wide confidence intervals and this should be taken into consideration when interpreting these results.

Survival for childhood and adolescent cancer in Canada has improved substantially. The predicted five-year survival of 82% for children and adolescents recently diagnosed with cancer is 11% higher (expressed as difference of percentages) than was reported in the only previous Canadian national study,[6] which analysed cases diagnosed from 1985 to 1988 with follow-up to 1991. Among diagnostic groups, the largest survival increases were observed for hepatic tumours (20%), leukaemias (15%) and central nervous system neoplasms (14%). There were also substantial improvements in survival in most subgroups studied. Improvements in five-year OSPs in the range of 12–14% were observed for lymphoid leukaemias, non-Hodgkin lymphomas and astrocytomas. While a direct comparison was not possible, it is likely that the five-year survival for those diagnosed with acute myeloid leukaemia (60%) increased by an even greater amount as the five-year OSP for acute non-lymphoblastic leukaemia, a subgroup which would have predominantly been composed of acute myeloid leukaemia cases, was previously reported as 39%.[6] A 4% increase was observed for Hodgkin lymphomas, a subgroup whose five-year survival had reached 90% in the late 1980s.

Increases in childhood and adolescent cancer survival in Canada since previously reported[6] were greatest for those diagnostic groups originally found to have the lowest survival. An alternative index of the change in survival which depends less on the original survival estimate is the percent change in cumulative probability of death—a measure of the proportion of deaths avoided.[23] The overall increase in five-year survival from 71% to 82% corresponds to a 37% decrease in the cumulative probability of death at five years. Among diagnostic groups, the decrease in the cumulative probability of death at five years was greatest for retinoblastoma (70%), other and unspecified malignant neoplasms (47%), leukaemias (45%) and lymphomas and reticuloendothelial neoplasms (41%), and least for renal (0%) and malignant bone tumours (17%).

The overall five-year survival estimate in this study was higher than those recently published in the United States by

the Surveillance, Epidemiology and End Results (SEER) program of the National Cancer Institute and in Europe through the Automated Childhood Cancer Information System (ACCIS) project.[8,23,24] Survival in Canada was 4% higher than in the United States for all childhood and adolescent cancers combined (82% versus 78%) and 6–7% higher than estimated for Europe where childhood (75%) and adolescent (76%) cancer survival were reported separately. Part of this is likely due to the use of more recent data in the current study, mainly through the employment of period survival analysis.

Five-year survival for those diagnosed with leukaemia before their first birthday or during adolescence was observed to be considerably poorer than for children diagnosed in the intervening years. This is consistent with other published results[8,25] and likely reflects the differing leukaemia subtypes in different age groups.[25] In addition, adolescents are less likely to be managed in specialised paediatric facilities or enrolled in clinical trials which are both known to improve survival.[26,27] Consistent with the favourable biological profile of neuroblastoma when diagnosed before the age of one,[28] those diagnosed with a neuroblastoma or other peripheral nervous cell tumours during infancy fared relatively well; the opposite was true among those diagnosed with a neoplasm of the central nervous system. Similar results have been reported elsewhere.[8,29,30]

Our results indicate that there has been substantial improvement in survival for childhood and adolescent cancer survival in Canada since the late 1980s. Improvements in survival may generally be attributed to a number of changes in the management of childhood and adolescent cancers; the most notable being the widespread uptake of multimodal therapy, which combines surgery and radiation to treat local disease with chemotherapy to treat systematic disease.[31] The current survival estimates provide a more realistic outlook of survival in this population and may consequently prevent patients, their families and clinicians from being unduly discouraged.

Conflict of interest statement

None declared.

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