Component of Statistics Canada Catalogue no. 82-003-X
Health Reports

Article

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by Dianne Zakaria

August, 2013

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.	not available for any reference period
..	not available for a specific reference period
...	not applicable
0	true zero or a value rounded to zero
0^s	value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p}	preliminary
^{r}	revised
x	suppressed to meet the confidentiality requirements of the *Statistics Act*
^{E}	use with caution
F	too unreliable to be published
*	significantly different from reference category ($p < 0.05$)

An examination of the NAACCR method of assessing completeness of case ascertainment using the Canadian Cancer Registry

by Dianne Zakaria

Abstract

Background
Despite use of the North American Association of Central Cancer Registries' indicator for assessing completeness of case ascertainment in population-based cancer registries, little has been published about its methodology, usefulness and accuracy in Canada.

Data and methods
Canadian cancer incidence, cancer mortality, and population census data were used to quantify case completeness in 2007. Two indicators (I_1 and I_2) that expressed the observed age-standardized incidence rate relative to the expected rate were calculated. The assumption of stable age-standardized sex- and cancer-site-specific incidence-to-mortality rate ratios across regions was assessed. Associations between I_1, I_2 and simpler indicators of completeness were examined.

Results
The assumption of stable age-standardized sex- and cancer-site-specific incidence-to-mortality rate ratios across regions was not consistently supported—substantial regional differences emerged. I_1 was strongly correlated with I_2 ($r=0.93$, $n=315$, $p<0.0001$), and both were most strongly and consistently associated with the age-standardized incidence-to-mortality rate ratio. The frequency of undercoverage did not increase consistently with expected case-finding difficulty.

Interpretation
The age-standardized incidence-to-mortality rate ratio may provide a less complicated method of identifying undercoverage.

Keywords
Cancer, data collection, incidence, mortality, neoplasms, SEER Program, registries

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Reliable cancer registry data are needed for planning, monitoring, and evaluating cancer control programs. An important aspect of data quality is case ascertainment, generally defined as the percentage of all incident tumours in a registry's surveillance population that are captured in the registry's database.[1] Incomplete case ascertainment can lead to underestimated incidence and prevalence, and biased socio-demographic and clinical characteristics (for example, stage at diagnosis, treatment provided, survival) if the cancers recorded by a registry differ substantially from those that are missed.

According to a recent survey of European cancer registries, 86% estimated their case ascertainment completeness.[2] The methods used most frequently were comparing current with historical incidence (73%) and comparisons with a presumably complete reference registry (65%). More complex procedures, such as the capture-recapture method (25%)[3-6] and flow method (21%),[4,7,8] were employed less often. The use of more than one method was also infrequent (29%).

The method used by the North American Association of Central Cancer Registries (NAACCR) to estimate case completeness is to express the *observed* number of cancers as a percentage of the *expected* number for a given population.[9] Age-standardized race-, sex- and cancer-site-specific incidence-to-mortality rate ratios are calculated, based on Surveillance Epidemiology and End Results (SEER) Program cancer incidence data and U.S. cancer mortality data. The products of these rate ratios and mortality rates for the region and year of interest provide *expected* age-standardized race-, sex- and cancer-site-specific incidence rates for that region and year. Summation of these estimates yields

the overall *expected* age-standardized cancer incidence rate for the race, sex, region and year of interest. The *observed* cancer incidence rate is then expressed as a percentage of this *expected* incidence rate to estimate the completeness of case ascertainment.[9-11]

This method assumes that cancer death data are complete and that the ratio of age-standardized cancer incidence rates to age-standardized cancer mortality rates by race, sex and cancer site varies little by geographic area (within ± 20% attributed to differential case fatality).[9] But despite the latter assumption, NAACCR uses U.S. cancer mortality data, rather than SEER cancer mortality data, to produce ASRRs and then adjusts for differences between region-specific and U.S. mortality. If the age-standardized region-specific mortality rate is greater than the age-standardized U.S. mortality rate, the region-specific mortality rate is adjusted downward before calculating the expected incidence rate; if the region-specific rate is lower than the U.S. rate, the region-specific rate is adjusted upward.[12]

Completeness of case ascertainment can also be estimated with simpler indicators: the percentage of cancers registered by death certificate only (%DCO); the percentage microscopically confirmed (%MC); and the age-standardized incidence-to-mortality rate ratio (I:M). In fact, simpler case completeness indicators are routinely used for the publication, *Cancer Incidence in Five Continents*,[1] and by other international studies.[13,14]

A high %DCO suggests incomplete case ascertainment due to failure to capture cases while patients are alive. This means that missed non-fatal cases (cancer not indicated on the death certificate) will probably never be registered.[15] Conversely, %DCO=0% suggests that death certificates are not being used, or that linkage with a vital statistics registry to identify missed cases is not occurring, and thus, incomplete case ascertainment is likely.[1,9,16]

High and low %MC can also signal completeness issues. A high percentage may reflect over-reliance on hospital or pathology laboratory cases; a very low percentage may indicate a lack of adequate pathology laboratories or a lack of collaboration between a cancer registry and pathology laboratories.[1,16-18] Based on the experience of the SEER Program, the %MC for all cancer cases combined is expected to range from 92% to 96%.[18]

Finally, the I:M should exceed 1.00. A ratio below 1.00 indicates under-reporting.[9]

Despite use of the NAACCR case completeness indicator, little has been published about its methodology, usefulness, and accuracy in Canada. The effect that limiting mortality data to the same geographic region that contributed the incidence data would have on calculations of the age-standardized incidence-to-mortality rate ratios is unknown. The indicator is based on the assumption that age-standardized incidence-to-mortality rate ratios by race, sex and cancer site are approximately constant across geographic areas. Therefore, better performance might be expected of the indicator if both incidence and mortality data were derived from the same geographic area. As well, the benefits of the NAACCR indicator over simpler methods have not been thoroughly explored.

Using data from the Canadian Cancer Registry (CCR), vital statistics, and population statistics, the first objective of the present study is to examine the impact of limiting mortality data to the same geographic regions that contribute incidence data when calculating age-standardized incidence-to-mortality rate ratios. This includes assessing the assumption that the age-standardized incidence-to-mortality rate ratios by sex and cancer site vary little by region. The second objective is to quantify relationships between simpler methods of estimating completeness and the NAACCR indicator. The final objective is to determine if the NAACCR indicator identifies known differences in difficulty of case ascertainment, and known case completeness issues in the CCR.

Data and methods

The NAACCR indicator was calculated for primary cancers diagnosed in Canada during 2007, because, at the time of analysis, this was the most recent year for which national data were available; it was the most recent year linked to national vital statistics data; and it minimized confounding of case completeness and timeliness.[15] The methodology for calculating the indicator has been described by NAACCR.[12] Statistics Canada's CCR,[19] Vital Statistics Death Database[20] and Census of Population[21] furnished cancer incidence, cancer mortality, and population data, respectively, for all provinces and territories for the five-year period (2003 to 2007) ending in the evaluation year (2007). These five years of data were combined to calculate sex-, age-, and cancer-site-specific incidence and mortality rates, which were age-standardized using the July 1, 1991 population (Appendix A). The cancer sites included in the NAACCR indicator and the method of extraction from the CCR and Vital Statistics Death Database are presented in Appendix B.

The age-standardized sex- and cancer-site-specific incidence-to-mortality rate ratios (ASRR) used in the indicator were calculated two ways: $ASRR_1$ and $ASRR_2$. For $ASRR_1$, the cancer incidence and mortality data were limited to provinces attaining NAACCR gold or silver certification in each year from 2003 through 2007: Alberta, Saskatchewan, Manitoba, New Brunswick, and Prince Edward Island. For $ASRR_2$, consistent with the NAACCR approach, cancer incidence rates were derived from data for the best-performing provinces, but mortality rates were derived from data for all Canada.

The expected age-standardized sex- and cancer-site-specific incidence rate for a province or territory in 2007 was calculated using ASRR1 or ASRR2 (equation 1) (Formulas). To account for differences in cancer case fatality rates across regions, NAACCR incorporates a mortality adjustment term (equation 2), which is used to adjust the age-standardized sex- and cancer-site-specific

mortality rate for the region of interest (equation 3). Completeness of case ascertainment for a specific sex and cancer site in a province/territory was calculated (equation 4), and overall completeness of case ascertainment for a specific sex in a province/territory was calculated (equation 5).

The case completeness indicators produced using these two methods are referred to as I_1 and I_2. Variances for age-standardized rates were calculated as per Fay and Feuer,[22] and confidence intervals for age-standardized rate ratios were calculated as per Armitage, Berry and Matthews.[23] Confidence intervals were not calculated for the completeness of case ascertainment indicators because of the lack of published methods, a previously identified limitation, particularly for estimates based on small counts.[24]

The Pearson product-moment correlation coefficient was used to examine associations between sex- and cancer-site-specific I_1, I_2 and I:M (quantified for 2007). Because associations between the sex- and cancer-site-specific estimates of case completeness (I_1 and I_2) and %DCO and %MC (both quantified for 2007) were not expected to be linear, they were assessed using the point biserial correlation coefficient. This statistic measures the degree of association between a dichotomous variable (%DCO or %MC) and an interval or ratio variable (I_1 and I_2). Its properties and interpretation are similar to the Pearson product-moment correlation coefficient in that it ranges from -1 to +1, with larger absolute values indicating a stronger relationship. It shows the degree to which %DCO or %MC discriminates between complete and incomplete case ascertainment: larger absolute values indicate better discrimination.[25] %DCO was dichotomized such that values of 0% or more than 5% (exceeding upper limit for NAACCR silver certification) were considered to suggest incomplete case ascertainment. %MC was dichotomized such that values less than 90% or greater than 98% were considered to suggest incomplete case ascertainment, a slightly wider range than the NAACCR guideline for all cases combined (92% to 96%). Pearson product-moment correlation coefficients were also used to examine the association between I_1 and I_2 and the continuous forms of the %MC and %DCO, but the findings were similar (data not shown).

To meet the confidentiality requirements of the Statistics Act, all estimates based on fewer than five cases, or comprised of other estimates based on fewer than five cases, were suppressed. Because suppression occurred frequently for Nunavut, Northwest Territories, Yukon Territory and Prince Edward Island, estimates are presented only for the remaining nine provinces. However, the results for the smaller provinces and territories are included in the estimates for Canada as a whole. All analyses were conducted using SAS 9.2©.[26]

Formulas
Equations for calculating completeness of cancer case ascertainment

Equation 1

expected age-standardized sex- and cancer-site-specific incidence rate for a province/territory in 2007 = (ASRR$_1$* or ASRR$_2$†) (age-standardized sex- and cancer-site-specific mortality rate for a province/territory in 2006 to 2007‡)

Equation 2

$$\text{sex- and cancer-site-specific mortality adjustment term for a province/territory} = \frac{\text{5-year age-standardized sex- and cancer-site-specific mortality for Canada (2003 to 2007)}}{\text{5-year age-standardized sex- and cancer-site-specific mortality for specific province/territory (2003 to 2007)}}$$

Equation 3

adjusted age-standardized sex- and cancer-site-specific mortality rate for a province/territory = (0.8)(age-standardized sex- and cancer-site-specific mortality rate for a province/territory in 2006 to 2007) + (0.2)(sex- and cancer-site-specific mortality adjustment term for a province/territory)(age-standardized sex- and cancer-site-specific mortality rate for a province/territory in 2006 to 2007)

Equation 4

$$\text{sex- and cancer-site-specific completeness of case ascertainment for a province/territory in 2007} = \left[\frac{\text{observed age-standardized sex- and cancer-site-specific incidence rate for a specific province/territory in 2007}}{\text{expected age-standardized sex- and cancer-site-specific incidence rate for a specific province/territory in 2007}}\right](100)$$

Equation 5

$$\text{sex-specific completeness of case ascertainment for a province/territory in 2007} = \left[\frac{\sum \text{observed age-standardized cancer-site-specific incidence rates for a specific sex in a province/territory in 2007}}{\sum \text{expected age-standardized cancer-site-specific incidence rates for a specific sex in a province/territory in 2007}}\right](100)$$

ASRR = age-standardized sex- and cancer-site-specific incidence-to-mortality rate ratio.

* age-standardized sex- and cancer-site-specific incidence-to-mortality rate ratio derived from best-performing provinces using 2003 through 2007 data

† age-standardized sex- and cancer-site-specific incidence rate derived from best-performing provinces and age-standardized sex- and cancer-site-specific mortality rate based on all Canada using 2003 through 2007 data

‡ for provinces/territories with population less than 500,000 in 2006 or 2007, three years of mortality data were used (2005 to 2007); when using ASRR$_2$, the adjusted age-standardized sex- and cancer-site-specific mortality rate for a province/territory were used

Results

$ASRR_1$ and $ASRR_2$ were generally similar (overlapping confidence intervals) (Table 1). When differences did exist (non-overlapping confidence intervals), $ASRR_1$ was generally greater, indicating that the mortality rate in the best-performing provinces was lower than that for Canada overall.

Comparisons of cancer-site-specific $ASRR_1$s across the best-performing provinces showed that only prostate cancer and female breast cancer had instances of non-overlapping confidence intervals (Table 2). Both cancers are excluded from NAACCR's overall estimate of case completeness (Appendix B).

However, even when the smallest province (Prince Edward Island) was excluded, substantial differences in $ASRR_1$s were apparent across regions. For example, the female stomach cancer $ASRR_1$ in Saskatchewan was 2.00, compared with 1.35 in Manitoba, a relative difference larger than that for female breast cancer (4.37 versus 4.01, respectively). Examination of the underlying age-standardized rates revealed that differences in mortality, not incidence, created the disparity between the two provinces. However, the power to identify these differences as statistically significant was limited by the small case counts, compared with prostate cancer and female breast cancer.

The two sex- and cancer-site-specific case completeness indicators—I_1 and I_2—calculated for the nine provinces with adequate case counts were highly correlated ($r=0.93$, $n=315$, $p<0.0001$). Generally, they were either 90%+ (adequate for NAACCR silver case completeness certification) or less than 90%. However, in 11% of comparisons, differences emerged, with one indicator scoring 90%+, and the other, less than 90%. In the majority of these instances (67%), I_1 scored lower than I_2 because the $ASRR_1$ was larger than the $ASRR_2$ (Table 1). A larger ASRR means that the expected number of cases will be greater, which translates into lower case completeness (a lower observed-to-expected ratio). I_1 identified about 27% of the sex- and cancer-site-specific completeness indicators across the nine provinces as less than 90%; I_2 identified 23% as less than 90% (data not shown).

Of the simpler indicators, I:M was most strongly and consistently associated with I_1 and I_2; correlations of %MC and %DCO with I_1 and I_2 were rare (Table 3).

Table 1
Age-standardized incidence-to-mortality rate ratios (ASRR), by sex, cancer site and method of calculation, Canada, 2003 to 2007

	Males						Females					
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
Cancer site	$ASRR_1$*	from	to	$ASRR_2$†	from	to	$ASRR_1$*	from	to	$ASRR_2$†	from	to
Oral cavity, pharynx	3.24	2.96	3.55	2.95	2.79	3.12	3.68	3.21	4.22	3.37	3.11	3.65
Esophagus	0.93	0.85	1.01	0.94	0.88	1.01	1.02	0.87	1.20	0.99	0.88	1.12
Stomach	**1.82**	1.69	1.98	**1.56**	1.48	1.65	1.63	1.47	1.81	1.44	1.34	1.55
Colon, rectum	**2.54**	2.44	2.63	**2.32**	2.27	2.38	2.53	2.43	2.64	2.39	2.33	2.46
Liver	1.22	1.10	1.35	1.07	0.99	1.16	1.04	0.88	1.22	1.01	0.89	1.14
Pancreas	1.09	1.02	1.17	1.10	1.05	1.16	1.10	1.03	1.18	1.13	1.07	1.19
Bronchus, lung	**1.23**	1.20	1.27	**1.12**	1.09	1.14	1.35	1.31	1.40	1.32	1.29	1.35
Melanoma of skin	5.04	4.54	5.60	4.57	4.31	4.85	7.42	6.52	8.43	7.31	6.83	7.83
Breast‡	...	...	...	...	...	...	4.44	4.29	4.59	4.31	4.22	4.39
Cervix uteri	...	...	...	...	...	...	4.10	3.65	4.60	4.55	4.23	4.88
Corpus uterus, uterus not otherwise specified	...	...	...	...	...	...	6.94	6.35	7.58	6.42	6.13	6.73
Ovary	...	...	...	...	...	...	1.42	1.32	1.52	1.48	1.41	1.55
Prostate‡	**5.12**	4.95	5.29	**6.15**	6.03	6.27	...	...	...	...	...	...
Kidney, renal pelvis	2.98	2.77	3.22	3.20	3.05	3.36	3.24	2.93	3.57	3.73	3.51	3.98
Bladder	4.45	4.16	4.76	4.23	4.07	4.40	**5.00**	4.45	5.62	**4.02**	3.77	4.29
Brain, other parts of central nervous system	1.43	1.30	1.56	1.36	1.27	1.45	1.54	1.39	1.72	1.48	1.37	1.60
Hodgkin lymphoma	**7.56**	5.79	9.88	**6.83**	5.94	7.85	12.45	8.77	17.67	8.93	7.61	10.49
Non-Hodgkin lymphoma	2.47	2.32	2.64	2.52	2.42	2.63	2.76	2.57	2.97	2.69	2.56	2.81
Leukemia	2.04	1.90	2.18	2.04	1.95	2.14	2.17	2.00	2.35	2.27	2.15	2.40
Multiple myeloma	1.65	1.49	1.83	1.64	1.53	1.76	1.51	1.35	1.70	1.60	1.47	1.73

* based on age-standardized incidence rates and mortality rates from Alberta, Saskatchewan, Manitoba, New Brunswick and Prince Edward Island, 2003 to 2007
† based on age-standardized incidence rates from Alberta, Saskatchewan, Manitoba, New Brunswick and Prince Edward Island and age-standardized Canadian mortality rates, 2003 to 2007
‡ not included in North American Association of Central Cancer Registries' case completeness indicator
...not applicable
Note: $ASRR_1$ and $ASRR_2$ are boldface when confidence intervals do not overlap.
Sources: Canadian Cancer Registry; Canadian Vital Statistics Death Database; Census of Population.

Table 2
Age-standardized incidence-to-mortiality rate ratios ($ASRR_1$), by sex and cancer site, Alberta, Saskatchewan, Manitoba, New Brunswick and Prince Edward Island, 2003 to 2007

	Males			Females		
		95% confidence interval			95% confidence interval	
Cancer site	$ASRR_1$	from	to	$ASRR_1$	from	to
Oral cavity, pharynx						
Alberta	3.00	2.62	3.43	3.43	2.82	4.18
Saskatchewan	3.50	2.76	4.43	3.76	2.68	5.29
Manitoba	3.25	2.70	3.93	3.69	2.78	4.90
New Brunswick	3.69	2.87	4.74	4.85	3.16	7.44
Prince Edward Island	3.56	1.90	6.65	4.28	1.91	9.60
Esophagus						
Alberta	0.99	0.88	1.13	1.16	0.91	1.48
Saskatchewan	0.82	0.66	1.02	0.88	0.60	1.28
Manitoba	0.79	0.65	0.96	0.84	0.59	1.21
New Brunswick	0.98	0.79	1.23	1.07	0.72	1.58
Prince Edward Island	1.08	0.62	1.87	1.22	0.46	3.26
Stomach						
Alberta	1.86	1.65	2.10	1.64	1.40	1.92
Saskatchewan	1.80	1.47	2.20	2.00	1.51	2.65
Manitoba	1.80	1.52	2.13	1.35	1.08	1.69
New Brunswick	1.80	1.47	2.20	1.79	1.37	2.32
Prince Edward Island	1.61	0.94	2.76	1.44	0.79	2.64
Colon, rectum						
Alberta	2.57	2.43	2.73	2.57	2.41	2.73
Saskatchewan	2.62	2.40	2.85	2.57	2.33	2.83
Manitoba	2.38	2.19	2.58	2.54	2.32	2.78
New Brunswick	2.51	2.27	2.78	2.51	2.24	2.80
Prince Edward Island	2.80	2.21	3.55	2.17	1.72	2.73
Liver						
Alberta	1.30	1.13	1.49	1.17	0.94	1.47
Saskatchewan	1.03	0.77	1.38	0.73	0.48	1.12
Manitoba	1.20	0.96	1.52	1.03	0.73	1.46
New Brunswick	1.08	0.77	1.51	0.97	0.54	1.73
Prince Edward Island	1.01	0.51	2.00	X	X	X
Pancreas						
Alberta	1.12	1.01	1.24	1.08	0.98	1.19
Saskatchewan	1.06	0.90	1.25	1.20	1.01	1.41
Manitoba	1.03	0.88	1.20	1.04	0.88	1.22
New Brunswick	1.12	0.95	1.33	1.12	0.94	1.33
Prince Edward Island	1.16	0.77	1.75	1.32	0.83	2.10
Bronchus, lung						
Alberta	1.24	1.18	1.29	1.36	1.30	1.43
Saskatchewan	1.25	1.16	1.33	1.38	1.27	1.49
Manitoba	1.24	1.16	1.32	1.34	1.25	1.44
New Brunswick	1.21	1.13	1.30	1.31	1.21	1.42
Prince Edward Island	1.22	1.03	1.44	1.33	1.10	1.61
Melanoma of skin						
Alberta	4.96	4.27	5.76	7.51	6.28	8.98
Saskatchewan	4.42	3.42	5.71	6.11	4.38	8.52
Manitoba	4.53	3.51	5.84	6.24	4.59	8.50
New Brunswick	6.56	4.86	8.86	8.40	5.91	11.92
Prince Edward Island	5.88	3.22	10.76	14.47	5.75	36.44
Breast†						
Alberta	...	...	...	4.65	4.42	4.89
Saskatchewan	...	...	...	4.37	4.02	4.75
Manitoba	...	...	...	4.01	3.73	4.31
New Brunswick	...	...	...	4.69	4.27	5.15
Prince Edward Island	...	...	...	4.04	3.28	4.96
Cervix uteri						
Alberta	...	...	...	4.16	3.54	4.88
Saskatchewan	...	...	...	4.47	3.26	6.14
Manitoba	...	...	...	3.39	2.60	4.42
New Brunswick	...	...	...	4.28	3.07	5.95
Prince Edward Island	...	...	...	5.36	2.54	11.33
Corpus uterus, uterus not otherwise specified						
Alberta	...	...	...	6.60	5.81	7.49
Saskatchewan	...	...	...	7.10	5.71	8.83
Manitoba	...	...	...	8.38	6.84	10.25
New Brunswick	...	...	...	5.93	4.69	7.50
Prince Edward Island	...	...	...	7.96	4.26	14.85
Ovary						
Alberta	...	...	...	1.37	1.24	1.52
Saskatchewan	...	...	...	1.40	1.19	1.64
Manitoba	...	...	...	1.43	1.23	1.65
New Brunswick	...	...	...	1.57	1.31	1.89
Prince Edward Island	...	...	...	1.89	1.13	3.16
Prostate†						
Alberta	5.43	5.16	5.72	...	...	...
Saskatchewan	4.76	4.44	5.10	...	...	...
Manitoba	4.12	3.83	4.45	...	...	...
New Brunswick	6.10	5.55	6.70	...	...	...
Prince Edward Island	6.55	5.30	8.09	...	...	...
Kidney, renal pelvis						
Alberta	3.10	2.76	3.48	3.40	2.92	3.97
Saskatchewan	2.75	2.29	3.30	2.80	2.21	3.54
Manitoba	2.87	2.45	3.37	3.35	2.70	4.17
New Brunswick	3.04	2.51	3.67	3.45	2.71	4.40
Prince Edward Island	3.12	1.98	4.90	2.06	1.20	3.56
Bladder						
Alberta	4.86	4.38	5.39	4.74	4.00	5.62
Saskatchewan	4.06	3.48	4.75	4.58	3.48	6.02
Manitoba	3.86	3.34	4.46	5.04	3.84	6.63
New Brunswick	4.82	4.02	5.78	6.59	4.73	9.18
Prince Edward Island	4.57	2.99	6.98	3.91	1.99	7.66
Brain, other parts of central nervous system						
Alberta	1.38	1.22	1.56	1.49	1.28	1.74
Saskatchewan	1.47	1.16	1.85	1.57	1.21	2.03
Manitoba	1.52	1.22	1.89	1.52	1.19	1.96
New Brunswick	1.38	1.09	1.75	1.85	1.40	2.45
Prince Edward Island	1.94	1.11	3.37	1.15	0.63	2.10

Table 2, concluded
Age-standardized incidence-to-mortiality rate ratios ($ASRR_1$), by sex and cancer site, Alberta, Saskatchewan, Manitoba, New Brunswick and Prince Edward Island, 2003 to 2007

	Males			Females		
		95% confidence interval			95% confidence interval	
Cancer site	$ASRR_1$	from	to	$ASRR_1$	from	to
Hodgkin lymphoma						
Alberta	6.78	4.68	9.80	12.61	7.68	20.70
Saskatchewan	10.28	5.27	20.05	20.06	7.80	51.57
Manitoba	6.43	3.55	11.65	13.34	5.92	30.08
New Brunswick	12.22	5.28	28.29	7.15	3.14	16.28
Prince Edward Island	‡	‡	‡	‡	‡	‡
Non-Hodgkin lymphoma						
Alberta	2.66	2.41	2.94	2.98	2.66	3.33
Saskatchewan	2.34	2.01	2.72	2.57	2.16	3.05
Manitoba	2.15	1.88	2.47	2.39	2.05	2.77
New Brunswick	2.51	2.11	2.99	3.14	2.56	3.84
Prince Edward Island	3.15	2.02	4.91	2.32	1.51	3.55
Leukemia						
Alberta	2.19	1.98	2.43	2.29	2.03	2.58
Saskatchewan	1.99	1.71	2.32	2.13	1.77	2.58
Manitoba	1.79	1.54	2.07	2.08	1.74	2.50
New Brunswick	1.99	1.61	2.45	1.93	1.53	2.44
Prince Edward Island	2.15	1.46	3.16	1.95	1.15	3.32
Multiple myeloma						
Alberta	1.63	1.40	1.89	1.54	1.30	1.83
Saskatchewan	1.64	1.27	2.11	1.53	1.16	2.02
Manitoba	1.57	1.24	1.98	1.27	0.99	1.62
New Brunswick	1.72	1.29	2.28	1.75	1.29	2.38
Prince Edward Island	2.24	1.29	3.90	1.72	0.76	3.87

† non-overlapping confidence intervals across provinces
‡ undefined because there were no deaths with an underlying cause of Hodgkin lymphoma from 2003 through 2007
X suppressed to meet confidentiality requirements of *Statistics Act*
...not applicable
Sources: Canadian Cancer Registry; Canadian Vital Statistics Death Database; Census of Population.

Table 4 presents I_1 and I_2 for selected cancers with varying degrees of difficulty of ascertainment.[10] If less than 90% is considered to represent potentially incomplete ascertainment, difficulty of ascertainment was not consistently associated with undercoverage. Aside from pancreatic cancer, the frequency of undercoverage based on I_2 did not increase for cancers of average difficulty compared with those of low difficulty. Undercoverage of breast cancer, which is considered to have average difficulty of ascertainment, was low based on both I_1 and I_2. As well, I_1 did not identify any instances of undercoverage of prostate cancer, which is considered to be one of the most difficult to ascertain.

Both I_1 and I_2 suggested undercoverage of bladder cancer in Ontario (Table 4),[27] a finding that was expected because Ontario does not report in situ bladder tumours to the CCR. For Quebec, both I_1 and I_2 suggested undercoverage of melanoma of the skin, but only I_2 suggested undercoverage of prostate cancer. In 1996, incomplete ascertainment of prostate and melanoma skin cancer had been documented for adults in Quebec.[28]

Cancer sites not presented in Table 4 were examined to identify other potential instances of substantial undercoverage (less than 80% complete); 10 emerged:

- esophageal cancer in Saskatchewan females (I_1=72%, I_2=75%) and Manitoba females (I_1=64%, I_2=66%);
- liver cancer in Manitoba females (I_1=55%, I_2=58%);
- ovarian cancer in Nova Scotia (I_1=79%, I_2=77%) and Newfoundland (I_1=75%, I_2=71%);
- kidney and renal pelvis cancer in Manitoba males (I_1=75%, I_2=73%);
- cancer of the brain and other parts of the central nervous system in Newfoundland females (I_1=67%, I_2=71%);
- Hodgkin lymphoma in Saskatchewan males (I_1=62%, I_2=65%) and Quebec females (I_1=47%, I_2=69%); and
- multiple myeloma in Nova Scotia males (I_1=58%, I_2=59%).

Caution is warranted, however, because of the small counts underlying some of these estimates (for example, esophageal and liver cancer).

The overall completeness-of-case-ascertainment indicator identified undercoverage among males in Newfoundland (Table 5), with or without inclusion of prostate cancer. Newfoundland's I:M and %MC were at the lower and upper end, respectively, of the range of values for the nine provinces. These patterns also held for Newfoundland females, among whom one of the four completeness indicators dipped slightly below 90%.

Discussion

An assumption underlying the NAACCR indicator is that the ratio of age-standardized cancer incidence-to-mortality rates by race, sex and cancer site varies little by geographic region. That is, cancer incidence and mortality rates may vary across regions, but the *ratio* of the two will not. However, examination of this assumption across Canadian provinces used to develop the age-standardized incidence-to-mortality rate ratios revealed differences of practical importance, apart from prostate and female breast cancer, both of which are excluded from the NAACCR indicator.

In the present analysis, differences between $ASRR_1$ and $ASRR_2$ contributed to disparities between I_1 and I_2 in about 11% of comparisons. Users who want to identify potential undercoverage may prefer I_1 over I_2

because, in instances of disagreement, I_1 was more likely to score below 90%.

Of the simpler indicators, only I:M showed frequent, statistically significant associations with I_1 and I_2. This seems reasonable in light of the underlying assumptions of I_1 and I_2 (stability of the age-standardized cancer incidence-to-mortality rate ratios across regions and completeness of cancer death data). Given these assumptions, a relatively small I:M would signal missed cancer incidence. The I:M need not be less than 1.00, but merely low in relation to other regions. Thus, the I:M may offer a less complicated, more direct initial signal of case completeness issues, which can then be investigated by comparing age-standardized cancer incidence and mortality rates over time within a province or territory, and across provinces and territories. An advantage of the I:M is the ability to calculate confidence intervals for more meaningful comparisons with a standard I:M based on the best-performing provinces.

The lack of association of %DCO and %MC with I_1 and I_2 probably arises because of the lack of consistent cut-points across cancer sites,[13,18] and because %DCO, by itself, is not an indicator of completeness of registration.[1,4] A low %DCO could result from efficient registration of cancer cases while patients are alive, or from aggressive follow-back procedures for cases brought to a registry's attention through death certificates. In the latter situation, missed cases are likely. De Angelis et al.[13] state that the extent of microscopic confirmation depends on the accessibility of the cancer to biopsy, whether surgery is performed, and the availability of pathology reports to cancer registries. For %DCO and %MC, examination of the range of values across provinces and territories, in conjunction with knowledge of registry procedures (use of death certificates, linkage to vital statistics database, follow-back procedures), would be of greater value in identifying undercoverage.

The importance of cancer-specific estimates for each province and territory was illustrated by how coverage issues were masked when sites with high and low completeness estimates were aggre-

Table 3
Correlations between North American Association of Central Cancer Registries (NAACCR) completeness indicators and simpler completeness indicators, by sex and cancer site, 2007

Cancer site	NAACCR indicator	Males			Females		
		%MC	%DCO	I:M	%MC	%DCO	I:M
Oral cavity, pharynx	I_1	-0.07	-0.51	0.91*	0.53	0.35	0.88*
	I_2	-0.11	-0.53	0.91*	0.49	0.32	0.91*
Esophagus	I_1	0.71*	0.47	0.91*	-0.18	-0.23	0.46
	I_2	0.65	0.52	0.90*	-0.23	-0.23	0.50
Stomach	I_1	-0.05	-0.43	0.61	-0.49	0.17	0.96*
	I_2	0.06	-0.36	0.68*	-0.51	0.22	0.87*
Colon, rectum	I_1	-0.50	0.08	0.82*	-0.88*	-0.93*	0.84*
	I_2	-0.55	0.12	0.84*	-0.58	-0.81*	0.63
Liver	I_1	†	-0.60	0.71*	†	0.06	0.83*
	I_2	†	-0.63	0.73*	†	0.04	0.86*
Pancreas	I_1	†	-0.63	0.96*	†	0.21	0.41
	I_2	†	-0.56	0.96*	†	0.15	0.59
Bronchus, lung	I_1	0.13	-0.12	0.94*	-0.05	0.02	0.91*
	I_2	0.21	0.07	0.85*	0.03	0.07	0.91*
Melanoma of skin	I_1	0.42	0.06	0.60	-0.57	0.15	0.94*
	I_2	0.38	-0.01	0.67*	-0.53	0.12	0.93*
Breast	I_1	...	...	...	0.10	0.31	0.63
	I_2	...	...	...	0.04	0.31	0.58
Cervix uteri	I_1	...	...	...	0.49	0.24	0.79*
	I_2	...	...	...	0.43	0.27	0.86*
Corpus uterus, uterus not otherwise specified	I_1	...	...	...	0.49	-0.42	0.96*
	I_2	...	...	...	0.46	-0.44	0.95*
Ovary	I_1	...	...	...	0.05	0.13	0.84*
	I_2	...	...	...	0.05	0.11	0.82*
Prostate	I_1	-0.35	0.33	0.91*	...	...	...
	I_2	-0.40	0.30	0.89*	...	...	...
Kidney, renal pelvis	I_1	0.23	0.26	0.85*	-0.06	0.59	0.24
	I_2	0.23	0.33	0.80*	-0.07	0.66	0.31
Bladder	I_1	-0.82*	0.38	0.96*	-0.05	0.33	0.95*
	I_2	-0.83*	0.39	0.94*	-0.04	0.33	0.93*
Brain, other parts of central nervous system	I_1	0.70*	-0.45	0.73*	0.61	-0.50	0.87*
	I_2	0.73*	-0.50	0.78*	0.60	-0.48	0.88*
Hodgkin lymphoma	I_1	†	†	0.47	0.27	0.27	0.80*
	I_2	†	†	0.44	0.24	0.24	0.72*
Non-Hodgkin lymphoma	I_1	0.07	-0.16	0.78*	-0.21	0.09	0.66
	I_2	-0.08	-0.32	0.69*	-0.26	0.09	0.62
Leukemia	I_1	-0.14	-0.15	0.93*	0.26	0.04	0.93*
	I_2	-0.21	-0.21	0.88*	0.29	-0.06	0.97*
Multiple myeloma	I_1	0.64	-0.59	0.86*	-0.08	-0.18	0.83*
	I_2	0.66	-0.59	0.92*	-0.13	-0.24	0.83*

%MC = percentage microscopically confirmed
%DCO = percentage death certificate only
I:M = age-standardized cancer incidence-to-mortality rate ratio
I_1 = percentage case completeness indicator derived using 2003 to 2007 cancer incidence and mortality data from best-performing provinces (Alberta, Saskatchewan, Manitoba, New Brunswick and Prince Edward Island), and a region-specific mortality rate
I_2 = percentage case completeness indicator derived using 2003 to 2007 cancer incidence data from best-performing provinces and Canadian mortality data, and an adjusted region-specific mortality rate
* significantly different from 0 ($p<0.05$)
† point biserial correlation coefficient not calculable because of lack of variability in dichotomous indicators for %MC or %DCO across provinces
... not applicable
Notes: Point biserial correlation coefficients were calculated for %MC and %DCO. Pearson's product-moment correlation coefficient was used for I:M. For point biserial correlation coefficients, %MC was dichotomized: values from 90% through 98% were assigned 0, and all others, 1. For %DCO, a value of 1 was assigned if no cancers were registered by DCO or the %DCO was greater than 5%. Correlations excluded estimates from Nunavut, Northwest Territories, Yukon Terrritory, and Prince Edward Island.
Sources: Canadian Cancer Registry; Canadian Vital Statistics Death Database; Census of Population.

Table 4
Percentage case completeness for I_1 and I_2, by difficulty of ascertainment, sex and province, selected cancer sites, 2007

	Males		Females	
Difficulty of ascertainment	I_1	I_2	I_1	I_2
Least difficulty				
Colon, rectum				
Canada	97	106	100	106
British Columbia	102	107	102	105
Alberta	106	112	102	106
Saskatchewan	102	110	102	107
Manitoba	102	112	104	110
Ontario	96	105	103	109
Quebec	90	101	94	102
New Brunswick	111	121	97	102
Nova Scotia	99	113	103	113
Newfoundland	**89**	105	90	103
Bronchus, lung				
Canada	96	106	96	98
British Columbia	102	107	97	99
Alberta	101	107	100	100
Saskatchewan	102	109	108	110
Manitoba	104	113	94	97
Ontario	94	101	96	97
Quebec	94	109	94	98
New Brunswick	107	123	**84**	**89**
Nova Scotia	97	111	106	111
Newfoundland	**73**	**83**	**76**	**77**
Average difficulty				
Oral cavity, pharynx				
Canada	99	109	105	114
British Columbia	111	120	95	105
Alberta	**81**	**87**	113	123
Saskatchewan	**80**	**83**	90	94
Manitoba	**86**	96	**83**	92
Ontario	103	113	113	125
Quebec	94	105	93	101
New Brunswick	110	118	290	279
Nova Scotia	155	169	92	97
Newfoundland	**85**	93	X	X
Pancreas				
Canada	96	95	96	94
British Columbia	**89**	**88**	91	**89**
Alberta	109	107	**88**	**87**
Saskatchewan	117	114	114	110
Manitoba	83	83	82	79
Ontario	99	97	101	97
Quebec	94	94	94	93
New Brunswick	101	104	94	94
Nova Scotia	91	94	**87**	**87**
Newfoundland	**51**	**50**	103	93
Breast				
Canada	...	...	102	105
British Columbia	...	...	110	111
Alberta	...	...	108	109
Saskatchewan	...	...	104	107
Manitoba	...	...	97	102
Ontario	...	...	103	107
Quebec	...	...	99	103
New Brunswick	...	...	116	116
Nova Scotia	...	...	97	101
Newfoundland	...	...	**77**	**80**

	Males		Females	
Difficulty of ascertainment	I_1	I_2	I_1	I_2
Average difficulty				
Bladder				
Canada	**87**	92	**75**	94
British Columbia	**85**	90	**83**	101
Alberta	105	107	**81**	97
Saskatchewan	**89**	93	128	154
Manitoba	92	98	102	118
Ontario	**66**	**70**	**47**	**60**
Quebec	117	124	95	120
New Brunswick	106	111	179	205
Nova Scotia	**86**	92	125	152
Newfoundland	**58**	**62**	**75**	92
Most difficult				
Melanoma of skin				
Canada	92	102	100	102
British Columbia	127	141	110	114
Alberta	109	119	**87**	**89**
Saskatchewan	**80**	**87**	**80**	**81**
Manitoba	**80**	**85**	**78**	**77**
Ontario	90	102	105	109
Quebec	**67**	**69**	**66**	**62**
New Brunswick	152	161	173	176
Nova Scotia	94	108	192	203
Newfoundland	**64**	**73**	X	X
Prostate				
Canada	118	98	...	...
British Columbia	130	106	...	...
Alberta	103	**88**	...	...
Saskatchewan	101	**89**	...	...
Manitoba	90	**78**	...	...
Ontario	131	109	...	...
Quebec	104	**84**	...	...
New Brunswick	151	128	...	...
Nova Scotia	129	108	...	...
Newfoundland	103	**88**	...	...
Leukemia				
Canada	101	100	104	100
British Columbia	113	110	105	98
Alberta	116	114	128	123
Saskatchewan	104	106	113	111
Manitoba	**79**	**81**	**78**	**76**
Ontario	104	104	117	112
Quebec	90	90	**87**	**83**
New Brunswick	116	111	90	**86**
Nova Scotia	**82**	**84**	**79**	**77**
Newfoundland	**69**	**65**	**81**	**68**

I_1 = percentage case completeness indicator derived using 2003 to 2007 cancer incidence and mortality data from best-performing provinces (Alberta, Saskatchewan, Manitoba, New Brunswick and Prince Edward Island) and a region-specific mortality rate

I_2 = percentage case completeness indicator derived using 2003 to 2007 cancer incidence data from best-performing provinces and Canadian mortality data, and an adjusted region-specific mortality rate

X suppressed to meet confidentiality requirements of *Statistics Act*

… not applicable

Notes: Cancer sites are presented by difficulty of case ascertainment. I_1 and I_2 are boldface when less than 90% (potential incomplete case ascertainment).

Sources: Canadian Cancer Registry; Canadian Vital Statistics Death Database; Census of Population.

gated. Despite potential undercoverage of specific cancers in several provinces, the overall completeness-of-case-ascertainment indicator identified undercoverage only for Newfoundland males.

What is already known on this subject?

- Incomplete ascertainment of cancer cases by cancer registries can lead to biased estimates, particularly if the missed cases differ substantially from those captured.
- The North American Association of Central Cancer Registries' (NAACCR) completeness measure expresses the observed number of cancers as a percentage of the expected number, which is calculated using data from registries known to have superb case ascertainment.
- Despite its use, little has been published about the methodology, relative usefulness and accuracy of this measure in Canada.

What does this study add?

- NAACCR's cancer site-specific completeness of case ascertainment indicator was associated with the basic incidence-to-mortality rate ratio for a region, but not with the percentage of cancers microscopically confirmed or the percentage registered by death certificate only.
- Undercoverage, as identified by the indicator, did not increase consistently with expected case-finding difficulty, but the indicator did identify known undercoverage issues in the Canadian Cancer Registry.
- The importance of examining cancer-specific indicators rather than an overall indicator of case completeness was reinforced, as aggregation of cancer sites with high and low completeness estimates can obscure undercoverage in specific cancers.

The primary limitations of this study are the assumptions underlying the completeness-of-case-ascertainment indicators and the lack of confidence intervals, particularly for estimates based on small counts. As Fulton and Howe[10] observed, even among SEER registries with superb case completeness, percentage case completeness varied, suggesting the existence of differences in age-standardized incidence-to-mortality rate ratios across states. Consistent with the findings of the present report, they concluded that percentage case completeness may be used to "cautiously" identify cancer sites for which undercoverage may be an issue and which require further exploration to rule out real differences in case fatality, incidence, and random variation before concluding that under-reporting is the cause.[10]

Because of the importance of case completeness, registries could pursue alternative evaluation methods, such as the capture-recapture method, flow method, Parkin's death certificate notification method, and basic case-finding audits.[4] If registries captured and submitted information on all the distinct sources of notification for a case, the extent of case completeness could be explored by the CCR through capture-recapture methods.[3,29-32] Similarly, submitting information on whether a case was death-certificate-notified and the date it was first registered would allow

Table 5
Overall case completeness estimates, by method, sex and province, 2007

	Males					Females				
	%MC	%DCO	I:M	I_1	I_2	%MC	%DCO	I:M	I_1	I_2
All*										
Canada	90	0.9	2.4	103	102	90	1.2	2.5	100	103
British Columbia	90	2.2	2.5	110	106	91	3.0	2.6	102	104
Alberta	92	0.2	2.5	105	101	93	0.4	2.7	103	105
Saskatchewan	91	1.2	2.5	100	97	90	1.5	2.6	105	107
Manitoba	89	0.3	2.2	94	93	90	0.9	2.5	97	101
Ontario	95	1.2	2.5	105	103	94	1.8	2.7	101	104
Quebec	79	0.0	2.1	97	98	82	0.0	2.3	94	98
New Brunswick	93	X	2.6	121	121	91	X	2.5	106	109
Nova Scotia	89	0.8	2.4	104	106	91	0.8	2.5	103	108
Newfoundland	96	1.1	2.1	**85**	**88**	95	1.0	2.2	**89**	93
As per North American Association of Central Cancer Registries (NAACCR)†										
Canada	88	1.0	1.9	97	103	87	1.6	2.1	98	102
British Columbia	87	2.8	1.9	102	105	87	3.9	2.1	99	101
Alberta	91	0.3	2.0	105	109	91	0.4	2.2	102	103
Saskatchewan	90	1.2	1.9	99	103	87	2.0	2.2	106	107
Manitoba	87	0.3	1.8	95	101	86	1.1	2.1	98	100
Ontario	94	1.5	1.9	95	100	93	2.3	2.2	100	103
Quebec	78	0.0	1.7	95	103	78	0.0	1.9	92	97
New Brunswick	90	X	2.0	110	117	88	X	2.0	103	106
Nova Scotia	85	1.0	1.9	96	105	88	0.8	2.2	105	110
Newfoundland	94	1.1	1.6	**79**	**88**	94	1.2	1.8	95	99

%MC = percentage microscopically confirmed
%DCO = percentage registered by death certificate only
I:M = age-standardized cancer incidence to mortality rate ratio
I_1 = percentage case completeness indicator derived using 2003 to 2007 cancer incidence and mortality data from best-performing provinces (Alberta, Saskatchewan, Manitoba, New Brunswick and Prince Edward Island), and a region-specific mortality rate
I_2 = percentage case completeness indicator derived using 2003 to 2007 cancer incidence data from best-performing provinces and Canadian mortality data, and an adjusted region-specific mortality rate
* excludes male breast cancer
† excludes male breast and prostate cancer and female breast cancer
X suppressed to meet confidentiality requirements of *Statistics Act*
Note: I_1 and I_2 are boldface when less than 90% (potential incomplete case ascertainment).
Sources: Canadian Cancer Registry, Canadian Vital Statistics Death Database, and Census of Population.

the CCR to estimate case completeness using the flow method[7] and Parkin's death certificate notification method.[4]

Conclusion

The assumption of stable age-standardized sex- and cancer-site-specific incidence-to-mortality rate ratios across regions, which underlies NAACCR's completeness of case ascertainment indicator, was not consistently supported by CCR data—substantial regional differences emerged. Although the frequency of undercoverage did not increase consistently with expected case finding difficulty, some known undercoverage issues in the CCR were identified. The importance of examining cancer-specific indicators was reinforced, as aggregation of cancer sites with high and low completeness estimates can obscure undercoverage in specific cancers. NAACCR's indicator was associated with the basic incidence-to-mortality rate ratio for a region, but not with the %MC or the %DCO. Thus, the I:M and corresponding 95% confidence interval may offer a less complicated method of identifying undercoverage. ■

Acknowledgement

Statistics Canada maintains the Canadian Cancer Registry and Vital Statistics Death Database, which are comprised of data supplied by the provinces and territories, whose cooperation is gratefully acknowledged.

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Appendix

Table A
Canadian standard population, 1991

Age group (years)	Weight (proportion of population in age group*)
Total	**1.00000**
0 to 4	0.06946
5 to 9	0.06945
10 to 14	0.06803
15 to 19	0.06849
20 to 24	0.07502
25 to 29	0.08994
30 to 34	0.09240
35 to 39	0.08339
40 to 44	0.07606
45 to 49	0.05954
50 to 54	0.04765
55 to 59	0.04404
60 to 64	0.04233
65 to 69	0.03857
70 to 74	0.02966
75 to 79	0.02213
80 to 84	0.01360
85 or older	0.01024

* distribution based on final postcensal estimates of July 1, 1991 population, adjusted for census undercoverage
Source: Census and Demography Branch, Statistics Canada.

Table B
Cancer site definitions using ICD-10 and ICD-0-3

		Malignant primary tumours (ICD-0-3)		
	Mortality (ICD-10)	Topography	Histology	Behaviour
Oral cavity, pharynx	C00 to C14	C00 to C14	Excludes: 9050 to 9055, 9140, 9590 to 9989	3
Esophagus	C15	C15	Excludes: 9050 to 9055, 9140, 9590 to 9989	3
Stomach	C16	C16	Excludes: 9050 to 9055, 9140, 9590 to 9989	3
Colon, rectum	C18 to C20 C26.0	C18 to C20 C26.0	Excludes: 9050 to 9055, 9140, 9590 to 9989	3
Liver	C22.0, C22.2 to C22.9	C22.0	Excludes: 9050 to 9055, 9140, 9590 to 9989	3
Pancreas	C25	C25	Excludes: 9050 to 9055, 9140, 9590 to 9989	3
Bronchus, lung	C34	C34	Excludes: 9050 to 9055, 9140, 9590 to 9989	3
Melanoma of skin	C43	C44	8720 to 8790	3
Breast†	C50	C50	Excludes: 9050 to 9055, 9140, 9590 to 9989	3
Cervix uteri	C53	C53	Excludes: 9050 to 9055, 9140, 9590 to 9989	3
Corpus uterus, uterus not otherwise specified	C54 to C55	C54 to C55	Excludes: 9050 to 9055, 9140, 9590 to 9989	3
Ovary	C56	C56	Excludes: 9050 to 9055, 9140, 9590 to 9989	3
Prostate†	C61	C61	Excludes: 9050 to 9055, 9140, 9590 to 9989	3
Kidney, renal pelvis	C64 to C65	C64 to C65	Excludes: 9050 to 9055, 9140, 9590 to 9989	3
Bladder (includes in-situ tumours)	C67, D09.0	C67	Excludes: 9050 to 9055, 9140, 9590 to 9989	2, 3
Brain, other parts of central nervous system	C70 to C72	C70 to C72	Excludes: 9050 to 9055, 9140, 9590 to 9989	3
Hodgkin lymphoma	C81	All sites	9650 to 9667	3
Non-Hodgkin lymphoma	C82 to C85, C96.3	All sites	9590 to 9596, 9670 to 9729	3
		Excludes: C42.0 C42.1, C42.4	9823, 9827	
Leukemia	C91 to C95, C90.1	All sites	9733, 9742, 9800 to 9820, 9826, 9831 to 9948, 9963, 9964	3
		C42.0,C42.1, C42.4	9823, 9827	3
Multiple myeloma	C90.0, C90.2	All sites	9731, 9732, 9734	3

† excluded from North American Association of Central Cancer Registries' overall estimate of case completeness
ICD-10 = International Statistical Classification of Diseases and Related Health Problems, 10th revision
ICD-0-3 = International Classification of Diseases for Oncology, 3rd edition
Note: Fourth character of ICD-10 and ICD-0-3 topography provided only when needed for classification.