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Calibrating Time-Dependent One-Year Relative Survival Ratio for Selected Cancers

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Abstract—We provided proof of the relationship between cumulative relative survival ratio (RSR) and RSR at each time unit. Based on published five-year RSRs for all cancers and selected cancers in Canada, we demonstrated five methods to calibrate one-year RSR, conditional on having survived years.

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1. INTRODUCTION

A relative survival ratio (RSR) for cancer is the ratio of the observed survival in cancer patients to the expected survival of a group of similar non-cancer individuals (in practice, the general population) [1]. RSR is the preferred measure for cancer survival, and the five-year ratio is often chosen as the primary measurement of analysis [1]. However, the time-dependent one-year RSR for patients at risk can be used to predict the risk of mortality in the following year for cancer survival, and also is the desired parameter input in some situations, such as when using a yearly cycle in the Markov decision-analytic model. Based on the published five-year RSR conditional on having survived years 0 to 5, and one-year RSR at year 0 for 6 selected types of cancers (colorectal cancer, female breast cancer, leukemia, lung and bronchus cancer, non-Hodgkin lymphoma, and prostate cancer) and all cancers (any type of cancer) (Table 1), in this article we demonstrated methods to approximate the conditional one-year RSR from year 1 to year 9 (Note: the one-year RSRs at year 0 were available for all cancers and the 6 selected cancers [2], but not other types of cancers in Canada).

Next, in this article we introduced proof of the relationship between the cumulative RSR and RSR at each time unit in Section 2. Under the assumption that one-year RSR conditional on having survived 6 years or more is the same as that conditional on having survived 5 years, we estimated the one-year RSRs in Section 3. In Section 4, we used calibration methods to correct rounding errors in publications, under the same assumption as in Section 3. In Section 5, we added an adjustment factor in estimating one-year RSR. In Section 6, we released the assumptions above, and calibrated one-year RSRs using rules in accordance with the biological system (e.g. RSR at time $i+1$ should be greater than that at time i). We discussed our methods and its application in the health economic model in Section 7.

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Table 1. Published conditional relative survival ratios of 6 selected cancers and all cancers

	One-year relative survival ratio at year 0	Five-year relative survival ratio (95% confidence interval), conditional on having survived years					
		0	1	2	3	4	5
All cancers	0.769	0.63 (0.63, 0.63)	0.81 (0.81, 0.81)	0.87 (0.87, 0.87)	0.90 (0.90, 0.90)	0.92 (0.92, 0.92)	0.93 (0.93, 0.93)
Colorectal cancer	0.823	0.64 (0.64, 0.65)	0.77 (0.76, 0.77)	0.83 (0.82, 0.83)	0.88 (0.87, 0.88)	0.91 (0.9, 0.92)	0.94 (0.93, 0.95)
Female breast cancer	0.969	0.88 (0.87, 0.88)	0.89 (0.89, 0.90)	0.90 (0.90, 0.91)	0.92 (0.91, 0.92)	0.93 (0.92, 0.93)	0.94 (0.93, 0.94)
Leukemia	0.721	0.59 (0.58, 0.60)	0.80 (0.78, 0.81)	0.83 (0.82, 0.85)	0.84 (0.83, 0.86)	0.85 (0.84, 0.87)	0.85 (0.83, 0.86)
Lung and bronchus cancer	0.404	0.17 (0.17, 0.17)	0.39 (0.38, 0.40)	0.55 (0.54, 0.57)	0.65 (0.64, 0.66)	0.70 (0.69, 0.72)	0.75 (0.73, 0.76)
Non-Hodgkin lymphoma	0.79	0.66 (0.65, 0.67)	0.82 (0.81, 0.83)	0.85 (0.84, 0.86)	0.87 (0.85, 0.88)	0.88 (0.87, 0.89)	0.89 (0.88, 0.90)
Prostate cancer	0.982	0.96 (0.95, 0.96)	0.97 (0.97, 0.97)	0.98 (0.97, 0.98)	0.98 (0.97, 0.98)	0.98 (0.97, 0.98)	0.98 (0.97, 0.98)

Data sources: The same group of researchers applied the same methods for the same population for one-year and five-year RSRs and published the results separately in two sources [1, 2]: Table 2 in Ellison et al. (2014) [2] for one-year RSR at time 0; and Table 5.4 in Canadian Cancer Statistics 2015 [1], for five-year RSRs conditional on having survived the specified number of years (for patients aged 15–99 years at diagnosis for selected cancers from 2006 to 2008 in Canada, excluding Quebec).

2. RELATIONSHIP BETWEEN CUMULATIVE RSR AND RSR AT EACH TIME UNIT

Let CP_t^O and CP_t^E be the probability of surviving exceeding time t for patients with cancer (cumulative observed survival probability) and for the general population (cumulative expected survival probability), respectively [3]. Then, the cumulative RSR to time t for patients with cancer CR_t) is:

$$CR_t = CP_t^O / CP_t^E. \tag{2.1}$$

The probability of observed survival to time t for patients with cancer is: $CP_t^O = \prod_{j=1}^{t} P_j^O$, where P_j^O is the observed survival probability at interval j.

The expected survival of a comparable group from the general population (e.g., matched for age, sex, and calendar time period) can be estimated using the Ederer I method, Ederer II method, and the Hakulinen method [3, 4]. Statistics Canada used the Ederer II method with minor adaptations to estimate the expected survival [1, 2]. Based on the Ederer II method, the probability of expected survival to time t for the comparable general population is: $CP_t^E = \prod_{j=1}^{t} P_j^E$, where P_j^E is the expected survival probability at interval j. Thus, Formula (2.1) can be expressed as

$$CR_t = \frac{P_1^O \times P_2^O \times P_3^O \ldots P_t^O}{P_1^E \times P_2^E \times P_3^E \ldots P_t^E}. \tag{2.2}$$

Formula (2.2) can be re-written as

$$CR_t = \left(\frac{P_1^O}{P_1^E}\right) \times \left(\frac{P_2^O}{P_2^E}\right) \times \left(\frac{P_3^O}{P_3^E}\right) \ldots \left(\frac{P_t^O}{P_t^E}\right) = \prod_{j=1}^{t} R_j, \tag{2.3}$$

where R_j is the RSR of each time unit, conditional on survival at the start point of the time unit [3]. Thus, the cumulative RSR to time t is the product of a series of RSRs at each time unit, up to time t.

3. CRUDE METHOD TO ESTIMATE TIME-DEPENDENT ONE-YEAR RSR

Table 1 shows that the conditional five-year RSR increased over time, but the rate of increase decreased over the same period [1, 2]. For female breast cancer, leukemia, non-Hodgkin lymphoma, prostate cancer, and all cancers, the five-year RSR conditional on 5 years survival was very close to that conditional on 4 years survival. Thus, for simplicity, we assumed that one-year RSR conditional on surviving 6 years or more is the same as that conditional on surviving 5 years. Based on Formula (2.3):

$$R5Y_{t0} = R1Y_{t0} \times R1Y_{t1} \times R1Y_{t2} \times R1Y_{t3} \times R1Y_{t4}, \tag{3.1}$$

Table 2. Uncorrected one-year relative survival ratio of selected cancers (Section 3)

	One-year relative survival ratio, conditional on having survived years					
	0	1	2	3	4	5 or more
All cancers	0.769	0.92053	0.95576	0.96722	0.97808	0.98871
Colorectal cancer	0.823	0.91859	0.93391	0.95753	0.95857	0.99017
Female breast cancer	0.969	0.96912	0.95871	0.96947	0.96959	0.98001
Leukemia	0.721	0.94229	0.96599	0.96613	0.97763	0.97763
Lung and bronchus cancer	0.404	0.65720	0.78424	0.86062	0.86504	0.92682
Non-Hodgkin lymphoma cancer	0.790	0.94687	0.95895	0.97036	0.97049	0.98152
Prostate cancer	0.982	0.98210	0.99223	0.99223	0.99223	0.99223

$$R5Y_{t1} = R1Y_{t1} \times R1Y_{t2} \times R1Y_{t3} \times R1Y_{t4} \times R1Y_{t5}, \tag{3.2}$$

where $R1Y_{t0}, R1Y_{t1}, R1Y_{t2}, R1Y_{t3}, R1Y_{t4}, R1Y_{t5}$ are the one-year RSR for those who survive at time 0, 1, 2, 3, 4, 5 (years), and $R5Y_{t0}, R5Y_{t1}, R5Y_{t2}, R5Y_{t3}, R5Y_{t4}, R5Y_{t5}$ are the five-year RSR for those who survive at time 0, 1, 2, 3, 4, 5.

Let Formula (3.1) be divided by Formula (3.2). Then

$$\frac{R5Y_{t0}}{R5Y_{t1}} = \frac{R1Y_{t0}}{R1Y_{t5}} \tag{3.3}$$

and

$$R1Y_{t5} = \frac{R5Y_{t1} \times R1Y_{t0}}{R5Y_{t0}}, \tag{3.4}$$

where $R1Y_{t5}$ is the one-year RSR conditional on having survived 5 years. Using the same method, we can calculate one-year RSR conditional on having survived 1 to 4 years:

$$R1Y_{t1} = \frac{R5Y_{t0} \times {R1Y_{t5}}^2}{R1Y_{t0} \times R5Y_{t2}}, \quad R1Y_{t2} = \frac{R5Y_{t0} \times {R1Y_{t5}}^3}{R1Y_{t0} \times R1Y_{t1} \times R5Y_{t3}},$$

$$R1Y_{t3} = \frac{R5Y_{t0} \times {R1Y_{t5}}^4}{R1Y_{t0} \times R1Y_{t1} \times R1Y_{t2} \times R5Y_{t4}},$$

$$R1Y_{t4} = \frac{R5Y_{t0} \times {R1Y_{t5}}^5}{R1Y_{t0} \times R1Y_{t1} \times R1Y_{t2} \times R1Y_{t3} \times R5Y_{t5}}, \tag{3.5}$$

where the notation is the same as in Formulae (3.1) and (3.2).

Based on Formulae (3.4) to (3.5) and published data in Table 1, we calculated the one-year RSR conditional on having survived year 1 to 5 (Table 2). Using the estimated one-year RSRs, we projected the five-year RSRs using Formula (2.3). Almost no projected five-year RSRs fell in the 95% confidence interval (CI) for the 6 types of cancers and all cancers (except the projected five-year RSRs for colorectal cancer, conditional on year 0). We also assessed the absolute deviation (absolute difference between projected RSR and observed RSR) and the percentage of error (absolute difference between projected RSR and observed RSR divided by the observed RSR), but the table is too large to present in the article. The percentages of bias for leukemia and lung and bronchus cancer were larger than 3%. For colorectal cancer, although the percentage of bias was small (1.26%), it seems unreasonable that the difference (0.0316) of one-year RSR at year 5 and year 4 (0.99017 versus 0.95857) was much greater than that (0.00104) between year 4 and year 3 (0.95857 versus 0.95753), because the difference between 2 consecutive RSRs should be reduced over time. This method yielded acceptable results for all cancers and prostate cancer with a percentage of bias less than 2% and no obviously questionable RSRs.

4. CORRECTING FOR ROUNDING ERRORS IN PUBLISHED DATA

The underlying assumption of the analysis in Section 3 was that the published point estimates of five-year RSRs were the true values of RSRs. However, the true values would likely be within an uncertainty interval, and not a fixed point estimate. For instance, the published five-year RSRs [1] and one-year RSRs conditional on surviving at time zero [2] were rounded to two decimals and three decimals, respectively. Given the narrow 95% CI of RSR (i.e., same value for the rounded upper limit and lower limit of the 95% CI of the five-year RSRs for all cancers [1, 2]), rounding errors became more significant. Incorporating the rounding error and 95% CI, we assumed that the value of the true RSR would be between the lower and upper limit of the true RSR:

$$\text{Lower limit of the true } RSR = LR - \varepsilon, \tag{4.1}$$

$$\text{Upper limit of the true } RSR = UR + \varepsilon, \tag{4.2}$$

where LR is the lower limit of published 95% CI of RSR without correction for rounding error, UR is the upper limit of published 95% CI of RSR without correction for rounding error and ε is the maximum error by rounding. The ε is 0.005 for rounding to 2 decimals in published five-year RSRs, and 0.0005 for rounding to 3 decimals for published one-year RSRs at time 0.

We calibrated one-year RSRs using the following methods introduced by Vanni et al. [5]. The calibration process is summarized in Figure 1. We generated 10 million sets of uniformly distributed five-year RSRs conditional on surviving year 0 to year 5, and one-year RSR conditional on surviving year 0, whose values ranged from the lower limit and upper limit defined above (Formulae (4.1) and (4.2)). We then used the formulae introduced in Section 3 (Formulae (3.4) to (3.5)) to calculate the one-year RSRs and projected five-year RSRs.

We aimed to obtain calibrated one-year RSRs conditional on surviving year 1 to year 5 that are consistent with the biological system [6], and outputs (projected five-year RSRs) that are consistent with the observed data. We developed the following acceptance criteria to select calibrated one-year RSRs:

- One-year RSR is less than 1 ($R_i < 1$) (note that the case $R_i > 1$ is discussed in Section 7);
- One-year RSR in a given year is greater than in the previous year ($R_{i+1} > R_i$);

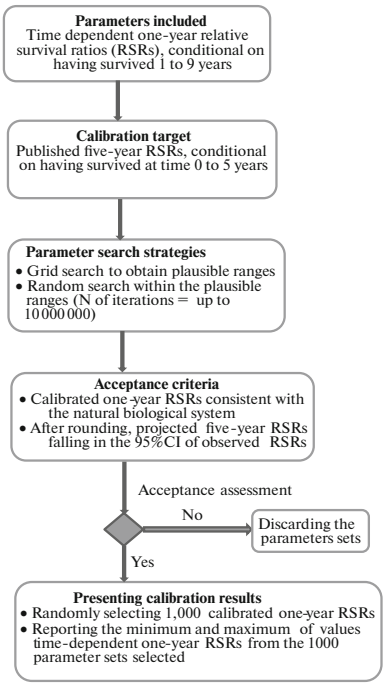

Fig. 1. Flow chart of calibration for time-dependent one-year relative survival ratio.

- The difference between two consecutive one-year RSRs decreases over time ($R_i - R_{i-1} > R_{i+1} - R_i$);
- The rounded projected five-year RSRs (2 decimals) fall into the 95% CI of the published five-year RSRs from year 0 to year 5.

We randomly selected up to 1000 calibrated one-year RSR sets for each type of cancer from all parameter sets that met the acceptance criteria. The simulation yielded eligible results for all cancers, leukemia, lung and bronchus, and non-Hodgkin lymphoma cancer (we cannot present the table with the results in the article due to the article volume constraints); however, there were few eligible results for female breast cancer, colorectal cancer, and prostate cancer.

5. APPLYING AN ADJUSTMENT FACTOR

In Sections 3 and 4, estimations of one-year RSRs were based on the assumption of a constant one-year RSR after having 5 years survival. However, under this assumption we did not obtain eligible calibrated one-year RSRs for some types of cancers (female breast, colorectal, and prostate cancer). We released this assumption in the following sections. There are various ways to define one-year RSRs conditional on survival at 6 years or later. We used two approaches.

5.1. Approach 1

We assumed that after 5 years of cancer survival, the one-year RSR would be equal to λ (a constant coefficient) multiplied by the one-year RSR in the preceding year, with an upper limit RSR of 1.

$$R1Y_{ti+1} = \min\{1, R1Y_{ti} \times \lambda\},$$

$R1Y_{ti}$ is the one-year RSR for those who survive at time $i (i > 5$ years) and λ is a constant coefficient (adjustment factor) greater than 1, whose value varies depending on the type of cancer.

Let $R1Y_{t5}$ be one-year RSR conditional on having 5 years survival (calculated using Formula (3.4)). Then, the one-year RSR in year 6 to year 9 can be expressed below as: $R1Y_{t6} = \min\{1, R1Y_{t5} \times \lambda\}$; $R1Y_{t7} = \min\{1, R1Y_{t5} \times \lambda^2\}$; $R1Y_{t8} = \min\{1, R1Y_{t5} \times \lambda^3\}$; $R1Y_{t9} = \min\{1, R1Y_{t5} \times \lambda^4\}$. Using the same methods introduced in Sections 3 and 4, we can calculate one-year RSR conditional on having survived 1 to 4 years with the adjustment factor:

$$R1Y_{t1} = \frac{R5Y_{t0} \times R1Y_{t5} \times R1Y_{t6}}{R1Y_{t0} \times R5Y_{t2}}, \quad R1Y_{t2} = \frac{R5Y_{t0} \times R1Y_{t5} \times R1Y_{t6} \times R1Y_{t7}}{R1Y_{t0} \times R1Y_{t1} \times R5Y_{t3}},$$

$$R1Y_{t3} = \frac{R5Y_{t0} \times R1Y_{t5} \times R1Y_{t6} \times R1Y_{t7} \times R1Y_{t8}}{R1Y_{t0} \times R1Y_{t1} \times R1Y_{t2} \times R5Y_{t4}},$$

$$R1Y_{t4} = \frac{R5Y_{t0} \times R1Y_{t5} \times R1Y_{t6} \times R1Y_{t7} \times R1Y_{t8} \times R1Y_{t9}}{R1Y_{t0} \times R1Y_{t1} \times R1Y_{t2} \times R1Y_{t3} \times R5Y_{t5}},$$

where $R1Y_{t0}, R1Y_{t1} \ldots$ is the one-year RSR for those who survive at time 0, 1 year ... and $R5Y_{t0}, R5Y_{t1} \ldots$ is the five-year RSR for those who survive at time 0, 1 year ...

Although the exact value of λ was unknown, it would be greater than 1 since RSR increases over time. Initially we set a wider range (e.g., λ follows a uniform distribution from 1 to 1.1) in the parameter search, but gradually narrowed it to the possible parameter space. We generated 10 million parameter sets from the plausible ranges for λ, the unrounded five-year RSRs and one-year RSR at time zero. Using the same acceptance criteria introduced in Section 4, we randomly selected up to 1000 calibrated one-year RSR sets for each type of cancer. Except for female breast cancer and prostate cancer, we obtained calibrated one-year RSR for the other five types of cancer. The uncertainty interval (minimum to maximum) of calibrated one-year RSRs can be very large, such as the one-year RSRs from year 1 to year 9 for lung and bronchus cancer (again, the corresponding table is too large to be presented in this article).

5.2. Approach 2

We also used the following method with an adjustment factor to estimate one-year RSR. Adapting the formula for risk to time t in survival analysis, we developed the following formula to estimate one-year RSRs:

$$R1Y_{ti} = 1 - e^{-\text{rate}\times(1+(i-5)/\lambda)}, \tag{5.1}$$

where i is the year, from 1 to 9; rate is calculated from the one-year RSRs in year 5 by Formula (3.4): rate $= -(\log(1 - R1Y_{t5}))$; and λ is the adjustment factor, whose value varies depending on the type of cancer. Using Formula (5.1), we obtained eligible parameter sets of one-year RSRs from year 1 to year 9 for five types of cancers (leukemia, non-Hodgkin lymphoma, female breast cancer, colorectal cancer, and prostate cancer). We obtained eligible parameter sets for the other two types of cancers (all cancers, and lung and bronchus cancer) by using Formula (5.1) to estimate one-year RSR from year 6 to year 9, and using Formulae (3.4) to (3.5) for the estimation of RSR from one-year RSR from year 1 to year 5. The results are summarized in Table 3. Compared with one-year RSRs estimated in Section 5.1, the uncertainty (i.e., range) of calibrated one-year RSRs was reduced substantially, and narrowed over time.

6. CALIBRATING ONE-YEAR RSR IN ACCORDANCE WITH THE BIOLOGICAL SYSTEM

In this section we released the assumptions for applying adjustment factors. Then, we generated one-year RSRs conditional on having survived 1 to 9 years in accordance with the biological system, under two remaining assumptions: one-year RSRs increase over time (up to 1), and the difference between two consecutive one-year RSRs decreases over time. We used Formula (2.3) again to project the five-year RSR conditional on having survived 0 to 5 years. We used the same acceptance criteria as that in Section 4, and randomly selected up to 1000 calibrated one-year RSRs sets for each cancer (Table 4). Under the fewest assumptions, we obtained the calibrated results for all types of cancers. The range of calibrated one-year RSRs reduced over time. The one-year RSRs at year 1 and 2 for leukemia, lung and bronchus cancer, and non-Hodgkin lymphoma cancer were rather large.

Table 3. Calibrated one-year relative survival ratios of selected cancers, applying an adjustment factor (Section 5.2)

	Minimum, maximum of calibrated one-year relative survival ratio, conditional on having survived years									
	0	1	2	3	4	5	6	7	8	9
All cancers	0.769	0.90782, 0.92644	0.94304, 0.95512	0.96173, 0.97046	0.97410, 0.98254	0.98211, 0.98661	0.98342, 0.98662	0.98453, 0.98670	0.98454, 0.98805	0.98454, 0.98926
Colorectal cancer	0.823	0.89932, 0.91837	0.93120, 0.93904	0.95105, 0.95569	0.96456, 0.96932	0.97401, 0.97909	0.98087, 0.98576	0.9858, 0.99030	0.98939, 0.99339	0.99208, 0.99550
Female breast cancer	0.969	0.97158, 0.97479	0.97442, 0.97682	0.97693, 0.97943	0.97920, 0.98222	0.98124, 0.98462	0.98308, 0.98670	0.98464, 0.98850	0.98586, 0.99006	0.98698, 0.99140
Leukemia	0.721	0.94473, 0.95359	0.95056, 0.95608	0.95578, 0.95924	0.96010, 0.96270	0.96251, 0.96587	0.96470, 0.96885	0.96659, 0.97175	0.96839, 0.97473	0.97008, 0.97740
Lung and bronchus cancer	0.404	0.64405, 0.71178	0.77319, 0.82597	0.84589, 0.88267	0.89562, 0.93214	0.93245, 0.94679	0.93582, 0.94680	0.93772, 0.94681	0.93774, 0.94833	0.93776, 0.95257
Non-Hodgkin lymphoma cancer	0.79	0.94110, 0.95604	0.95088, 0.95989	0.95900, 0.96472	0.96501, 0.96953	0.96857, 0.97382	0.97168, 0.97751	0.97418, 0.98085	0.97641, 0.98412	0.97844, 0.98683
Prostate cancer	0.982	0.99068, 0.99489	0.99213, 0.99492	0.99291, 0.99496	0.99296, 0.99540	0.99300, 0.99593	0.99305, 0.99649	0.99309, 0.99703	0.99312, 0.99749	0.99316, 0.99787

Statistics were based on the 1,000 parameter sets that were randomly selected from all sets meeting the acceptance criteria.

Table 4. Calibrated one-year relative survival ratio of selected cancers, using rules in accordance with the biological system (Section 6)

	Minimum, maximum of calibrated one year relative survival ratio, conditional on having survived years									
	0	1	2	3	4	5	6	7	8	9
All cancers	0.769	0.90800, 0.92825	0.94264, 0.95566	0.96198, 0.9686	0.97375, 0.98207	0.98466, 0.9866	0.98468, 0.98702	0.98468, 0.98705	0.98468, 0.98711	0.98468, 0.98711
Colorectal cancer	0.823	0.89046, 0.92407	0.9277, 0.94446	0.94809, 0.96286	0.96189, 0.97223	0.97244, 0.97786	0.97965, 0.98976	0.98490, 0.99590	0.98654, 1	0.98654, 1
Female breast cancer	0.969	0.97109, 0.97286	0.97357, 0.97647	0.97602, 0.97956	0.97843, 0.98248	0.98070, 0.98507	0.98284, 0.98727	0.98476, 0.98907	0.98542, 0.99118	0.98572, 0.99318
Leukemia	0.721	0.88038, 0.94601	0.93856, 0.96885	0.95725, 0.97020	0.96404, 0.97022	0.96856, 0.97027	0.96857, 0.97161	0.96858, 0.97204	0.96858, 0.97248	0.96858, 0.97285
Lung and bronchus cancer	0.404	0.63500, 0.68497	0.77785, 0.82108	0.86766, 0.89965	0.89424, 0.91235	0.91438, 0.92784	0.92856, 0.94245	0.93979, 0.95311	0.94394, 0.96381	0.94495, 0.97505
Non-Hodgkin lymphoma cancer	0.79	0.90959, 0.94906	0.94604, 0.96400	0.95924, 0.97546	0.96890, 0.97790	0.97531, 0.97904	0.97536, 0.98047	0.97541, 0.98095	0.97542, 0.98174	0.97542, 0.98239
Prostate cancer	0.982	0.98677, 0.99482	0.99065, 0.99606	0.99299, 0.99675	0.99299, 0.99693	0.99300, 0.99694	0.99300, 0.99706	0.99300, 0.99707	0.99300, 0.99728	0.99300, 0.99757

Statistics were based on the 1,000 parameter sets that were randomly selected from all sets meeting the acceptance criteria.

7. DISCUSSION

We selected 6 types of cancer and all cancers to calibrate due to the availability of data. We used five methods to estimate the one-year RSRs. There is no definitive answer for which method is the best. The choice is dependent on the nature of the disease and the feasibility of applying the methods. For example, it may be reasonable to assume that for prostate cancer, one-year RSR beyond 6 years is the same as that for 5 years. Prostate cancer is typically a slow-growing cancer and a relatively small percentage of bias was obtained, thus the simplest method (Section 3) to estimate one-year RSR may be appropriate. In addition, although there are no robust justifications to assume that one-year RSRs at subsequent years follow any relationship as preceding years, applying an adjustment factor (Formula (5.1)) in Section 5.2 yielded valid results for all cancers and the 6 selected cancers. In Section 6, we introduced a method consistent with the biological system and released most assumptions, but it is computationally intensive. However, the method described in Section 6 may offer the ultimate solution when other methods cannot yield adequate acceptance parameters sets. Calibrated one-year RSRs in Sections 5.2 and 6 had considerable overlap, and showed that the precision of calibrated RSRs increases over conditional surviving years. Although the true time-dependent one-year RSRs are unknown, it may suggest agreement between calibrated results from different methods. In addition, the accuracy of calibrated results cannot be overestimated.

In Canadian cancer statistics, the 95% CIs of five-year RSRs were narrow for most types of cancer [1, 2]. For example, the published point estimate and upper and lower limits were the same values for all cancers. Therefore, we have to take into considerations errors due to rounding in the calibration since the true unrounded RSRs are unknown. For the same reason, we cannot always select the best-fitting parameter sets based on available data. Instead we should treat the parameter sets equally, such as when the projected five-year RSRs after rounding are the same as the five-year RSRs reported in Canadian Cancer Statistics 2015 [1]. In addition to cancer type and the number of years post-cancer diagnosis, there are other factors that impact the RSRs, including demography (age-group, sex, ethnicity, etc.), calendar year of diagnosis, method of estimating the expected survival, and the unadjusted or adjusted RSR (to mortality due to cancer) [3, 7]. Although theoretically the RSR can be greater than 1 [8], it was seldom seen in practice, even for low risk cancers [1, 3, 9]. Thus, it is reasonable to assume a one-year

RSR less than 1 for the calibrated cancers in most situations. However, one can certainly release this assumption and define another appropriate upper limit (or range) of RSR in the calibration.

7.1. Application of RSRs in a Health Economic Model

In an economic model, we often need the probability of death for patients with cancer given the one-year RSR, and the probability of death in the general population (e.g., from the Canadian life table [10]). Approximately, one-year RSR at year i post-cancer diagnosis also can be expressed as $RSR_i = (1 - P_C) = (1 - P_G)$, where P_C is probability of death for patients with cancer and P_G is the probability of death in the age- and sex- specific general population, based on the Canadian life table. Then, $P_C = 1 - RSR_i \times (1 - P_G)$. We can estimate the probability of death for patients with cancer, conditional on having survived years, and with their age and sex.

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