EVALUATING THE USE OF INCIDENCE-MORTALITY RATIOS IN ESTIMATING THE COMPLETENESS OF CANCER REGISTRATION

John P. Fulton, PhD
Holly L. Howe, PhD

OBJECTIVES

The Data Evaluation and Publication Committee of the North American Association of Central Cancer Registries (NAACCR) sought objective estimates of the completeness of cancer registration among member registries, to complement self-reported estimates of completeness. Ratios of incidence to mortality had been used previously to estimate the completeness of cancer registration across cancer types in a single state registry.[1] The technique was applied to data from U.S. member registries of NAACCR and evaluated for its validity in estimating the relative completeness of case registration across registries. A simpler method, which does not require mortality rates, but relies exclusively on comparing local cancer incidence rates to SEER incidence rates (LI/SI), was also evaluated using data from both U.S. and Canadian member registries.

METHODS

Background

Previous analysis had demonstrated considerable stability in the ratio of cancer incidence to cancer mortality (I/M) among U.S. whites for all cancers combined and for most specific cancer types, with a few exceptions, such as breast and prostate cancers.[1] Even in the case of these two cancer types, for which upward trends in I/M were observed, the trends were gradual and monotonic. This stability had been exploited to explore the relative completeness of reporting among various cancer types in Rhode Island.[1] Expected cause-specific cancer incidence values were derived for Rhode Island from SEER I/Ms (SEER *I*, U.S. *M*) and state cancer mortality, then compared with observed cause-specific cancer incidence values for the state. Observed values were found to be similar to expected values. A few notable exceptions included less-than-expected incidence for malignant melanomas and cancers of the oral cavity, breast, and prostate. Additional exploration revealed credible explanations for these differences, including under-reporting attributable to the use of ambulatory care and out-of-state pathology labs, among others.[1]

Strategy

To evaluate the validity of the I/M and LI/SI methods as means for estimating the relative completeness of case registration across registries, we worked with cancer types selected for known differences in the difficulty usually associated with completeness of case reporting:

Least difficulty: Cancers of the colon-rectum and lung
Average difficulty: Cancers of the bladder, breast, oral cavity, and pancreas
Most difficulty: Cancer of the prostate, leukemias, and melanomas of the skin

The level of difficulty associated with completeness of case reporting is often related to the proportion of cases treated in an inpatient hospital setting during the first four to six months following diagnosis. The lower this proportion, the greater the difficulty in identifying reportable cases. This is attributable to the number of cases that exceed the grasp of experienced hospital reporters and established hospital cancer registries and must be identified through other means.

Computing Expected Values from I/Ms

Assuming that cause-specific cancer I/Ms would be relatively stable within sex and race categories in North America, the expected cancer incidence for whites was computed by central cancer registry (state), gender, and site of primary cancer, thus:

$$EXPECTED\ I_s = (M_s)\left(\frac{I_{SEER}}{M_{U.S.}}\right)$$

where:
I = Age-standardized incidence rate (gender-race-site-specific); M = Age-standardized mortality rate (gender-race-site-specific); s = State, province, or territory; SEER = combined SEER program; U.S. = United States; and where the U.S. mortality was an average from 1987-1991,[2] the SEER incidence was an average from 1987-91,[2] and the state incidence rate was an average of 1988-1990.[3] All rates had been age-standardized using the 1970 population of the U.S. as the standard population. The observed number of cases was obtained from *Cancer Incidence in North America, 1988-1990*,[3] by averaging from one to three years of data (three years for most). Since race-specific incidence was not available for Canadian registries, the rates and observed numbers of cancer incidence for "All Races" were used.

Computing Expected Values without Mortality Data

Geographical variation in cancer mortality among whites across states and provinces in the U.S. and Canada may be sufficiently limited and stable to substitute direct comparisons of local-to-US. SEER incidence ("LI/SI") for comparisons of observed-to-expected incidence based on I/Ms. In fact, the two comparisons are equivalent whenever local and national age-standardized mortality rates for whites are equal. The LI/SI method is simpler than the I/M method, as the former does not use mortality rates.

Analysis

Aggregate Rate Ratios

I/M Method. Aggregate rate ratios of observed to expected cancer incidence for whites, 1988-1990, by SEER status, gender, and cause (site of primary cancer) were computed by summing observed and expected incidence rates across 34 central cancer registries in the U.S. (excluding Puerto Rico, for which the appropriate mortality statistics were not immediately available), weighted for population size by using values of observed incidence, then dividing sums of weighted observed incidence rates by sums of weighted expected incidence rates.

LI/SI Method. Analogous aggregate ratios of local to SEER cancer incidence were computed across 35 central cancer registries in the U.S. (including Puerto Rico) and 12 central cancer registries in Canada. Ratios were used to explore differences among cancer types and registry types which might be indicative of differences in completeness of case reporting.

Mean Rate Ratios

I/M Method. Mean rate ratios of observed to expected cancer incidence for whites, 1988-1990, by SEER status, gender, and site of primary cancer were computed from ratios of observed to expected cancer incidence calculated individually for 34 central cancer registries in the U.S. (excluding Puerto Rico).

LI/SI Method. Analogous mean ratios of local to SEER cancer incidence were computed across 35 central cancer registries in the U.S. (including Puerto Rico) and 12 central cancer registries in Canada.

For both the I/M and LI/SI methods, standard deviations were also computed and used to explore the extent of variation in ratios across registry types.

RESULTS

Comparisons: I/M Method

As shown in Table 1, aggregate U.S. SEER ratios of observed to expected cancer are all close to 1.00, varying from 0.93 to 1.14. U.S. non-SEER (hereafter referred to as *state*) ratios for cancers of the colon-rectum and lung vary between 0.93 and 1.02. State ratios are low for cancer of the prostate and melanoma, but vary from 0.82 to 0.91 for other primary sites.

TABLE 1. Aggregate rate ratios of observed to expected cancer incidence, U.S. 1988-1990, state and regional cancer registries, by SEER status, gender, race, and site of primary cancer, based on the I/M method

	All U.S.	SEER	Other U.S. States
WHITE MALES			
Colon-rectum	1.00	1.06	0.94
Lung	1.08	1.14	1.02
Bladder	0.94	1.02	0.86
Oral Cavity	0.92	0.98	0.86
Pancreas	0.96	1.02	0.91
Prostate	0.83	0.93	0.73
Leukemia	0.91	1.01	0.82
Melanoma	0.85	1.06	0.67
WHITE FEMALES			
Colon-rectum	1.00	1.04	0.97
Lung	0.97	1.01	0.93
Bladder	0.92	0.96	0.88
Breast	0.93	0.98	0.88
Oral Cavity	0.91	0.96	0.85
Pancreas	0.93	0.99	0.87
Leukemia	0.93	0.99	0.87
Melanoma	0.76	0.94	0.59

Mean U.S. SEER ratios of observed to expected cancer incidence equal or exceed 0.94, but display considerable variation: from 0.94 to 1.26 with standard deviations which start at 0.04 and go as high as 0.65 (see Table 2). The latter is related to the abnormally high incidence of melanoma among white males in Hawaii, one of the SEER areas. When this standard deviation is excluded, the range of standard deviations for SEER areas varies between 0.04 and 0.31. Mean U.S. state ratios order themselves similarly to aggregate U.S. state ratios. The range of standard deviations for mean U.S. state ratios, 0.06 to 0.25, is not unlike the range of standard deviations for mean U.S. SEER ratios.

TABLE 2. Mean rate ratios of observed to expected cancer incidence, U.S., 1988-1990, all state and regional cancer registries, by SEER status, gender, race, and site of primary cancer, based on the I/M method

	All U.S.		SEER		Other States	
	Mean	**S.D.†**	**Mean**	**S.D.**	**Mean**	**S.D.**
WHITE MALES						
Colon-rectum	0.96	0.09	1.06	0.04	0.93	0.09
Lung	1.05	0.11	1.15	0.08	1.02	0.10
Bladder	0.94	0.19	1.11	0.26	0.89	0.12
Oral Cavity	0.92	0.20	1.04	0.19	0.88	0.18
Pancreas	0.92	0.13	1.00	0.06	0.89	0.14
Prostate	0.79	0.18	0.98	0.22	0.72	0.10
Leukemia	0.86	0.14	0.98	0.10	0.81	0.13
Melanoma	0.79	0.46	1.26	0.65	0.61	0.14
WHITE FEMALES						
Colon-rectum	0.98	0.09	1.05	0.07	0.95	0.08
Lung	0.94	0.10	1.03	0.13	0.91	0.06
Bladder	0.92	0.22	0.94	0.07	0.91	0.25
Breast	0.91	0.13	1.03	0.17	0.87	0.07
Oral Cavity	0.86	0.13	0.94	0.14	0.84	0.11
Pancreas	0.88	0.17	0.96	0.10	0.84	0.18
Leukemia	0.88	0.13	0.95	0.12	0.85	0.12
Melanoma	0.69	0.30	1.04	0.31	0.56	0.15

† Standard Deviation

Comparisons: LI/SI Method

Aggregate U.S. SEER ratios of observed to expected cancer incidence are all close to 1.00, as shown in Table 3. U.S. state ratios for cancers of the colon-rectum and lung are close to 0.95, the level of completeness reported by most state registries. U.S. state ratios are low for leukemia, melanoma, and cancer of the prostate, but vary from 0.87 to 0.91 for other primary sites. In general, Canadian ratios are similar to U.S. state ratios, with some notable exceptions, including higher-than-U.S. ratios for cancers of the pancreas and oral cavity among males, and lower ratios for cancers of the lung and breast among females.

TABLE 3. Aggregate ratio of observed to expected cancer incidence, U.S. and Canada, 1988-1990, all state, regional, and provincial cancer registries, by country, SEER status, gender, race, and site of primary cancer, based on the LI/SI method

	All U.S.	SEER	Other U.S. States	Canada
WHITE MALES				
Colon-rectum	0.95	1.00	0.94	0.93
Lung	0.96	1.00	0.95	0.95
Bladder	0.89	1.00	0.87	0.82
Oral Cavity	0.89	0.98	0.88	1.14
Pancreas	0.91	1.00	0.90	1.03
Prostate	0.76	0.95	0.73	0.67
Leukemia	0.82	0.98	0.80	0.88
Melanoma	0.71	0.98	0.67	0.56
WHITE FEMALES				
Colon-rectum	0.97	1.01	0.97	0.98
Lung	0.94	1.00	0.93	0.75
Bladder	0.93	1.01	0.91	0.95
Breast	0.90	0.99	0.89	0.79
Oral Cavity	0.90	0.99	0.89	0.81
Pancreas	0.91	1.01	0.89	0.95
Leukemia	0.86	0.97	0.84	0.94
Melanoma	0.66	0.96	0.61	0.77

The mean U.S. SEER ratios of observed to expected cancer incidence, as shown in Table 4, equal or exceed 0.90, but display considerable variation: from 0.90 to 1.05 with standard deviations which start at 0.08 and go as high as 0.25. Mean U.S. state ratios order themselves similarly to aggregate U.S. state ratios. The ranges of standard deviations for mean U.S. state ratios, 0.11 to 0.21, and for mean Canadian ratios, 0.04 to 0.24, are not unlike the range of standard deviations for mean U.S. SEER ratios, 0.08 to 0.25. Note that some variance was removed from the Canadian ratios by excluding three provinces with very small populations from the calculation of mean ratios. Mean Canadian ratios are ordered somewhat differently than mean U.S. ratios, although the patterns are not totally dissimilar. Mean Canadian ratios for prostate cancer and melanomas are lowest, a finding similar to mean U.S. ratios.

TABLE 4. Mean rate ratios of observed to expected cancer incidence, U.S. and Canada, 1988-1990, all state, regional, and provincial cancer registries, by country, SEER status, gender, race, and site of primary cancer, based on the LI/SI method

	All U.S.		SEER		Other U.S. States		Canada	
	Mean	**S.D.†**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
WHITE MALES								
Colon-rectum	0.93	0.17	0.96	0.12	0.92	0.18	0.96	0.08
Lung	0.95	0.21	0.94	0.22	0.96	0.21	1.03	0.16
Bladder	0.90	0.18	0.94	0.14	0.89	0.18	0.86	0.07
Oral Cavity	0.90	0.13	0.97	0.10	0.88	0.13	1.12	0.24
Pancreas	0.91	0.16	0.98	0.08	0.89	0.17	0.97	0.18
Prostate	0.80	0.18	0.97	0.18	0.74	0.13	0.68	0.11
Leukemia	0.83	0.15	0.94	0.12	0.79	014	0.86	0.14
Melanoma	0.72	0.28	1.05	0.21	0.60	0.20	0.57	0.18
WHITE FEMALES								
Colon-rectum	0.94	0.15	0.96	0.13	0.94	0.16	1.02	0.10
Lung	0.91	0.22	0.94	0.25	0.90	0.20	0.76	0.15
Bladder	0.94	0.20	0.95	0.17	0.94	0.21	0.94	0.04
Breast	0.89	0.11	0.97	0.08	0.87	0.11	0.78	0.07
Oral Cavity	0.90	0.16	0.98	0.22	0.87	0.11	0.78	0.16
Pancreas	0.90	0.17	0.97	0.13	0.88	0.18	0.91	0.17
Leukemia	0.84	0.14	0.90	0.18	0.82	0.12	0.93	0.11
Melanoma	0.68	0.26	0.99	0.13	0.57	0.19	0.73	0.19

Note: Means for Canada do not include Prince Edward Island, Northwest Territories, or Yukon, because these three provinces had very few observed cases for some cancer sites.

† Standard Deviation

DISCUSSION

Comparisons: I/M Method

Aggregate U.S. SEER ratios of observed to expected cancer incidence are all close to 1.00, which would be expected in areas with highly developed infrastructures for cancer registration. That they do not equal 1.00 exactly is also to be expected, since the mortality rates from which U.S. I/Ms were calculated were not restricted to SEER areas, but rather reflected the U.S. as a whole.

Aggregate U.S. state ratios for colon-rectum and lung are close to 0.95, the level of completeness reported by most U.S. state registries. Case completeness of this magnitude is to be expected for cancers almost always requiring hospitalization at some point during cancer diagnosis and treatment.

Aggregate U.S. state ratios are low for melanoma of skin, a cancer notoriously difficult to register because many cases are treated in outpatient settings, exceeding the grasp of hospital cancer reporters. Aggregate U.S. state ratios are also low for cancer of the prostate. With contemporary procedures and protocols for screening, diagnosis, and treatment, many cancers of the prostate are treated in outpatient settings, thus like melanomas of the skin and leukemias, exceeding the grasp of hospital cancer reporters. Low ratios for cancer of the prostate may also reflect real differences in incidence, attributable to differential screening practices. For example, if SEER areas have a higher prevalence of screening for cancer of the prostate, these areas would be expected to have higher incidence rates for the disease.

As expected, most aggregate U.S. ratios for other cancer sites (varying from 0.82 to 0.91) fall between the high ratios observed for cancers of the colon-rectum and lung and the low ratios observed for melanomas of skin and cancer of the prostate. The cancer sites with intermediate ratios usually require hospitalization at some point, but to a lesser degree than cancers of the colon-rectum and lung.

Assuming superb case-completeness in all SEER areas, the variance observed among them in ratios of observed to expected incidence represents real differences from locale to locale in underlying I/M ratios. Given the true variation in I/Ms observed for SEER registries, it is not unreasonable to conclude that mean U.S. state ratios in the middle range, possibly as low as 0.87, for instance, are consistent with a self-reported case completeness of about 0.95. Nonetheless, it is also not unreasonable to conclude that melanomas are under-reported to U.S. state registries, and that some state registries should examine the completeness of reporting for leukemias and cancer of the prostate. In examining the latter, it would help to have regional or state estimates of the level of prostate cancer screening.

Comparisons: LI/SI Method

Comparisons based on the LI/SI method yielded results very similar to comparisons based on the I/M method. Using the LI/SI method, the Canadian comparisons were similar to the U.S. state comparisons with some exceptions:

* The Canadian ratio for lung cancer among females was lower, at 0.75. This is probably attributable to a real difference in female lung cancer case fatality between the two nations. It would be difficult to support an alternative explanation that most cases of male lung cancer are reported, while fully one-fourth the cases of female lung cancer are not.

* The Canadian ratios for leukemias exceeded the U.S. state ratios for leukemias by about ten percentage points. This may be indicative of real differences in the completeness of reporting, perhaps linked to differences between the two nations in the use of inpatient hospital treatment for leukemias.

* The aggregate Canadian ratio for cancer of the breast was lower, at 0.79. Since the use of U.S. SEER incidence was used for expected Canadian incidence, this finding may be attributable to differences in the way multiple primary tumors are counted in the U.S. and Canada, as opposed to differences in case completeness or incidence.

CONCLUSIONS

Ratios of observed to expected cancer incidence based on the I/M method and the LI/SI method broadly reflect known differences in the difficulty with which case completeness is achieved. It appears that ratios based on either method may be used cautiously to identify cancer types for which "relative" case completeness is problematic. However, they should not be used to estimate the absolute completeness of case reporting, given the broad range of real variation in these

ratios observed among SEER areas, where case completeness has been shown to be superb. Furthermore, low state ratios should be explored thoroughly to rule out real differences in case fatality, incidence, and random variation (from year to year, for example), before concluding that under-reporting is the cause. Large central registries may find ratio comparisons useful in targeting case completeness audits to selected local areas, if attention is paid to the variance of local rates.

REFERENCES

1. Fulton JP, Stanis DM, Buechner, JS. Completeness of cancer registration in Rhode Island: an evaluation of early data. *RI Med.* 1992; 75(11):515-520.

2. Ries LAG, et al. (Eds). SEER Cancer Statistics Review, 1973-1991: Tables and Graphs. Bethesda, MD: National Cancer Institute. NIH Pub. No. 94-2789, 1994.

3. Howe HL, et al. (Eds). Cancer Incidence in North America, 1988-1990. Springfield, IL: American Association of Central Cancer Registries, April 1994.