Are Increasing 5-Year Survival Rates Evidence of Success Against Cancer?

H. Gilbert Welch, MD, MPH

Lisa M. Schwartz, MD, MS

Steven Woloshin, MD, MS

A RECENT PRESS RELEASE FROM the US Department of Health and Human Services[1] stated: "The five-year survival rate for all cancers improved from 51 percent in the early 1980s to almost 60 percent in the early 1990s. . . . since the 1971 National Cancer Act, much of the research into early cancer detection and treatment has paid off." The 5-year survival rate is perhaps the most common statistic used to report progress in the war against cancer. Improvements in 5-year survival are held up as an unambiguous sign of success: if cancer patients are living longer now compared with cancer patients in the past, then society's enormous investment in cancer research and improved treatments must be paying off.

While 5-year survival is a perfectly valid measure to compare cancer therapies in a randomized trial, comparisons of 5-year survival rates across time (or place) may be extremely misleading. If cancer patients in the past always had palpable tumors at the time of diagnosis while current cancer patients include those diagnosed with microscopic abnormalities, then 5-year survival would be expected to increase over time even if new screening and treatment strategies are ineffective. To avoid the problems introduced by changing patterns of diagnosis, observers have argued that progress against cancer be assessed using population-based mortality rates.[2,3]

Nonetheless, improvements in 5-year survival are frequently presented to the public and to policymakers as proof that we are making progress against cancer. To see if 5-year survival statistics really provide such proof, we used data from the Surveillance, Epidemiology and End Results (SEER) program to compare changes in 5-year survival, mortality rates, and cancer incidence rates for the 20 most common solid tumor types from 1950 to 1995.

METHODS

Measures

We examined how changes in 5-year survival rates were related to changes in 2 other measures of cancer burden:

Context Increased 5-year survival for cancer patients is generally inferred to mean that cancer treatment has improved and that fewer patients die of cancer. Increased 5-year survival, however, may also reflect changes in diagnosis: finding more people with early-stage cancer, including some who would never have become symptomatic from their cancer.

Objective To determine the relationship over time between 5-year cancer survival and 2 other measures of cancer burden, mortality and incidence.

Design and Setting Using population-based statistics reported by the National Cancer Institute Surveillance, Epidemiology, and End Results Program, we calculated the change in 5-year survival from 1950 to 1995 for the 20 most common solid tumor types. Using the tumor as the unit of analysis, we correlated changes in 5-year survival with changes in mortality and incidence.

Main Outcome Measure The association between changes in 5-year survival and changes in mortality and incidence measured using simple correlation coefficients (Pearson and Spearman).

Results From 1950 to 1995, there was an increase in 5-year survival for each of the 20 tumor types. The absolute increase in 5-year survival ranged from 3% (pancreatic cancer) to 50% (prostate cancer). During the same period, mortality rates declined for 12 types of cancer and increased for the remaining 8 types. There was little correlation between the change in 5-year survival for a specific tumor and the change in tumor-related mortality (Pearson $r=.00$; Spearman $r=-.07$). On the other hand, the change in 5-year survival was positively correlated with the change in the tumor incidence rate (Pearson $r=+.49$; Spearman $r=+.37$).

Conclusion Although 5-year survival is a valid measure for comparing cancer therapies in a randomized trial, our analysis shows that changes in 5-year survival over time bear little relationship to changes in cancer mortality. Instead, they appear primarily related to changing patterns of diagnosis.

JAMA. 2000;283:2975-2978   www.jama.com

mortality and incidence. The 5-year survival rate is actually not a rate; instead, it is the proportion of individuals with cancer who are alive 5 years after diagnosis (referred to hereafter as *5-year survival*). Five-year survival is a

Author Affiliations: VA Outcomes Group, Veterans Administration Hospital, White River Junction, Vt (Drs Welch, Schwartz, and Woloshin); the Center for the Evaluative Clinical Sciences, Dartmouth Medical School, Hanover, NH (Drs Welch, Schwartz, and Woloshin); and the Norris Cotton Cancer Center, Dartmouth-Hitchcock Medical Center, Lebanon, NH (Drs Schwartz and Woloshin).

Corresponding Author and Reprints: H. Gilbert Welch, MD, MPH, VA Outcomes Group (111B), Department of Veterans Affairs Medical Center, White River Junction, VT 05009.

case-based measure—the denominator only includes patients diagnosed with the disease. Mortality and incidence rates, on the other hand, are population-based measures—their denominators include the entire population at risk for the disease. The numerator for mortality is the number of deaths caused by cancer; the numerator for incidence is the number of new cases of cancer. Both are measured as age-adjusted annual rates per 100 000 people.

Data

The data reported herein were obtained from the Web site of the National Cancer Institute's SEER program—the federal government's primary effort to collect and report cancer incidence, initial treatment, and survival. The SEER Cancer Statistics Review 1973-1996 uses historical data to summarize changes in cancer incidence and mortality from 1950 through 1996.[4] In the same table, SEER reports 5-year survival for 1950-1954 and for 1989-1995 (the most recent year available in the SEER data).

Analysis

Our analysis includes all 20 solid tumor types reported by the SEER program. For each tumor, we calculated the absolute difference in 5-year survival from 1989-1995 and from 1950-1954. Because the absolute difference was always positive, herewith we refer to it as the *absolute increase in 5-year survival* since 1950. We used simple correlation to analyze the relationship between the variables (Pearson r). The unit of analysis is the tumor. Because correlation can be powerfully influenced by observations with extreme values, we also performed a nonparametric analysis correlating the observations ranks (Spearman r). Finally, we repeated the analysis using different time periods and after excluding outliers. All analyses were performed using STATA 4.0 (College Station, Tex).

RESULTS

From 1950 to 1995, there was an increase in 5-year survival for each of the 20 solid tumor types. The absolute increase in 5-year survival ranged from

3% (pancreatic cancer) to 50% (prostate cancer). Over the same period, mortality rates declined for 12 tumors, while they increased for the remaining 8. Incidence decreased in only 5 of the 20 tumors. The data for the individual tumors are shown in TABLE 1.

5-Year Survival and Mortality

The left side of the FIGURE shows the relationship between the absolute increase in 5-year survival for 1950-1995 and the change in mortality over the same period. Although the expectation might be that large increases in 5-year survival would be associated with declining mortality (ie, a negative correlation), no obvious relationship is evident in the Figure. This observation is confirmed by the data presented in TABLE 2, which show little correlation between the increase in 5-year survival for a specific tumor and the change in tumor-related mortality (Pearson r=.00, Spearman r=−.07).

5-Year Survival and Incidence

The right side of the Figure shows the relationship between the absolute increase in 5-year survival for 1950-1995 and the change in incidence over the same period. In the classic epidemiology model, no relationship would be expected between incidence and 5-year survival (unless there is some concurrent change in tumor biology). A positive correlation is evident in the Figure, however, suggesting that large increases in 5-year survival are associated with increasing incidence. This observation is confirmed by the data presented in Table 2, which show a positive correlation between the increase in 5-year survival for a specific tumor and the change in the tumor incidence rate (Pearson r=+.49, Spearman r=+.37).

Other Analyses

Because lung cancer has some unique characteristics (eg, most years of lives lost, dramatic increase in both incidence and mortality temporally related to a single exposure, ie, cigarette smoking), SEER routinely recalculates summary cancer statistics after ex-

Table 1. Changes in 5-Year Survival, Mortality, and Incidence for 20 Solid Tumors

Primary Site	5-Year Survival, %		Absolute Increase in 5-Year Survival, %	% Change (1950-1996)	
	1950-1954	1989-1995		Mortality	Incidence
Prostate	43	93	50	10	190
Melanoma	49	88	39	161	453
Testis	57	96	39	−73	106
Bladder	53	82	29	−35	51
Kidney	34	61	27	37	126
Breast	60	86	26	−8	55
Colon	41	62	21	−21	12
Rectum	40	60	20	−67	−27
Ovary	30	50	20	−2	3
Thyroid	80	95	15	−48	142
Larynx	52	66	14	−14	38
Uterus	72	86	14	−67	0
Cervix	59	71	12	−76	−79
Oral cavity	46	56	10	−37	−38
Esophagus	4	13	9	22	−8
Brain	21	30	9	45	68
Lung	6	14	8	259	249
Stomach	12	19	7	−80	−78
Liver	1	6	5	34	140
Pancreas	1	4	3	16	9

Figure. Relationship Between the Change in 5-Year Survival and the Change in Mortality and Incidence for Solid Tumors in the Surveillance, Epidemiology, and End Results (SEER) Data
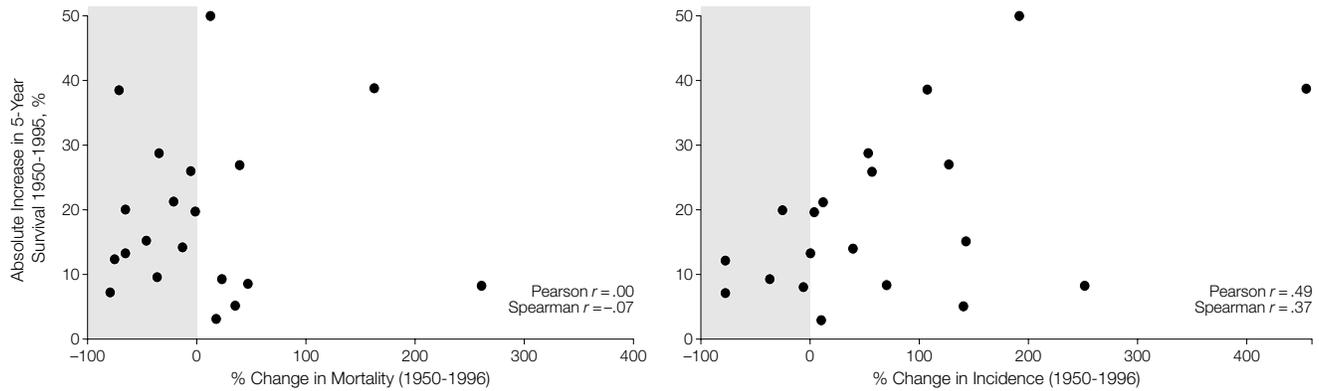
Each data point represents a solid tumor type. The shaded areas represent decreased mortality (left graph) or incidence (right graph).

cluding lung cancer. Table 2 shows the effect of this exclusion: the correlation between the 5-year survival and mortality becomes positive (increased 5-year survival associated with increased mortality) and the relationship between 5-year survival and incidence becomes stronger.

Some might reasonably question whether the starting date of 1950 is too early to be confident about the change data (and, in fact, some of the 1950 data are only available from the Connecticut Tumor Registry). To address this concern, we repeated the analysis starting with the first year a complete year of data was collected by the SEER program: 1973. This analysis, also shown in Table 2, had little effect on the correlation between 5-year survival and mortality and actually strengthened the relationship with incidence. We also repeated the analysis using a 1989 stop date (to match the years during which the most recent 5-year survival rates were obtained) and with and without outliers. In each case, the correlation between 5-year survival and incidence was positive and was always stronger than the correlation between 5-year survival and mortality.

COMMENT

Our findings highlight that the presumed relationship between temporal trends in 5-year survival and the effec-

Table 2. Correlation Between the Change in 5-Year Survival and the Change in Mortality and Incidence for Solid Tumors in the Surveillance, Epidemiology, and End Results Data

	Correlation With Change in 5-Year Survival			
	Since 1950		Since 1973	
	Pearson *r*	Spearman *r*	Pearson *r*	Spearman *r*
All Solid Tumor Types				
Change in mortality	.00	−.07	−.05	+.02
Change in incidence	+.49*	+.37	+.55*	+.47*
Excluding Lung Cancer				
Change in mortality	+.22	+.04	.00	+.12
Change in incidence	+.60†	+.51*	+.57*	+.53*

*$P<.05$.
†$P<.01$.

Table 3. Expected Change in 5-Year Survival, Mortality, and Incidence Under Various Conditions*

	Expected Change in		
Condition	5-Year Survival	Mortality	Incidence
More effective treatment of existing disease	↑	↓	No change
More cases found early and early treatment is effective	↑	↓	↑
early treatment is not effective	↑	No change†	↑
Increase in the true occurrence of disease (assuming no change in tumor aggressiveness)	No change	↑	↑

*Expected changes assume only 1 condition occurs at a given time.
†If the enhanced ability to find cancer leads to cancer being more frequently coded as the primary cause of death, reported mortality may even increase.

tiveness of cancer care may be, at best, tenuous. Instead, we found that the increase in 5-year survival over time had little relationship to changes in the mortality from cancer.

Why are temporal changes in 5-year survival unrelated to mortality? As shown in **TABLE 3**, there are 3 ways for

5-year survival to increase. First, the treatment of established cancer may improve—that is, the same number of patients are found at the same point in their disease course, yet live to an older age because of improved therapy. In this case, mortality will decrease. The other 2 ways to increase 5-year survival both

involve finding more patients early in their disease course. Any advance in the time of diagnosis will increase 5-year survival because of the spurious effect of lead time.[5] If early treatment is effective, then there will be a further increase in 5-year survival, patients will live to an older age, and mortality will also decrease. If early treatment is ineffective, however, patients will die at the same age as before and mortality will be unchanged. Our data suggest that physicians (as well as policymakers and patients) cannot make any inferences about the effectiveness of early diagnosis or treatment from temporal changes in 5-year survival.

Why are temporal changes in 5-year survival related to incidence? As shown in Table 3, unless tumor biology were suddenly to change, how many people developed disease would not be expected to influence the prognosis of the individual case (eg, 5-year survival). However, increases in incidence may reflect changes in clinical practice rather than changes in the true occurrence of disease. Increasing efforts to diagnose disease early results in more cases being found. More important, detection of subclinical cancers (some of which may never produce symptoms) will increase incidence yet further. Advancing the time of diagnosis with early detection and finding cases of cancer not found previously will increase 5-year survival dramatically. The correlation between 5-year survival and incidence (combined with little correlation between 5-year survival and mortality) suggests that the most important explanation of variability in changes in 5-year survival in general is simply changes in diagnosis.

Nonetheless, increasing 5-year survival is often presented to the public as evidence of the value of cancer research and early detection. Arguing against Republican tax cuts, which would result in a lower budget for the National Institutes of Health, the vice president announced that 5-year survival rates for all cancers improved to almost 60% in the early 1990s from 51% in the early 1980s.[6] Similarly, a recent article in the *New York Times* about screening for lung cancer with spiral computed tomography quoted a researcher at Cornell University as saying that "the method [spiral computed tomography] could allow as many as 80 percent of lung cancer patients to survive at least five years. Just 15 percent live that long now."[7]

It is important that our work not be misconstrued. We are not suggesting that our results imply that there has been no real progress in cancer treatment. Instead, we argue that improving 5-year survival over time for a specific tumor may not reflect reduced disease burden and should not be taken as evidence of improved prevention, screening, or therapy. Improved 5-year survival may instead reflect more cases diagnosed and unchanged mortality—arguably an increased disease burden.

When the National Cancer Institute convened experts to assess the various measures of progress against cancer, the committee was clear about which measure was most important: mortality rates.[3] Mortality rates would be expected to decrease with any improvement in cancer control: be it risk factor reduction (ie, primary prevention), successful early detection efforts (ie, screening), or better treatment of advanced disease. While it is possible that increasing mortality may reflect our enhanced ability to find cancer patients (making cancer more likely to be labeled the primary cause of death), there is no ambiguity about decreasing mortality. To measure true progress in the "war against cancer," physicians and policymakers should focus on mortality.

REFERENCES

1. Cancer survivorship [press release]. Washington, DC: US Dept of Health and Human Services; August 12, 1999.
2. Bailar JC III, Smith EM. Progress against cancer? *N Engl J Med.* 1986;314:1226-1232.
3. Extramural Committee to Assess Measures of Progress Against Cancer. Measurement of progress against cancer. *J Natl Cancer Inst.* 1990;82:825-835.
4. SEER Cancer Statistics Review 1973-1996. Available at: http://www-seer.ims.nci.nih.gov/Publications/CSR1973_1996/. Accessed March 2000.
5. Black WC, Welch HG. Advances in diagnostic imaging and overestimations of disease prevalence and the benefits of therapy. *N Engl J Med.* 1993;328:1237-1243.
6. Gore faults GOP on cancer effort [press release]. Washington, DC: United Press International; August 10, 1999.
7. Kolata G. Large study urged for new method of detecting lung cancer. *New York Times.* October 27, 1999:A19.