



**Population-based cancer survival in the US: data, quality control and statistical methods**

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Complete List of Authors:	Allemani, Claudia; London School of Hygiene and Tropical Medicine, NCDEU Harewood , Rhea; London School of Hygiene and Tropical Medicine Spika , Devon; London School of Hygiene and Tropical Medicine Johnson, Christopher; Cancer Data Registry of Idaho, Bonaventure, Audrey; London School of Hygiene and Tropical Medicine, NCDEU Ward, Kevin; Emory University, Carreira, Helena; London School of Hygiene and Tropical Medicine Weir, H.K.; Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion Coleman, Michel; London School of Hygiene and Tropical Medicine, NCDEU
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3 **Population-based cancer survival in the US: data, quality control and statistical**  
4 **methods**  
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7 Claudia Allemani,<sup>1</sup> Rhea Harewood,<sup>1</sup> Chris Johnson,<sup>2</sup> Helena Carreira,<sup>1</sup> Devon Spika,<sup>1</sup>  
8 Audrey Bonaventure,<sup>1</sup> Kevin Ward,<sup>3</sup> Hannah K Weir,<sup>4</sup> Michel P Coleman<sup>1</sup>  
9

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11 **Running title:** Data, quality control and statistical methods  
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16 <sup>1</sup> Cancer Survival Group, Department of Non-Communicable Disease Epidemiology,  
17 London School of Hygiene and Tropical Medicine, Keppel Street, London WC1E 7HT,  
18 UK  
19

20  
21 <sup>2</sup> Cancer Data Registry of Idaho, Boise, ID, USA  
22

23  
24 <sup>3</sup> Georgia Center for Cancer Statistics, Emory University, Atlanta, GA, USA  
25

26  
27 <sup>4</sup> Division of Cancer Prevention and Control, National Center for Chronic Disease  
28 Prevention and Health Promotion, Centers for Disease Control and Prevention, 4770  
29 Buford Highway, Atlanta, GA 30341, USA  
30

31 **Correspondence:** Claudia Allemani, Cancer Survival Group, Department of Non-  
32 Communicable Disease Epidemiology, London School of Hygiene and Tropical Medicine,  
33 Keppel Street, London WC1E 7HT, UK. Tel +44 20 7927 2855  
34  
35

36  
37 [Claudia.Allemani@lshtm.ac.uk](mailto:Claudia.Allemani@lshtm.ac.uk)  
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53 Prevention.  
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**Precis for use in the Table of Contents:** Population-based cancer survival is a key measure of the overall effectiveness of health systems in managing the cancer burden. The high quality of US cancer registry data, 80% population coverage in the CONCORD-2 study and the use of an unbiased estimator of net survival ensure that the survival trends we report are robustly comparable by race and state. These results can be used to plan and evaluate cancer control strategy, in each state and for the US nationally.

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**Abstract**

**Background:** Robust comparisons of population-based cancer survival estimates require tight adherence to study protocol, standardized quality control, appropriate life tables of background mortality, and centralized analysis. The CONCORD program established worldwide surveillance of population-based cancer survival in 2015, analyzing individual data on 26 million patients (10 million US patients) diagnosed 1995-2009 with one of 10 common malignancies.

**Methods:** In this *Supplement*, we analyzed data from 37 state cancer registries covering approximately 80% of the U.S. population that participated in CONCORD-2. We performed data quality checks in three consecutive phases: protocol adherence, exclusions, and editorial checks. We estimated 1-, 3- and 5-year age-standardized net survival using the Pohar Perme estimator and state- and race-specific life tables of all-cause mortality for each year. We adopted the cohort approach for patients diagnosed 2001-2003 and the complete approach for patients diagnosed 2004-2009.

**Results** Articles in this *Supplement* report population coverage, data quality indicators and age-standardized 5-year net survival by state, race and stage at diagnosis. Examples of tables, bar-charts and funnel plots are provided in this article.

**Conclusions** Population-based cancer survival is a key measure of the overall effectiveness of services in providing equitable health care. The high quality of US cancer registry data, 80% population coverage and use of an unbiased net survival estimator ensure that the survival trends reported in this *Supplement* are robustly comparable by race and state. The results can be used by policy-makers to identify and address inequities in cancer survival, in each state and for the US nationally.

## INTRODUCTION

Population-based cancer survival is a measure of the overall effectiveness of the health system in dealing with cancer.<sup>1</sup> Comparisons of population-based cancer survival require adherence to a well-designed protocol, standardized quality-control procedures, appropriate life tables of background mortality and centralized analysis with the latest statistical methods.<sup>2,3</sup>

CONCORD-2 established world-wide surveillance of cancer survival in 2015, with estimates of 5-year net survival based on individual data for more than 25 million cancer patients (about 10 million patients in the US) diagnosed during 1995-2009 with one of ten common cancers: stomach, colon, rectum, liver, lung, breast (female), cervix, ovary, prostate and leukemia in adults (15-99 years), and acute lymphoblastic leukemia in children (0-14 years).<sup>3</sup> Patients were followed up to Dec 31, 2009.

For the articles in this *Supplement*, we analyzed data from 37 statewide cancer registries (27 funded by the National Program for Cancer Registries (NPCR) program, 5 funded by the Surveillance, Epidemiology and End Results (SEER) program and 5 funded by both NPCR and SEER) that participated in CONCORD-2, covering approximately 80% of the U.S. population, and which agreed to the inclusion of their data in more detailed analyses by stage at diagnosis and by race. The CONCORD protocol required data on stage only for patients diagnosed from Jan 1, 2001, therefore these analyses, focused mainly on survival by stage, were restricted to patients diagnosed during 2001-2009.

Public health surveillance using the data from population-based cancer registries is a key component of cancer control.<sup>4</sup> The North American Association of Central Cancer Registries (NAACCR)<sup>a</sup> develops and promotes uniform data standards for all cancer registries in North America. Participating US registries had to meet the NAACCR certification criteria and to have conducted record linkage with both the state vital records and the National Death Index (NDI) to update the vital status of registered patients. NAACCR members developed a detailed SAS program to map the NAACCR database record structure to the CONCORD protocol and thus to enable all North American registries to exclude cases that would not have been considered reportable primaries according to the International Association of Cancer Registries (IACR) multiple primary rules,<sup>5</sup> before their datasets for 1995–2009 were extracted for CONCORD-2. This was necessary because North American registries define

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<sup>a</sup> <http://www.naacr.org/standardsandregistryoperations/volumeii.aspx>

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3 multiple primary cancers under the rules of the Surveillance, Epidemiology and End Results  
4 (SEER) program,<sup>6</sup> whereas registries in the European Network of Cancer Registries (ENCR)  
5 and in other continents generally use the rules of the IACR,<sup>5</sup> which are more conservative.  
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9 Topography and morphology were coded according to the International Classification of  
10 Diseases for Oncology (3rd edition; ICD-O-3<sup>7</sup>). Solid tumors were defined by anatomical site  
11 (**Table 1**). For ovarian cancer, we included the fallopian tube, uterine ligaments, and adnexa,  
12 and the peritoneum and retroperitoneum, where high-grade serous ovarian carcinomas are  
13 often detected; this was done to improve international comparability of the data sets. Kaposi's  
14 sarcoma and solid tumors with lymphoma morphology were excluded from analysis.  
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19 Leukemias were defined by morphology. In this *Supplement* we cover only precursor-cell  
20 acute lymphoblastic leukemia in children (ICD-O-3 morphology codes 9727, 9728, 9729,  
21 9835, 9836, 9837). Estimates of survival by race, state and sub-type of adult leukemia will be  
22 presented in other publications.  
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27 Only primary invasive cancers (ICD-O-3 behavior code 3) were included in survival  
28 analyses. We included cancers at a given site regardless of whether the patient had had a  
29 previous cancer. If a patient was diagnosed with two or more cancers of a given organ,  
30 including paired organs, during 2001-2009, only the first was considered in survival analyses.  
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### 34 **Follow-up**

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36 US registries were asked to submit follow-up data (vital status and date of last known vital  
37 status) as at Dec 31, 2009, after conducting linkages of all cancer registrations with both state  
38 vital records systems and the NDI. Patients whose cancer registration could not be linked to a  
39 death record were considered to be alive on Dec 31, 2009 (passive follow-up, also known as  
40 the "presumed alive" method).  
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45 SEER registries are required to meet a specific standard for the completeness and recency of  
46 follow-up. At least 90% of registered patients not known to be deceased were required to  
47 have a date of last known vital status on or after Jan 1, 2010. These follow-up dates could  
48 have been obtained from either passive or active follow-up.<sup>8</sup>  
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52 Patients whose survival time was unknown were excluded from analyses. This group  
53 comprised patients registered solely from a death certificate or diagnosed at autopsy.  
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### CONCORD-2 data quality control: three phases

We performed data quality checks in three consecutive phases: protocol adherence, exclusions, and editorial checks. After each phase a detailed report was sent to each cancer registry.

#### *Phase 1: Protocol adherence*

We first checked the compliance with the CONCORD-2 protocol of each of 37 variables (demographic characteristics, basis of diagnosis, date of diagnosis, topography, morphology, behavior, stage, vital status, date of last known vital status) in each tumor record in each data set. Any value not specified in the protocol was considered non-compliant. Each registry was sent a table of the number of records and the percentage compliance for each variable, and for each cancer. Minor issues were corrected by the CONCORD Central Analytic Team, after discussion with the registry. For major structural issues, 5 registries corrected and re-submitted their data.

#### *Phase 2: Exclusions*

Next, we checked for logical inconsistencies between the variables in each tumor record, for each cancer site. Exclusion criteria were defined *a priori*, based on the experience within the Cancer Survival Group, the checks performed in the first CONCORD study, the EUROcare (EUROpean CANcer REgistry based study on survival and care of cancer patients) data quality checks, the checks proposed by the International Agency for Research on Cancer (IARC), the descriptions of morphology in the World Health Organization (WHO)/IARC Classification of Tumors for each cancer and, finally, clinical expertise.<sup>3</sup>

We produced “exclusion tables” summarizing the quality of each data set. Data quality indicators were tabulated separately for patients diagnosed in 1995-99, 2000-04 and 2005-09, to enable evaluation of trends in data quality over time. We defined three broad categories for exclusion: ineligible (e.g., *in situ* neoplasm), definite error (e.g., sex-site mismatch) and possible error (e.g., apparent inconsistency between site and morphology). We had requested records of *in situ* neoplasms to assess the intensity of diagnostic activity, particularly for cancers of the breast and cervix, but *in situ* neoplasms were not included in survival analyses. The number and percentage of patients excluded from analysis are shown in **Table 2**.

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3 The majority (99.6%) of patients only had a single tumor record for any one cancer during  
4 1995-2009. However, since a small proportion of patients had more than one tumor record for  
5 a given cancer (“multiple tumor, same site”), it was necessary to apply the quality control  
6 checks to every tumor record independently before selecting the single tumor record to be  
7 included in survival analyses. For example, if a woman had an *in situ* neoplasm of the breast  
8 diagnosed in 2001 followed by an invasive primary breast cancer in 2007, the invasive cancer  
9 record was selected for inclusion in the analyses, provided it was free of error.  
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### 16 *Phase 3: Editorial tables*

17 We evaluated the distribution of key data quality indicators for each cancer and for each  
18 registry. These indicators included the proportion of cancers in the final data set that had been  
19 microscopically verified and the proportion of patients who had been lost to follow-up. We  
20 also checked the distributions of the day and the month of the dates of birth, diagnosis and  
21 last known vital status. These distributions should be flat, since one would expect about 8%  
22 of births, diagnoses and deaths to occur in each month, and about 3% on each day of a given  
23 month, except days 28-31: spikes in these distributions, often on the 1st, 15th or 16th day of  
24 the month, or for June or July, help to identify where registries had imputed missing elements  
25 of each date.  
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34 **Table 2** provides a summary of the exclusions and data quality indicators for adults (15-99  
35 years) diagnosed during 1995-2009 with one of 9 common cancers (all solid cancers), by US  
36 state. The calendar periods within which survival analyses could be performed by stage at  
37 diagnosis were constrained by the availability of data on stage only from 2001, and the  
38 change in coding from 2004 (see below). Therefore, the periods for which data quality  
39 indicators are presented do not exactly match the periods used for survival analysis.  
40 However, data quality has generally been very high in all US registries, and it tended to  
41 improve over the 15 years from 1995 to 2009. Only about 2% of tumors were registered from  
42 a death certificate only (DCO) or detected solely at autopsy. These records must be excluded  
43 from survival analyses because the follow-up time for these patients is unknown. However,  
44 the proportion of DCO registrations in the US was low overall (1.9%) and in all states (range:  
45 <0.1-3.5%). The proportion of other errors was very low (0.2%). Therefore, about 98% of the  
46 eligible patients were included in survival analyses. Practically all tumors (99.7%) were  
47 microscopically verified: this proportion was over 95% in almost all US states.  
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3 The proportion of the US population covered by this study is 80.6%. **Table 3** shows the  
4 population coverage by US state, as well as the number of patients diagnosed during 1995–  
5 2009 and included in the analyses.  
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### 8 9 **Study design**

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12 The focus of this monograph is on the striking differences in survival by race and stage at  
13 diagnosis. Since differences in survival between men and women were generally very small,  
14 compared to the differences in survival between blacks and whites (Table 4), we do not show  
15 survival estimates by sex in the articles on each cancer.  
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20 The CONCORD protocol required information on stage at diagnosis only for patients  
21 diagnosed from 2001 onward, because the completeness of data on stage in the US and many  
22 other countries was known to be much lower before 2001. For the analyses of survival by  
23 stage at diagnosis, patients were grouped by year of diagnosis into two calendar periods  
24 (2001-2003 and 2004-2009) to reflect changes in the methods used by US registries to collect  
25 data on stage at diagnosis. From 2001, most registries coded stage directly from the source  
26 data to SEER Summary Stage (SS) 2000.<sup>9</sup> From 2004, all registries began to derive Summary  
27 Stage 2000 from 15 pathological and clinical data items, using the Collaborative Staging  
28 System.<sup>10</sup> Data on stage at diagnosis were not available for Maryland or Wisconsin, or for  
29 cases diagnosed during 2004-2009 in Rhode Island.  
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34 We estimated net survival using the cohort approach for patients diagnosed in 2001-2003,  
35 since all patients had been followed up for at least five years by Dec 31, 2009. We used the  
36 complete approach to estimate net survival for patients diagnosed from 2004-2009, because  
37 five years of follow-up data were not available for all patients.  
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### 40 41 **Cohort approach**

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44 The cohort approach is the classical approach to survival analysis, in which all patients who  
45 are included in the analyses have had the opportunity to be followed for the full duration of  
46 survival analysis, in this case, five years. The cohort of patients is defined by the year or  
47 calendar period during which they were diagnosed, and each patient is followed up for the  
48 same length of time. In our analyses, at least 5 years of follow-up for vital status were  
49 available by the end of 2009 for all patients diagnosed during 2001-2003. Each patient,  
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3 irrespective of their actual year of diagnosis, contributes survival information at each point in  
4 follow-up time that, taken cumulatively, make up the survival estimate at 5 years.

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7 The cohort approach<sup>11, 12</sup> is considered the gold standard,<sup>11, 12</sup> because it provides a survival  
8 estimate for a group of patients who were diagnosed during the same year or period, who are  
9 likely to have been treated in similar fashion, and who have all been followed up for at least  
10 the duration of survival required. It is the natural approach to estimation of outcome, and is  
11 easy to interpret, but other approaches may be required if sufficient data are not available.  
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### 15 **Complete approach**

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18 The complete approach can be applied to estimate survival for patients who were diagnosed  
19 more recently, and for whom 5 full years of follow-up data may not be available at the  
20 closing date of the study. For example, some patients diagnosed 2004-2009 were followed up  
21 for less than 5 years. The ‘cohort’ approach can be used to estimate five-year survival for  
22 patients diagnosed in 2004, but 5-year survival can be estimated for the whole calendar  
23 period with the ‘complete’ approach, in which all the available follow-up data for patients  
24 diagnosed during 2004-2009 are used. The potential follow-up time for these patients varies  
25 between 1 year and 5 years.  
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### 32 **Age standardization**

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34 We compared survival estimates between US states, between blacks and whites, and between  
35 calendar periods of diagnosis. For age-specific survival estimates, comparison between  
36 populations or over time is straightforward, but if we want to compare overall (all-ages)  
37 survival estimates, age standardization is required. This is essentially for the same reasons as  
38 in comparison of overall incidence or mortality rates, namely that net survival may also vary  
39 widely with age at diagnosis, and the age profile of cancer patients may differ between the  
40 populations or change between the calendar periods among which we wish to compare  
41 overall survival.  
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48 For age-standardization of incidence or mortality rates, what matters is the age structure of  
49 the general population at risk of cancer. With cancer survival, however, what matters is the  
50 age profile of cancer patients, which is very different from the age profile of the general  
51 population. The weights used for age standardization of cancer survival estimates are thus  
52 completely different from those required for standardizing incidence or mortality rates. The  
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3 weight for each age group is provided by the proportion of cancer patients in that age group  
4 in a standard population of cancer patients.  
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7 The International Cancer Survival Standard (ICSS) weights<sup>13</sup> are strongly recommended for  
8 international comparisons of cancer survival. They comprise three sets of standard age  
9 weights, derived from discriminant analysis to find the smallest number of sets of weights  
10 that enable adequate standardization of survival. Each standard is applicable to a range of  
11 different cancers, and provides age-standardized survival estimates that are not too different  
12 from the unstandardized estimates. The same age weights can be used for men and women,  
13 and for direct comparisons of age-standardized net survival between patient groups defined  
14 by sex and race.  
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## 20 21 22 23 **Statistical methods**

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25 We estimated net survival up to 5 years after diagnosis, with 95% confidence intervals (CI),  
26 using the Pohar Perme estimator,<sup>14</sup> implemented in the *Stata*<sup>15</sup> algorithm *stns*.<sup>16</sup> We analyzed  
27 survival by state, race, stage at diagnosis and calendar period of diagnosis. Net survival is the  
28 probability of surviving up to a given time since diagnosis after controlling for other causes  
29 of death (background mortality). To control for the wide differences in background mortality  
30 among participating states and racial/ethnic groups, we constructed life tables of all-cause  
31 mortality in the general population of each state from the number of deaths and the  
32 population, by single year of age, sex, calendar year and, where possible, by race (black,  
33 white).  
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41 Net survival in adults was estimated for five age groups (15-44, 45-54, 55-64, 65-74, and 75-  
42 99 years; except for prostate cancer 15-54, 55-64, 65-74, 75-84 and 85-99 years). We  
43 obtained age-standardized survival estimates using the International Cancer Survival  
44 Standard (ICSS) weights. For children, survival was estimated for the age groups 0-4, 5-9  
45 and 10-14 years. We obtained age-standardized estimates by assigning equal weights to the  
46 three age-specific estimates.<sup>17</sup>  
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52 We derived standard errors for both unstandardized and age-standardized survival estimates  
53 using the Greenwood method,<sup>18</sup> assuming a normal distribution, and truncated to the range 0-  
54 100. We did not estimate survival if fewer than ten patients were available for analysis. Age-  
55 standardization was only performed if there were at least 10 patients in each of the age  
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3 categories specified above. If an age-specific estimate could not be obtained, we merged data  
4 for adjacent age groups and assigned the combined estimate to both age groups. If two or  
5 more age-specific estimates could not be obtained, we present only the pooled,  
6 unstandardized estimate for all ages combined: these estimates are italicized in Tables 2 and 3  
7 of the Appendix.  
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11 For each of the 37 states, we present estimates of age-standardized net survival for each  
12 cancer up to 5 years after diagnosis. For convenience, we report cumulative survival  
13 probabilities (in the range 0-1) as percentages in the range 0-100%.  
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### 16 **Life tables**

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18 For the analyses presented in this *Supplement*, we used the life tables for background  
19 mortality that were constructed for the CONCORD-2 study.<sup>19</sup>  
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23 To control for variation between US states in background mortality by age, sex, race and  
24 calendar year while estimating net survival, we used life tables of all-cause mortality rates by  
25 single year of age (0-99 years), for each state, race, calendar year (2001-2010) and sex. For a  
26 few states in which the black population is small, it was not possible to construct adequately  
27 robust life tables of all-cause mortality by single year of age and sex for blacks, so net  
28 survival estimates for blacks in those states are not presented separately. These life tables can  
29 be downloaded from the CONCORD library of over 12,000 life tables.<sup>20</sup> The library includes  
30 detailed statistical and graphical reports on the robustness of the life tables for each US state.  
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34 We received raw data on death counts and populations for each US state. To produce life  
35 tables for each US state by race, sex and calendar year (state- and race-specific life tables) we  
36 used a flexible Poisson model<sup>21</sup> that enables creation of single-year-of-age life tables even  
37 when the raw data are sparse. We checked the life tables by examination of semi-log plots of  
38 age-sex-mortality rates, life expectancy at birth, the probability of death in the age bands 15–  
39 59, 60–84 and 85–99 years and, where necessary, the model residuals, to examine the  
40 goodness of fit of the models by age and sex.  
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### 51 **Graphical representation**

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3 In each cancer-specific article in this *Supplement*, trends, geographic variations and  
4 differences in age-standardized survival by race are presented graphically in bar-charts and  
5 funnel plots.<sup>22</sup>  
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### 8 **Bar-charts**

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10 Results were summarized in bar-charts of 5-year age-standardized net survival by calendar  
11 period (2001-2003 and 2004-2009), for each state, grouped within the four US geographic  
12 Census Regions (Northeast, South, Midwest, West). The results for each Region are  
13 presented with a different color. Within each Region, darker shades indicate NPCR registries,  
14 while lighter shades indicate SEER registries. Five registries funded by both SEER and  
15 NPCR were grouped with SEER because they use both passive and active follow-up; they are  
16 indicated with an asterisk “\*”.  
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23 The survival estimates for each state in 2004-2009 are ranked from high to low within each  
24 US Census Region. The same ranking is then applied to the results for 2001-2003, to  
25 facilitate examination of changes in survival from 2001-2003 to 2004-2009 within each state.  
26 The absolute difference (%) in 5-year net survival between the two periods is also shown for  
27 each state.  
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32 Each graphic includes the pooled survival estimates for all 37 participating states combined.  
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### 35 **Funnel plots**

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37 Funnel plots are graphical representations designed to detect excessive variation in  
38 performance indicators by simple visual inspection of the data.<sup>23</sup> They can be used to provide  
39 a simple and informative display of geographical variation or time trends in population-based  
40 cancer survival measures (e.g. age-standardized net survival).  
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44 A funnel plot comprises four elements:<sup>22</sup> the target (or reference) value for the outcome, a set  
45 of control limits (the funnel), data points for the outcome variable (indicator) and the  
46 associated precision parameter for each data point. Data points outside the control limits (the  
47 funnel) indicate variation in the indicator beyond what would be expected by chance, while  
48 taking account of precision.<sup>23</sup>  
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53 The funnel plot in Figure 1 shows, as an example, 5-year age-standardized net survival for  
54 breast cancer in the US during 2004-2009, by race and state. It is constructed by plotting the  
55 37 state-specific survival estimates for breast cancer during 2004-2009, on the y-axis, against  
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3 their associated precision, on the x-axis, forming a scatter plot. Fewer data points are  
4 available for blacks (28 states) than for whites (37 states), because of the difficulty in  
5 constructing robust life tables for blacks in every state. The precision parameter in this  
6 example is in fact the precision of each age-standardized net survival estimate (the inverse of  
7 its variance). This is a natural choice to represent the statistical precision of each estimate, but  
8 it could be any function that is proportional to the inverse of the variance.  
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13 The target (the solid horizontal line in Figure 1) is then superimposed. This is a constant  
14 value, considered independent of the observations, and it specifies the expected value for the  
15 outcome. The target shown in Figure 1 is the 5-year age-standardized net survival estimate  
16 for the pooled US data for women diagnosed with breast cancer during 2004-2009. The  
17 pooled US estimate was selected as the target to show the extent to which survival for blacks  
18 and whites in each state varies around the overall survival estimate for the US.  
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23 The control limits (the dashed lines in Figure 1) are also independent of the individual  
24 survival estimates. They depend only on the target value, and their correct formulation  
25 depends on the underlying theoretical distribution of the target value. The control limits for a  
26 given level of significance ( $\alpha$ ) are drawn around the target value across the entire observed  
27 range of precision of the individual estimates. The most common levels of significance are  
28  $\alpha=5\%$  and  $\alpha=0.2\%$ , so that the resulting 95% and 99.8% control limits represent  
29 approximately two and three standard deviations, respectively, on either side of the target  
30 value, at each level of precision. An estimate that appears outside the control limits is  
31 identified as diverging from the target value, and is an "out-of-control" estimate, in other  
32 words a probable outlier that may need to be investigated further.  
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42 In Figure 1, as with all the funnel plots reported in this *Supplement*, 5-year age-standardized  
43 net survival is represented by open circles for white patients and by solid circles for black  
44 patients. Funnel plots are extremely powerful tools for visual examination of variation in an  
45 indicator: we can perceive at first glance that 5-year survival in blacks is persistently lower  
46 than would be expected (the pooled US survival estimate, the "target") and that survival for  
47 blacks is generally lower than for whites.  
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## 51 52 53 54 55 **DISCUSSION** 56 57 58 59 60

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3 This article summarizes the data quality control procedures, analytic methods and graphical  
4 presentations that have been deployed for all the data sets reported in this *Supplement*. The  
5 quality of population-based data from the 37 participating US cancer registries was  
6 impressively high (Table 2). More details about the quality indicators for each cancer can be  
7 found in the web-appendix<sup>b</sup> to the CONCORD-2 article.<sup>3</sup>

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11 For NPCR registries that use only passive follow-up to determine the vital status of registered  
12 cancer patients (the “presumed alive” method), survival estimates may be inflated if the  
13 cancer registrations for some patients who have in fact died could not be successfully linked  
14 to the data from their death certificate. The vital statistics offices in each state have reported  
15 all death certificate information to the National Death Index (NDI) since 1979. Passive  
16 methods of follow-up are known to be efficient because of the completeness and accuracy of  
17 the National Death Index, which tends to capture 1-3% more deaths than if the registry can  
18 only link its data to the state death index<sup>24</sup>. Most of the extra deaths captured in this way will  
19 be those of patients who migrated to a different state following their cancer diagnosis.  
20 However, the registries included in these analyses had all matched their data against the  
21 National Death Index before data submission, so the completeness of vital status  
22 ascertainment is expected to be extremely high, although it may not capture out-of-country  
23 deaths.  
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34 A major strength of this study is the use of life tables that are specific for each state, each race  
35 (white, black) and each calendar year, to control for differences and changes in background  
36 mortality by single year of age, sex, race and single calendar year. This approach provided  
37 the tightest possible control of background mortality with the available data. More specific  
38 life tables may be considered in future studies, subject to the availability of high-quality data  
39 on death and population counts for Hispanics or other major racial or ethnic groups.  
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45 The CONCORD-2 protocol required registries to provide information on stage at diagnosis  
46 for patients diagnosed in 2001 or later. Calendar years of diagnosis were then grouped for  
47 analysis of survival by stage into 2001-2003 and 2004-2009, to reflect a change in the US  
48 stage coding system from 2004.  
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52 This choice of calendar periods imposed the following selection of analytic approach. We  
53 were able to estimate 5-year net survival with the cohort approach for patients diagnosed in  
54 2001-2003, since all patients had at least 5 years of potential follow-up. However, the period  
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58 <sup>b</sup> [http://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(14\)62038-9/supplemental](http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(14)62038-9/supplemental)  
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3 approach<sup>25</sup> that was adopted to estimate 5-year survival for patients diagnosed 2005-2009 in  
4 the CONCORD-2 study<sup>3</sup> could only have been used to estimate 5-year survival by stage for  
5 patients diagnosed during 2004-2009 if stage data had also been available for patients  
6 diagnosed in 2000. We therefore adopted the complete approach. In this approach, more  
7 information is available to estimate survival in the early years of follow-up than later years.  
8 Only patients diagnosed in 2004 had the potential to be followed up for 5 years by Dec 31,  
9 2009; only patients diagnosed during 2004 and 2005 had the potential to contribute to the  
10 conditional survival probabilities between 4 and 5 years after diagnosis; and so on. This leads  
11 to some increased variation around the 5-year survival estimates for 2004-2009 compared  
12 with those for 2001-2003. This is reflected in the confidence intervals, and slightly lower  
13 precision, seen in the funnel plots for 2004-2009 in some of the site-specific articles.  
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18 This is the most extensive analysis of 5-year population-based cancer survival in the US to  
19 date, with survival trends for 10 common cancers in 37 states that include 80% of the US  
20 population. Here, we have focused on variations in survival by race and stage at diagnosis for  
21 patients diagnosed during 2001-2009.  
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26 Population-based cancer survival is a key measure of the overall effectiveness of the health  
27 system in in dealing with cancer. The high quality of the data from the US cancer registries,  
28 implementation of the most up-to-date and unbiased estimator of net survival, combined with  
29 the use of state- and race-specific life tables, all help to ensure that these cancer survival  
30 estimates are robust and comparable. We believe they can be confidently used by policy-  
31 makers to identify inequities in cancer survival by race in each state and for the US as a  
32 whole, and to plan cancer control strategies that promote equal opportunity for the best  
33 possible outcomes after a cancer diagnosis.  
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## Legends for Tables and Figures

### Table 1 Definition of malignancies

### Table 2 Data quality indicators for patients diagnosed during 1995–2009, by US state (all solid cancers combined)

Table 2 footnotes:

<sup>a</sup> *In situ* malignancy (ICD-O-3 behavior code 2): some registries do not register *in situ* cancers; other registries did not submit them. Other: records with incomplete data, or for tumors that are benign (behavior code 0), of uncertain behavior (1), metastatic from another organ (6), or unknown if primary or metastatic (9); or for patients with age outside the range 15-99 years (adults).

<sup>b</sup> DCO: tumors registered from a death certificate only (DCO), or detected solely at autopsy. Other: vital status or sex unknown; invalid sequence of dates; inconsistency of sex-site, site-morphology, age-site, age-morphology, or age-site-morphology.

<sup>c</sup> MV: microscopically verified. Non-specific morphology (solid tumors only): ICD-O-3 morphology code in the range 8000-8005. Censored: patients diagnosed during 1995-2004, with last known vital status "alive", but less than five years of follow-up.

<sup>d</sup> P=Passive ("presumed alive") method; P&A=Passive and Active ("reported alive") methods; see text.

### Table 3: Population coverage and number of patients diagnosed during 1995–2009, by US state

Table 3 footnotes:

<sup>a</sup> Data are from the UN Population Division for 2009

<sup>b</sup> Acute lymphoblastic leukemia, children (0-14 years) only

### Table 4: Age-standardized 5-year net survival (NS, %) for adults (15-99 years) diagnosed with one of 10 common malignancies and children (0-14 years) diagnosed with acute lymphoblastic leukemia (ALL) during 2004-2009, by race and sex: United States<sup>a</sup>

Table 4 footnotes:

<sup>a</sup> Population coverage represents 80.6 % of the US population in 2009 (UN Population Division)

<sup>b</sup> A negative value means that males have lower survival than females

<sup>c</sup> A negative value means that blacks have lower survival than whites

<sup>d</sup> Acute lymphoblastic leukemia, children (0-14 years) only

### Figure 1: 5-year age-standardized net survival for women (15-99 years) diagnosed with breast cancer in 2004-2009, by state and race

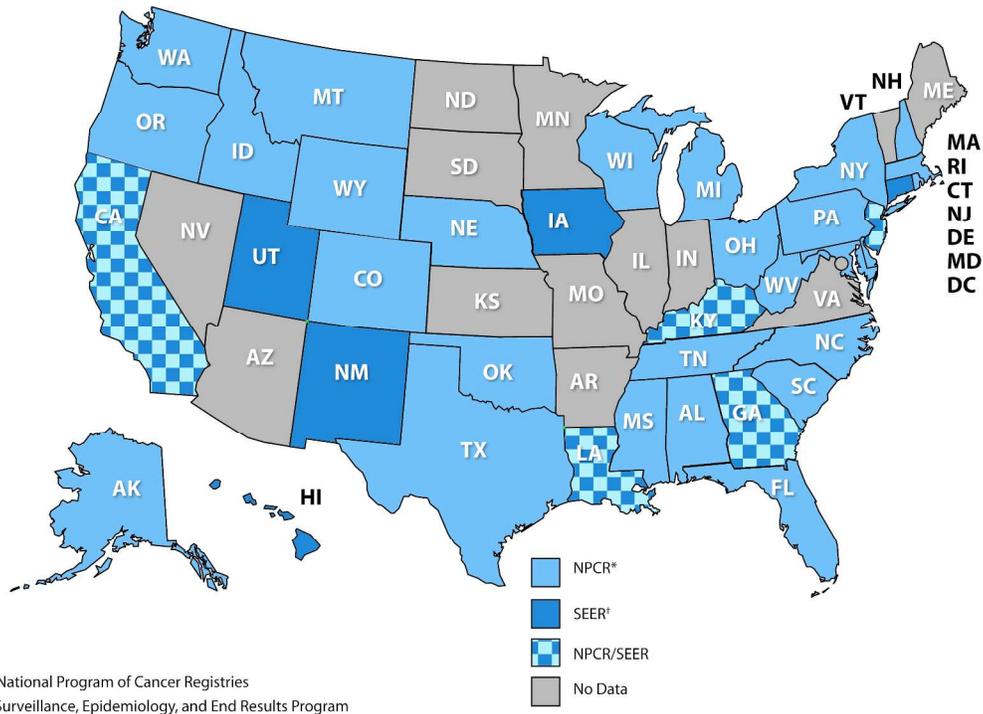
Figure 1 footnote: Each data point represents the survival estimate for a US state, either for blacks (28 states) or whites (37 states; see text).

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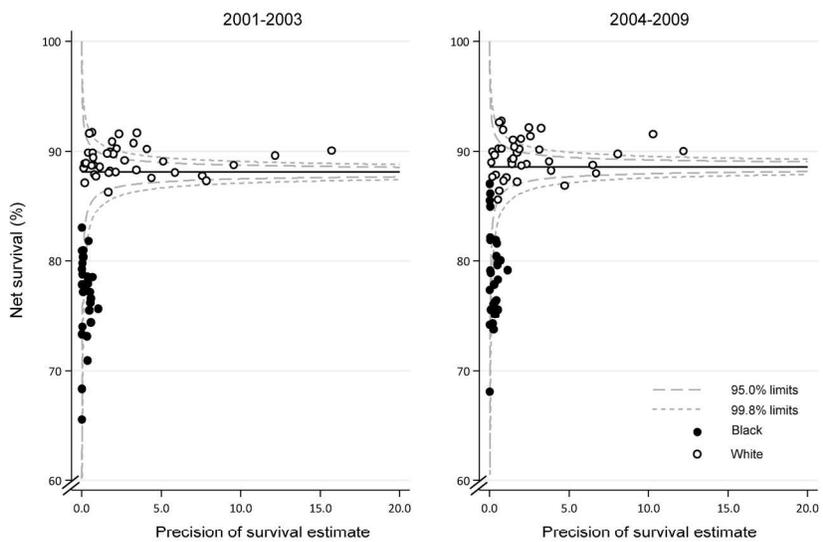


\*National Program of Cancer Registries  
 †Surveillance, Epidemiology, and End Results Program

Figure 1

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Table 1 Definition of malignancies

Malignancy	Topography or morphology codes	Description
Stomach	C16.0-C16.6; C16.8-C16.9	Stomach
Colon	C18.0-C18.9; C19.9	Colon and rectosigmoid junction
Rectum	C20.9; C21.0-C21.2, C21.8	Rectum, anus and anal canal
Liver	C22.0-C22.1	Liver and intrahepatic bile ducts
Lung	C34.0-C34.3; C34.8-C34.9	Lung and bronchus
Breast (women)	C50.0-C50.6; C50.8-C50.9	Breast
Cervix	C53.0-C53.1; C53.8-C53.9	Cervix uteri
Ovary	C48.0-C48.2; C56.9; C57.0-C57.4; C57.7-C57.9	Ovary, fallopian tube and uterine ligaments, other and unspecified female genital organs, peritoneum and retroperitoneum
Prostate	C61.9	Prostate gland
Leukaemia (children)	9727; 9728; 9729; 9835; 9836; 9837	Precursor-cell acute lymphoblastic leukaemia (ALL)

	Calendar period	Patients submitted	Ineligible (%) <sup>a</sup>		Exclusions (%) <sup>b</sup>			Available for analyses	Data quality indicators (%) <sup>c</sup>			Type of follow up <sup>d</sup>	
			In situ	Other	Eligible patients	DCO	Other		MV	Non-specific morphology	Lost to follow-up		Censored
<b>US registries</b>	<b>1995 - 2009</b>	<b>10,115,271</b>	<b>6.4</b>	<b>1.4</b>	<b>9,325,815</b>	<b>1.9</b>	<b>0.2</b>	<b>9,142,718</b>	<b>99.7</b>	<b>1.3</b>	<b>1.0</b>	<b>&lt;0.1</b>	
Alabama	1996 - 2009	184,581	0.0	1.3	182,156	1.9	0.2	178,484	95.9	1.1	0.0	0.0	P
Alaska	1996 - 2009	19,959	6.9	2.9	18,002	0.7	0.2	17,852	95.8	1.7	0.0	0.0	P
California	1995 - 2009	1,326,462	6.1	2.1	1,218,053	1.2	0.2	1,202,096	95.8	0.8	3.2	0.0	P & A
Colorado	1995 - 2009	162,405	6.4	1.4	149,860	2.4	0.2	146,306	95.8	0.8	0.0	0.0	P
Connecticut	1995 - 2009	180,154	7.8	1.1	164,128	1.3	0.2	161,865	97.0	0.7	4.5	0.0	P & A
Delaware	1995 - 2009	41,768	6.1	1.2	38,717	2.0	0.2	37,956	96.1	0.7	0.0	0.0	P
Florida	1995 - 2009	928,713	5.0	0.8	874,825	3.3	0.2	846,156	97.2	1.5	0.0	<0.1	P
Georgia	2000 - 2009	241,967	6.0	0.6	225,831	1.8	0.2	221,675	96.2	0.7	2.1	0.0	P & A
Hawaii	1995 - 2009	55,510	7.6	1.0	50,774	1.2	0.2	50,116	96.6	0.3	4.1	0.0	P & A
Idaho	1995 - 2009	51,319	4.6	1.3	48,277	2.5	0.2	47,086	95.8	0.4	0.0	0.0	P
Iowa	1995 - 2009	146,231	5.0	1.3	136,938	1.5	0.2	134,776	95.2	0.5	1.4	0.0	P
Kentucky	1995 - 2009	208,365	4.7	0.8	197,074	1.4	0.2	194,119	93.7	1.4	1.1	0.0	P & A
Louisiana	1995 - 2009	205,149	4.4	1.1	193,856	1.5	0.2	190,693	95.2	0.4	2.2	0.0	P & A
Maryland	1996 - 2009	225,540	10.6	1.1	199,088	2.9	0.3	193,230	94.8	1.8	0.0	0.0	P
Massachusetts	1995 - 2009	336,858	9.1	0.8	303,282	1.7	0.2	297,992	95.8	1.4	0.0	<0.1	P
Michigan	1995 - 2009	522,531	12.9	1.0	449,914	1.1	0.2	444,382	94.7	3.0	0.0	0.1	P & A
Mississippi	2003 - 2009	64,396	4.7	0.9	60,833	3.1	0.2	58,974	96.7	0.4	0.0	0.0	P
Montana	1995 - 2009	48,221	10.1	1.7	42,512	3.5	0.2	41,087	95.8	0.3	9.8	0.0	P & A
Nebraska	1995 - 2009	88,971	4.9	1.5	83,231	1.5	0.2	81,980	96.1	1.2	0.0	<0.1	P
New Hampshire	1995 - 2009	60,507	7.6	0.9	55,347	1.7	0.2	54,345	95.1	1.1	0.0	0.0	P
New Jersey	1995 - 2009	440,395	6.7	1.6	403,724	1.3	0.2	398,191	96.2	1.0	2.8	0.0	P & A
New Mexico	1995 - 2009	70,628	5.4	0.8	66,269	3.1	0.2	64,241	94.8	1.1	5.1	0.0	P & A
New York	1995 - 2009	940,361	7.7	2.6	842,888	1.7	0.2	827,621	94.8	0.9	0.0	0.0	P
North Carolina	1995 - 2009	375,205	5.9	0.7	350,656	1.7	0.1	344,750	96.3	0.7	0.0	0.0	P
Ohio	2001 - 2009	334,006	6.1	0.7	311,520	2.8	0.2	303,146	96.3	2.0	0.0	0.0	P
Oklahoma	1997 - 2009	147,158	4.3	1.0	139,322	2.9	0.2	135,165	93.1	1.6	0.0	0.0	P
Oregon	1996 - 2009	155,767	5.3	0.8	146,145	1.8	0.2	143,473	94.2	1.4	0.0	<0.1	P
Pennsylvania	1995 - 2009	682,922	6.5	1.5	628,121	1.3	0.2	619,287	95.7	0.7	0.0	0.0	P
Rhode Island	1995 - 2009	55,914	6.3	0.8	51,937	1.6	0.2	51,052	96.0	2.7	0.0	0.0	P
South Carolina	1996 - 2009	184,660	5.3	0.6	173,791	2.0	0.2	170,159	94.8	2.0	0.0	0.0	P
Tennessee	2003 - 2009	133,826	5.1	0.9	125,694	2.9	0.2	122,080	96.7	0.4	0.0	<0.1	P
Texas	1995 - 2009	814,295	5.0	1.4	762,429	3.2	0.2	737,811	94.0	2.5	0.0	0.0	P
Utah	1995 - 2009	63,227	5.9	1.2	58,729	0.4	0.2	58,373	97.0	0.4	3.0	0.0	P & A
Washington	1995 - 2008	246,015	5.9	1.3	228,416	1.2	0.2	225,458	95.1	0.8	1.9	<0.1	P & A
West Virginia	1995 - 2009	101,396	4.6	1.1	95,644	1.8	0.2	93,880	93.6	0.9	0.0	0.0	P
Wisconsin	1995 - 2009	248,955	7.1	1.3	228,035	<0.1	0.3	227,213	96.4	2.3	0.0	0.0	P
Wyoming	1995 - 2009	20,934	4.7	0.8	19,797	0.6	0.2	19,648	95.6	0.6	0.0	0.0	P & A

Cancer

	Population covered <sup>a</sup>	% of national	Stomach	Colon	Rectum	Liver	Lung	Breast (F)	Cervix	Ovary	Prostate	Leukemia	ALL <sup>b</sup>	Total
<b>1 Northeast</b>	<b>53,343,618</b>	<b>17.2</b>	<b>71,864</b>	<b>364,080</b>	<b>98,955</b>	<b>45,343</b>	<b>548,066</b>	<b>558,858</b>	<b>36,809</b>	<b>73,576</b>	<b>612,802</b>	<b>96,851</b>	<b>5,974</b>	<b>2,513,178</b>
2 Connecticut	3,518,288	1.1	4,890	23,612	6,708	2,817	36,756	39,027	1,987	4,717	41,351	6,435	412	168,712
4 Massachusetts	6,593,587	2.1	7,881	43,253	12,295	5,223	68,739	73,117	3,524	8,761	75,199	10,951	766	309,709
5 New Hampshire	1,324,575	0.4	1,119	7,570	2,272	691	12,905	13,540	706	1,608	13,934	2,310	145	56,800
6 New Jersey	8,707,739	2.8	12,299	59,971	15,731	7,074	86,105	90,804	6,766	12,189	107,252	15,908	1,081	415,180
7 New York	19,541,453	6.3	27,815	124,529	33,385	18,226	182,745	192,993	14,457	26,279	207,192	34,253	2,113	863,987
8 Pennsylvania	12,604,767	4.1	16,277	97,350	26,642	10,501	148,024	137,529	8,655	18,753	155,556	25,362	1,388	646,037
9 Rhode Island	1,053,209	0.3	1,583	7,795	1,922	811	12,792	11,848	714	1,269	12,318	1,632	69	52,753
<b>10 South</b>	<b>101,946,182</b>	<b>32.9</b>	<b>83,760</b>	<b>497,182</b>	<b>136,823</b>	<b>63,616</b>	<b>906,514</b>	<b>801,768</b>	<b>62,815</b>	<b>94,898</b>	<b>877,756</b>	<b>139,280</b>	<b>9,699</b>	<b>3,674,111</b>
11 Alabama	4,708,708	1.5	4,164	25,870	6,761	2,672	47,987	40,510	3,029	5,019	42,472	6,354	384	185,222
12 Delaware	885,122	0.3	882	5,235	1,471	555	9,670	8,320	605	1,014	10,204	1,320	93	39,369
13 Florida	18,537,969	6.0	20,634	124,316	31,640	14,460	215,900	184,051	13,971	24,081	217,103	34,954	1,779	882,889
14 Georgia	9,829,211	3.2	5,038	28,739	8,876	3,764	54,615	52,462	3,905	6,327	57,949	8,344	660	230,679
15 Kentucky	4,314,113	1.4	3,803	28,207	8,311	2,622	61,642	40,803	3,451	5,062	40,218	7,656	448	202,223
16 Louisiana	4,492,076	1.5	5,228	27,450	8,001	3,519	49,414	40,902	3,494	4,313	48,372	7,109	443	198,245
17 Maryland	5,699,478	1.8	4,443	26,837	7,112	3,051	45,181	47,220	2,865	5,364	51,157	6,171	271	199,672
18 Mississippi	2,951,996	1.0	1,403	8,436	2,353	1,027	15,995	12,124	965	1,327	15,344	2,007	137	61,118
19 North Carolina	9,380,884	3.0	7,405	46,540	13,170	5,200	88,642	82,085	5,357	9,650	86,701	12,557	909	358,216
20 Oklahoma	3,687,050	1.2	2,619	19,103	5,209	2,243	37,451	31,244	2,282	3,763	31,251	5,760	373	141,298
21 South Carolina	4,561,242	1.5	4,129	23,391	6,362	2,429	42,490	38,694	2,932	4,369	45,363	6,045	372	176,576
22 Tennessee	6,296,254	2.0	2,534	16,679	4,817	1,982	35,098	27,996	1,921	3,113	27,940	4,621	331	127,032
23 Texas	24,782,302	8.0	19,523	102,010	28,511	18,846	173,838	176,373	16,384	18,903	183,423	32,603	3,330	773,744
West Virginia	1,819,777	0.6	1,955	14,369	4,229	1,246	28,591	18,984	1,654	2,593	20,259	3,779	169	97,828
<b>24 Midwest</b>	<b>31,971,621</b>	<b>10.3</b>	<b>25,906</b>	<b>172,649</b>	<b>48,545</b>	<b>18,747</b>	<b>289,855</b>	<b>274,527</b>	<b>16,538</b>	<b>35,847</b>	<b>308,883</b>	<b>51,542</b>	<b>3,095</b>	<b>1,246,134</b>
25 Iowa	3,007,856	1.0	2,771	22,550	6,012	1,747	32,616	30,562	1,726	4,321	32,471	6,737	348	141,861
26 Michigan	9,969,727	3.2	10,491	59,825	16,607	7,499	108,252	99,647	6,373	13,398	122,290	18,459	1,136	463,977
27 Nebraska	1,796,619	0.6	1,670	13,064	3,837	1,226	18,417	19,170	1,229	2,399	20,968	3,929	223	86,132
28 Ohio	11,542,645	3.7	6,685	43,767	12,779	4,777	80,262	69,842	4,279	8,504	72,251	11,605	726	315,477
29 Wisconsin	5,654,774	1.8	4,289	33,443	9,310	3,498	50,308	55,306	2,931	7,225	60,903	10,812	662	238,687
<b>30 West</b>	<b>62,329,218</b>	<b>20.1</b>	<b>57,922</b>	<b>268,833</b>	<b>84,204</b>	<b>48,429</b>	<b>419,871</b>	<b>505,928</b>	<b>34,950</b>	<b>64,828</b>	<b>530,771</b>	<b>83,321</b>	<b>8,293</b>	<b>2,107,350</b>
31 Alaska	698,473	0.2	480	2,305	819	450	4,073	4,555	349	470	4,351	649	86	18,587
32 California	36,961,664	11.9	38,136	162,637	50,069	32,671	249,281	301,418	22,916	38,622	306,346	47,886	5,370	1,255,352
33 Colorado	5,024,748	1.6	3,214	19,086	5,905	2,696	27,649	39,349	2,375	4,942	41,090	6,703	593	153,602
34 Hawaii	1,295,178	0.4	2,576	7,559	2,428	1,766	10,079	12,011	825	1,314	11,558	1,685	150	51,951
35 Idaho	1,545,801	0.5	969	6,058	2,034	580	9,772	11,548	655	1,548	13,922	2,279	181	49,546
36 Montana	974,989	0.3	860	5,466	1,743	451	9,345	9,336	509	1,243	12,134	1,694	101	42,882
37 New Mexico	2,009,671	0.6	1,937	8,468	2,765	1,763	12,024	15,681	1,176	1,967	18,460	2,859	274	67,374
38 Oregon	3,825,657	1.2	2,883	18,637	5,868	2,431	34,325	36,514	1,886	4,537	36,392	5,419	427	149,319
39 Utah	2,784,572	0.9	1,266	7,430	2,564	864	7,440	14,803	905	2,044	21,057	2,983	353	61,709
40 Washington	6,664,195	2.2	5,200	28,488	9,253	4,484	51,862	56,176	3,045	7,536	59,414	10,349	708	236,515
41 Wyoming	544,270	0.2	401	2,699	756	273	4,021	4,537	309	605	6,047	815	50	20,513
<b>42 US registries</b>	<b>249,590,639</b>	<b>80.6</b>	<b>239,452</b>	<b>1,302,744</b>	<b>368,527</b>	<b>176,135</b>	<b>2,164,306</b>	<b>2,141,081</b>	<b>151,112</b>	<b>269,149</b>	<b>2,330,212</b>	<b>370,994</b>	<b>27,061</b>	<b>9,540,773</b>

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Cancer	All races						White						Black						Difference (%) between				
	Both sexes		Male		Female		Both sexes		Male		Female		Both sexes		Male		Female		Male - Female <sup>b</sup>		Black - White <sup>c</sup>		
	NS (%)	95% CI	NS (%)	95% CI	NS (%)	95% CI	NS (%)	95% CI	NS (%)	95% CI	NS (%)	95% CI	NS (%)	95% CI	NS (%)	95% CI	NS (%)	95% CI	All races	White	Black	Male	Female
Stomach	29.0	28.6 - 29.5	26.5	25.9 - 27.0	33.4	32.7 - 34.1	28.0	27.5 - 28.5	25.3	24.7 - 26.0	32.7	31.8 - 33.5	28.3	27.1 - 29.4	24.5	23.0 - 25.9	33.7	32.0 - 35.4	-6.9	-7.3	-9.2	-0.9	1.0
Colon	64.6	64.4 - 64.9	63.7	63.3 - 64.0	65.7	65.4 - 66.0	65.4	65.2 - 65.7	64.5	64.1 - 64.8	66.4	66.1 - 66.8	56.6	55.9 - 57.3	54.5	53.4 - 55.5	58.6	57.7 - 59.5	-2.0	-1.9	-4.1	-10.0	-7.8
Rectum	64.0	63.6 - 64.4	62.4	61.8 - 63.0	66.1	65.5 - 66.7	64.2	63.7 - 64.7	62.8	62.1 - 63.4	66.1	65.5 - 66.8	57.5	56.0 - 59.0	53.6	51.3 - 55.9	61.7	59.7 - 63.8	-3.7	-3.4	-8.1	-9.2	-4.4
Liver	14.8	14.4 - 15.2	14.3	13.8 - 14.8	16.8	16.1 - 17.6	14.3	13.8 - 14.8	13.8	13.3 - 14.4	16.4	15.5 - 17.3	11.4	10.3 - 12.5	10.8	9.4 - 12.3	14.2	12.2 - 16.2	-2.5	-2.6	-3.4	-3.0	-2.1
Lung	19.0	18.8 - 19.1	16.1	16.0 - 16.3	22.4	22.2 - 22.6	19.4	19.2 - 19.5	16.5	16.3 - 16.7	22.7	22.4 - 22.9	14.9	14.5 - 15.2	12.3	11.9 - 12.8	18.3	17.7 - 19.0	-6.2	-6.1	-6.0	-4.2	-4.3
Breast (F)	-	-	-	-	88.6	88.4 - 88.8	-	-	-	-	89.6	89.4 - 89.8	-	-	-	-	78.4	77.7 - 79.1	-	-	-	-	-11.2
Cervix	-	-	-	-	62.8	62.2 - 63.5	-	-	-	-	63.5	62.7 - 64.2	-	-	-	-	55.5	53.9 - 57.1	-	-	-	-	-7.9
Ovary	-	-	-	-	41.0	40.5 - 41.5	-	-	-	-	41.7	41.2 - 42.2	-	-	-	-	31.1	29.5 - 32.7	-	-	-	-	-10.6
Prostate	-	-	96.9	96.7 - 97.1	-	-	-	-	96.9	96.7 - 97.1	-	-	-	-	92.7	92.1 - 93.3	-	-	-	-	-	-4.2	-
Leukemia	52.1	51.7 - 52.5	52.0	51.5 - 52.5	52.3	51.7 - 52.9	52.7	52.3 - 53.1	52.5	51.9 - 53.0	52.9	52.3 - 53.6	41.9	40.4 - 43.5	41.1	38.9 - 43.3	42.7	40.6 - 44.9	-0.3	-0.4	-1.6	-11.3	-10.2
ALL <sup>d</sup>	88.1	87.2 - 88.9	87.4	86.2 - 88.6	88.9	87.6 - 90.2	88.6	87.6 - 89.5	88.1	86.8 - 89.4	89.1	87.7 - 90.6	83.6	80.6 - 86.6	82.3	78.4 - 86.2	85.1	80.1 - 90.1	-1.5	-1.0	-2.8	-5.8	-4.0

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3 **Population-based cancer survival in the US: data, quality control and statistical**  
4 **methods**  
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7 Claudia Allemani,<sup>1</sup> Rhea Harewood,<sup>1</sup> Chris Johnson,<sup>2</sup> Helena Carreira,<sup>1</sup> Devon Spika,<sup>1</sup>  
8 Audrey Bonaventure,<sup>1</sup> Kevin Ward,<sup>3</sup> Hannah K Weir,<sup>4</sup> Michel P Coleman<sup>1</sup>  
9

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11 **Running title:** Data, quality control and statistical methods  
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13 **Keywords:** cancer, population-based, survival, statistical methods, NPCR, SEER  
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15 <sup>1</sup> Cancer Survival Group, Department of Non-Communicable Disease Epidemiology,  
16 London School of Hygiene and Tropical Medicine, Keppel Street, London WC1E 7HT,  
17 UK  
18  
19

20  
21 <sup>2</sup> Cancer Data Registry of Idaho, Boise, ID, USA  
22

23 <sup>3</sup> Georgia Center for Cancer Statistics, Emory University, Atlanta, GA, USA  
24

25 <sup>4</sup> Division of Cancer Prevention and Control, National Center for Chronic Disease  
26 Prevention and Health Promotion, Centers for Disease Control and Prevention, 4770  
27 Buford Highway, Atlanta, GA 30341, USA  
28  
29  
30

31 **Correspondence:** Claudia Allemani, Cancer Survival Group, Department of Non-  
32 Communicable Disease Epidemiology, London School of Hygiene and Tropical Medicine,  
33 Keppel Street, London WC1E 7HT, UK. Tel +44 20 7927 2855  
34  
35

36  
37 [Claudia.Allemani@lshtm.ac.uk](mailto:Claudia.Allemani@lshtm.ac.uk)  
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44 **Text pages**  
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46 **Tables:** 3  
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8

9 **Precis for use in the Table of Contents:** Population-based cancer survival is a key measure  
10 of the overall effectiveness of health systems in managing the cancer burden. The high  
11 quality of US cancer registry data, 80% population coverage in the CONCORD-2 study and  
12 the use of an unbiased estimator of net survival ensure that the survival trends we report are  
13 robustly comparable by race and state. These results can be used to plan and evaluate cancer  
14 control strategy, in each state and for the US nationally.  
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## Abstract

**Background:** Robust comparisons of population-based cancer survival estimates require tight adherence to study protocol, standardized quality control, appropriate life tables of background mortality, and centralized analysis. The CONCORD program established worldwide surveillance of population-based cancer survival in 2015, analyzing individual data on 26 million patients (10 million US patients) diagnosed 1995-2009 with one of 10 common malignancies.

**Methods:** In this *Supplement*, we analyzed data from 37 state cancer registries covering approximately 80% of the U.S. population that participated in CONCORD-2. We performed data quality checks in three consecutive phases: protocol adherence, exclusions, and editorial checks. We estimated 1-, 3- and 5-year age-standardized net survival using the Pohar Perme estimator and state- and race-specific life tables of all-cause mortality for each year. We adopted the cohort approach for patients diagnosed 2001-2003 and the complete approach for patients diagnosed 2004-2009.

**Results** Articles in this *Supplement* report population coverage, data quality indicators and age-standardized 5-year net survival by state, race and stage at diagnosis. *Example* of tables, bar-charts and funnel plots are provided in this article.

**Conclusions** Population-based cancer survival is a key measure of the overall effectiveness of services in providing equitable health care. The high quality of US cancer registry data, 80% population coverage and use of an unbiased net survival estimator ensure that the survival trends reported in this *Supplement* are robustly comparable by race and state. The results can be used by policy-makers to identify and address inequities in cancer survival, in each state and for the US nationally.

## INTRODUCTION

Population-based cancer survival is a measure of the overall effectiveness of the health system in dealing with cancer.<sup>1</sup> Comparisons of population-based cancer survival require adherence to a well-designed protocol, standardized quality-control procedures, appropriate life tables of background mortality and centralized analysis with the latest statistical methods.<sup>2,3</sup>

CONCORD-2 established world-wide surveillance of cancer survival in 2015, with estimates of 5-year net survival based on individual data for more than 25 million cancer patients (about 10 million patients in the US) diagnosed during 1995-2009 with one of ten common cancers: stomach, colon, rectum, liver, lung, breast (female), cervix, ovary, prostate and leukemia in adults (15-99 years), and acute lymphoblastic leukemia in children (0-14 years).<sup>3</sup> Patients were followed up to Dec 31, 2009.

For the articles in this *Supplement*, we analyzed data from 37 statewide cancer registries (27 funded by the National Program for Cancer Registries (NPCR) program, 5 funded by the Surveillance, Epidemiology and End Results (SEER) program and 5 funded by both NPCR and SEER) that participated in CONCORD-2, covering approximately 80% of the U.S. population, and which agreed to the inclusion of their data in more detailed analyses by stage at diagnosis and by race. The CONCORD protocol required data on stage only for patients diagnosed from Jan 1, 2001, therefore these analyses, focused mainly on survival by stage, were restricted to patients diagnosed during 2001-2009.

Public health surveillance using the data from population-based cancer registries is a key component of cancer control.<sup>4</sup> The North American Association of Central Cancer Registries (NAACCR)<sup>a</sup> develops and promotes uniform data standards for all cancer registries in North America. Participating US registries had to meet the NAACCR certification criteria and to have conducted record linkage with both the state vital records and the National Death Index (NDI) to update the vital status of registered patients. NAACCR members developed a detailed SAS program to map the NAACCR database record structure to the CONCORD protocol and thus to enable all North American registries to exclude cases that would not have been considered reportable primaries according to the International Association of Cancer Registries (IACR) multiple primary rules,<sup>5</sup> before their datasets for 1995–2009 were extracted for CONCORD-2. This was necessary because North American registries define

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<sup>a</sup> <http://www.naacr.org/standardsandregistryoperations/volumeii.aspx>

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3 multiple primary cancers under the rules of the Surveillance, Epidemiology and End Results  
4 (SEER) program,<sup>6</sup> whereas registries in the European Network of Cancer Registries (ENCR)  
5 and in other continents generally use the rules of the IACR,<sup>5</sup> which are more conservative.  
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9 Topography and morphology were coded according to the International Classification of  
10 Diseases for Oncology (3rd edition; ICD-O-3<sup>7</sup>). Solid tumors were defined by anatomical site  
11 (**Table 1**). For ovarian cancer, we included the fallopian tube, uterine ligaments, and adnexa,  
12 and the peritoneum and retroperitoneum, where high-grade serous ovarian carcinomas are  
13 often detected; this was done to improve international comparability of the data sets. Kaposi's  
14 sarcoma and solid tumors with lymphoma morphology were excluded from analysis.  
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19 Leukemias were defined by morphology. In this *Supplement* we cover only precursor-cell  
20 acute lymphoblastic leukemia in children (ICD-O-3 morphology codes 9727, 9728, 9729,  
21 9835, 9836, 9837). Estimates of survival by race, state and sub-type of adult leukemia will be  
22 presented in other publications.  
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27 Only primary invasive cancers (ICD-O-3 behavior code 3) were included in survival  
28 analyses. We included cancers at a given site regardless of whether the patient had had a  
29 previous cancer. If a patient was diagnosed with two or more cancers of a given organ,  
30 including paired organs, during 2001-2009, only the first was considered in survival analyses.  
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### 34 **Follow-up**

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36 US registries were asked to submit follow-up data (vital status and date of last known vital  
37 status) as at Dec 31, 2009, after conducting linkages of all cancer registrations with both state  
38 vital records systems and the NDI. Patients whose cancer registration could not be linked to a  
39 death record were considered to be alive on Dec 31, 2009 (passive follow-up, also known as  
40 the "presumed alive" method).  
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45 SEER registries are required to meet a specific standard for the completeness and recency of  
46 follow-up. At least 90% of registered patients not known to be deceased were required to  
47 have a date of last known vital status on or after Jan 1, 2010. These follow-up dates could  
48 have been obtained from either passive or active follow-up.<sup>8</sup>  
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52 Patients whose survival time was unknown were excluded from analyses. This group  
53 comprised patients registered solely from a death certificate or diagnosed at autopsy.  
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## CONCORD-2 data quality control: three phases

We performed data quality checks in three consecutive phases: protocol adherence, exclusions, and editorial checks. After each phase a detailed report was sent to each cancer registry.

### *Phase 1: Protocol adherence*

We first checked the compliance with the CONCORD-2 protocol of each of 37 variables (demographic characteristics, basis of diagnosis, date of diagnosis, topography, morphology, behavior, stage, vital status, date of last known vital status) in each tumor record in each data set. Any value not specified in the protocol was considered non-compliant. Each registry was sent a table of the number of records and the percentage compliance for each variable, and for each cancer. Minor issues were corrected by the CONCORD Central Analytic Team, after discussion with the registry. For major structural issues, 5 registries corrected and re-submitted their data.

### *Phase 2: Exclusions*

Next, we checked for logical inconsistencies between the variables in each tumor record, for each cancer site. Exclusion criteria were defined *a priori*, based on the experience within the Cancer Survival Group, the checks performed in the first CONCORD study, the EUROCARE (EUROpean CANcer REgistry based study on survival and care of cancer patients) data quality checks, the checks proposed by the International Agency for Research on Cancer (IARC), the descriptions of morphology in the World Health Organization (WHO)/IARC Classification of Tumors for each cancer and, finally, clinical expertise.<sup>3</sup>

We produced “exclusion tables” summarizing the quality of each data set. Data quality indicators were tabulated separately for patients diagnosed in 1995-99, 2000-04 and 2005-09, to enable evaluation of trends in data quality over time. We defined three broad categories for exclusion: ineligible (e.g., *in situ* neoplasm), definite error (e.g., sex-site mismatch) and possible error (e.g., apparent inconsistency between site and morphology). We had requested records of *in situ* neoplasms to assess the intensity of diagnostic activity, particularly for cancers of the breast and cervix, but *in situ* neoplasms were not included in survival analyses. The number and percentage of patients excluded from analysis are shown in **Table 2**.

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3 The majority (99.6%) of patients only had a single tumor record for any one cancer during  
4 1995-2009. However, since a small proportion of patients had more than one tumor record for  
5 a given cancer (“multiple tumor, same site”), it was necessary to apply the quality control  
6 checks to every tumor record independently before selecting the single tumor record to be  
7 included in survival analyses. For example, if a woman had an *in situ* neoplasm of the breast  
8 diagnosed in 2001 followed by an invasive primary breast cancer in 2007, the invasive cancer  
9 record was selected for inclusion in the analyses, provided it was free of error.  
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### 16 *Phase 3: Editorial tables*

17 We evaluated the distribution of key data quality indicators for each cancer and for each  
18 registry. These indicators included the proportion of cancers in the final data set that had been  
19 microscopically verified and the proportion of patients who had been lost to follow-up. We  
20 also checked the distributions of the day and the month of the dates of birth, diagnosis and  
21 last known vital status. These distributions should be flat, since one would expect about 8%  
22 of births, diagnoses and deaths to occur in each month, and about 3% on each day of a given  
23 month, except days 28-31: spikes in these distributions, often on the 1st, 15th or 16th day of  
24 the month, or for June or July, help to identify where registries had imputed missing elements  
25 of each date.  
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34 **Table 2** provides a summary of the exclusions and data quality indicators for adults (15-99  
35 years) diagnosed during 1995-2009 with one of 9 common cancers (all solid cancers), by US  
36 state. The calendar periods within which survival analyses could be performed by stage at  
37 diagnosis were constrained by the availability of data on stage only from 2001, and the  
38 change in coding from 2004 (see below). Therefore, the periods for which data quality  
39 indicators are presented do not exactly match the periods used for survival analysis.  
40 However, data quality has generally been very high in all US registries, and it tended to  
41 improve over the 15 years from 1995 to 2009. Only about 2% of tumors were registered from  
42 a death certificate only (DCO) or detected solely at autopsy. These records must be excluded  
43 from survival analyses because the follow-up time for these patients is unknown. However,  
44 the proportion of DCO registrations in the US was low overall (1.9%) and in all states (range:  
45 <0.1-3.5%). The proportion of other errors was very low (0.2%). Therefore, about 98% of the  
46 eligible patients were included in survival analyses. Practically all tumors (99.7%) were  
47 microscopically verified: this proportion was over 95% in almost all US states.  
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3 The proportion of the US population covered by this study is 80.6%. **Table 3** shows the  
4 population coverage by US state, as well as the number of patients diagnosed during 1995–  
5 2009 and included in the analyses.  
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### 8 9 10 **Study design**

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12 The focus of this monograph is on the striking differences in survival by race and stage at  
13 diagnosis. Since differences in survival between men and women were generally very small,  
14 compared to the differences in survival between blacks and whites (Table 4), we do not show  
15 survival estimates by sex in the articles on each cancer.  
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20 **The CONCORD protocol required information on stage at diagnosis only for patients**  
21 **diagnosed from 2001 onward, because the completeness of data on stage in the US and many**  
22 **other countries was known to be much lower before 2001.** For the analyses of survival by  
23 stage at diagnosis, patients were grouped by year of diagnosis into two calendar periods  
24 (2001-2003 and 2004-2009) to reflect changes in the methods used by US registries to collect  
25 data on stage at diagnosis. From 2001, most registries coded stage directly from the source  
26 data to SEER Summary Stage (SS) 2000.<sup>9</sup> From 2004, all registries began to derive Summary  
27 Stage 2000 from 15 pathological and clinical data items, using the Collaborative Staging  
28 System.<sup>10</sup> Data on stage at diagnosis were not available for Maryland or Wisconsin, or for  
29 cases diagnosed during 2004-2009 in Rhode Island.  
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32 We estimated net survival using the cohort approach for patients diagnosed in 2001-2003,  
33 since all patients had been followed up for at least five years by Dec 31, 2009. We used the  
34 complete approach to estimate net survival for patients diagnosed from 2004-2009, because  
35 five years of follow-up data were not available for all patients.  
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### 38 39 40 **Cohort approach**

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42 The cohort approach is the classical approach to survival analysis, in which all patients who  
43 are included in the analyses have had the opportunity to be followed for the full duration of  
44 survival analysis, in this case, five years. The cohort of patients is defined by the year or  
45 calendar period during which they were diagnosed, and each patient is followed up for the  
46 same length of time. In our analyses, at least 5 years of follow-up for vital status were  
47 available by the end of 2009 for all patients diagnosed during 2001-2003. Each patient,  
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3 irrespective of their actual year of diagnosis, contributes survival information at each point in  
4 follow-up time that, taken cumulatively, make up the survival estimate at 5 years.  
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7 The cohort approach<sup>11, 12</sup> is considered the gold standard,<sup>11, 12</sup> because it provides a survival  
8 estimate for a group of patients who were diagnosed during the same year or period, who are  
9 likely to have been treated in similar fashion, and who have all been followed up for at least  
10 the duration of survival required. It is the natural approach to estimation of outcome, and is  
11 easy to interpret, but other approaches may be required if sufficient data are not available.  
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### 15 **Complete approach**

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17 The complete approach can be applied to estimate survival for patients who were diagnosed  
18 more recently, and for whom 5 full years of follow-up data may not be available at the  
19 closing date of the study. For example, some patients diagnosed 2004-2009 were followed up  
20 for less than 5 years. The ‘cohort’ approach can be used to estimate five-year survival for  
21 patients diagnosed in 2004, but 5-year survival can be estimated for the whole calendar  
22 period with the ‘complete’ approach, in which all the available follow-up data for patients  
23 diagnosed during 2004-2009 are used. The potential follow-up time for these patients varies  
24 between 1 year and 5 years.  
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### 32 **Age standardization**

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34 We compared survival estimates between US states, between blacks and whites, and between  
35 calendar periods of diagnosis. For age-specific survival estimates, comparison between  
36 populations or over time is straightforward, but if we want to compare overall (all-ages)  
37 survival estimates, age standardization is required. This is essentially for the same reasons as  
38 in comparison of overall incidence or mortality rates, namely that net survival may also vary  
39 widely with age at diagnosis, and the age profile of cancer patients may differ between the  
40 populations or change between the calendar periods among which we wish to compare  
41 overall survival.  
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48 For age-standardization of incidence or mortality rates, what matters is the age structure of  
49 the general population at risk of cancer. With cancer survival, however, what matters is the  
50 age profile of cancer patients, which is very different from the age profile of the general  
51 population. The weights used for age standardization of cancer survival estimates are thus  
52 completely different from those required for standardizing incidence or mortality rates. The  
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3 weight for each age group is provided by the proportion of cancer patients in that age group  
4 in a standard population of cancer patients.  
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7 The International Cancer Survival Standard (ICSS) weights<sup>13</sup> are strongly recommended for  
8 international comparisons of cancer survival. They comprise three sets of standard age  
9 weights, derived from discriminant analysis to find the smallest number of sets of weights  
10 that enable adequate standardization of survival. Each standard is applicable to a range of  
11 different cancers, and provides age-standardized survival estimates that are not too different  
12 from the unstandardized estimates. The same age weights can be used for men and women,  
13 and for direct comparisons of age-standardized net survival between patient groups defined  
14 by sex and race.  
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### 23 **Statistical methods**

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25 We estimated net survival up to 5 years after diagnosis, with 95% confidence intervals (CI),  
26 using the Pohar Perme estimator,<sup>14</sup> implemented in the *Stata*<sup>15</sup> algorithm *stns*.<sup>16</sup> We analyzed  
27 survival by state, race, stage at diagnosis and calendar period of diagnosis. Net survival is the  
28 probability of surviving up to a given time since diagnosis after controlling for other causes  
29 of death (background mortality). To control for the wide differences in background mortality  
30 among participating states and racial/ethnic groups, we constructed life tables of all-cause  
31 mortality in the general population of each state from the number of deaths and the  
32 population, by single year of age, sex, calendar year and, where possible, by race (black,  
33 white).  
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41 Net survival in adults was estimated for five age groups (15-44, 45-54, 55-64, 65-74, and 75-  
42 99 years; except for prostate cancer 15-54, 55-64, 65-74, 75-84 and 85-99 years). We  
43 obtained age-standardized survival estimates using the International Cancer Survival  
44 Standard (ICSS) weights. For children, survival was estimated for the age groups 0-4, 5-9  
45 and 10-14 years. We obtained age-standardized estimates by assigning equal weights to the  
46 three age-specific estimates.<sup>17</sup>  
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52 We derived standard errors for both unstandardized and age-standardized survival estimates  
53 using the Greenwood method,<sup>18</sup> assuming a normal distribution, and truncated to the range 0-  
54 100. We did not estimate survival if fewer than ten patients were available for analysis. Age-  
55 standardization was only performed if there were at least 10 patients in each of the age  
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3 categories specified above. If an age-specific estimate could not be obtained, we merged data  
4 for adjacent age groups and assigned the combined estimate to both age groups. If two or  
5 more age-specific estimates could not be obtained, we present only the pooled,  
6 unstandardized estimate for all ages combined: these estimates are italicized in Tables 2 and 3  
7 of the Appendix.  
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11 For each of the 37 states, we present estimates of age-standardized net survival for each  
12 cancer up to 5 years after diagnosis. For convenience, we report cumulative survival  
13 probabilities (in the range 0-1) as percentages in the range 0-100%.  
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### 16 **Life tables**

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18 For the analyses presented in this *Supplement*, we used the life tables for background  
19 mortality that were constructed for the CONCORD-2 study.<sup>19</sup>  
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23 To control for variation between US states in background mortality by age, sex, race and  
24 calendar year while estimating net survival, we used life tables of all-cause mortality rates by  
25 single year of age (0-99 years), for each state, race, calendar year (2001-2010) and sex. For a  
26 few states in which the black population is small, it was not possible to construct adequately  
27 robust life tables of all-cause mortality by single year of age and sex for blacks, so net  
28 survival estimates for blacks in those states are not presented separately. These life tables can  
29 be downloaded from the CONCORD library of over 12,000 life tables.<sup>20</sup> The library includes  
30 detailed statistical and graphical reports on the robustness of the life tables for each US state.  
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34 We received raw data on death counts and populations for each US state. To produce life  
35 tables for each US state by race, sex and calendar year (state- and race-specific life tables) we  
36 used a flexible Poisson model<sup>21</sup> that enables creation of single-year-of-age life tables even  
37 when the raw data are sparse. We checked the life tables by examination of semi-log plots of  
38 age-sex-mortality rates, life expectancy at birth, the probability of death in the age bands 15–  
39 59, 60–84 and 85–99 years and, where necessary, the model residuals, to examine the  
40 goodness of fit of the models by age and sex.  
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### 51 **Graphical representation**

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3 In each cancer-specific article in this *Supplement*, trends, geographic variations and  
4 differences in age-standardized survival by race are presented graphically in bar-charts and  
5 funnel plots.<sup>22</sup>  
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### 8 **Bar-charts**

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10 Results were summarized in bar-charts of 5-year age-standardized net survival by calendar  
11 period (2001-2003 and 2004-2009), for each state, grouped within the four US geographic  
12 Census Regions (Northeast, South, Midwest, West). The results for each Region are  
13 presented with a different color. Within each Region, darker shades indicate NPCR registries,  
14 while lighter shades indicate SEER registries. Five registries funded by both SEER and  
15 NPCR were grouped with SEER because they use both passive and active follow-up; they are  
16 indicated with an asterisk “\*”.  
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23 The survival estimates for each state in 2004-2009 are ranked from high to low within each  
24 US Census Region. The same ranking is then applied to the results for 2001-2003, to  
25 facilitate examination of changes in survival from 2001-2003 to 2004-2009 within each state.  
26 The absolute difference (%) in 5-year net survival between the two periods is also shown for  
27 each state.  
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32 Each graphic includes the pooled survival estimates for all 37 participating states combined.  
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### 35 **Funnel plots**

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37 Funnel plots are graphical representations designed to detect excessive variation in  
38 performance indicators by simple visual inspection of the data.<sup>23</sup> They can be used to provide  
39 a simple and informative display of geographical variation or time trends in population-based  
40 cancer survival measures (e.g. age-standardized net survival).  
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44 A funnel plot comprises four elements:<sup>22</sup> the target (or reference) value for the outcome, a set  
45 of control limits (the funnel), data points for the outcome variable (indicator) and the  
46 associated precision parameter for each data point. Data points outside the control limits (the  
47 funnel) indicate variation in the indicator beyond what would be expected by chance, while  
48 taking account of precision.<sup>23</sup>  
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53 The funnel plot in Figure 1 shows, as an example, 5-year age-standardized net survival for  
54 breast cancer in the US during 2004-2009, by race and state. It is constructed by plotting the  
55 37 state-specific survival estimates for breast cancer during 2004-2009, on the y-axis, against  
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3 their associated precision, on the x-axis, forming a scatter plot. Fewer data points are  
4 available for blacks (28 states) than for whites (37 states), because of the difficulty in  
5 constructing robust life tables for blacks in every state. The precision parameter in this  
6 example is in fact the precision of each age-standardized net survival estimate (the inverse of  
7 its variance). This is a natural choice to represent the statistical precision of each estimate, but  
8 it could be any function that is proportional to the inverse of the variance.  
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13 The target (the solid horizontal line in Figure 1) is then superimposed. This is a constant  
14 value, considered independent of the observations, and it specifies the expected value for the  
15 outcome. The target shown in Figure 1 is the 5-year age-standardized net survival estimate  
16 for the pooled US data for women diagnosed with breast cancer during 2004-2009. The  
17 pooled US estimate was selected as the target to show the extent to which survival for blacks  
18 and whites in each state varies around the overall survival estimate for the US.  
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23 The control limits (the dashed lines in Figure 1) are also independent of the individual  
24 survival estimates. They depend only on the target value, and their correct formulation  
25 depends on the underlying theoretical distribution of the target value. The control limits for a  
26 given level of significance ( $\alpha$ ) are drawn around the target value across the entire observed  
27 range of precision of the individual estimates. The most common levels of significance are  
28  $\alpha=5\%$  and  $\alpha=0.2\%$ , so that the resulting 95% and 99.8% control limits represent  
29 approximately two and three standard deviations, respectively, on either side of the target  
30 value, at each level of precision. An estimate that appears outside the control limits is  
31 identified as diverging from the target value, and is an "out-of-control" estimate, in other  
32 words a probable outlier that may need to be investigated further.  
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42 In Figure 1, as with all the funnel plots reported in this *Supplement*, 5-year age-standardized  
43 net survival is represented by open circles for white patients and by solid circles for black  
44 patients. Funnel plots are extremely powerful tools for visual examination of variation in an  
45 indicator: we can perceive at first glance that 5-year survival in blacks is persistently lower  
46 than would be expected (the pooled US survival estimate, the "target") and that survival for  
47 blacks is generally lower than for whites.  
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## 51 52 53 54 55 **DISCUSSION** 56 57 58 59 60

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3 This article summarizes the data quality control procedures, analytic methods and graphical  
4 presentations that have been deployed for all the data sets reported in this *Supplement*. The  
5 quality of population-based data from the 37 participating US cancer registries was  
6 impressively high (Table 2). More details about the quality indicators for each cancer can be  
7 found in the web-appendix<sup>b</sup> to the CONCORD-2 article.<sup>3</sup>

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11 For NPCR registries that use only passive follow-up to determine the vital status of registered  
12 cancer patients (the “presumed alive” method), survival estimates may be inflated if the  
13 cancer registrations for some patients who have in fact died could not be successfully linked  
14 to the data from their death certificate. The vital statistics offices in each state have reported  
15 all death certificate information to the National Death Index (NDI) since 1979. Passive  
16 methods of follow-up are known to be efficient because of the completeness and accuracy of  
17 the National Death Index, which tends to capture 1-3% more deaths than if the registry can  
18 only link its data to the state death index<sup>24</sup>. Most of the extra deaths captured in this way will  
19 be those of patients who migrated to a different state following their cancer diagnosis.  
20 However, the registries included in these analyses had all matched their data against the  
21 National Death Index before data submission, so the completeness of vital status  
22 ascertainment is expected to be extremely high, although it may not capture out-of-country  
23 deaths.  
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34 A major strength of this study is the use of life tables that are specific for each state, each race  
35 (white, black) and each calendar year, to control for differences and changes in background  
36 mortality by single year of age, sex, race and single calendar year. This approach provided  
37 the tightest possible control of background mortality with the available data. More specific  
38 life tables may be considered in future studies, subject to the availability of high-quality data  
39 on death and population counts for Hispanics or other major racial or ethnic groups.  
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45 The CONCORD-2 protocol required registries to provide information on stage at diagnosis  
46 for patients diagnosed in 2001 or later. Calendar years of diagnosis were then grouped for  
47 analysis of survival by stage into 2001-2003 and 2004-2009, to reflect a change in the US  
48 stage coding system from 2004.  
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52 This choice of calendar periods imposed the following selection of analytic approach. We  
53 were able to estimate 5-year net survival with the cohort approach for patients diagnosed in  
54 2001-2003, since all patients had at least 5 years of potential follow-up. However, the period  
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58 <sup>b</sup> [http://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(14\)62038-9/supplemental](http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(14)62038-9/supplemental)  
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3 approach<sup>25</sup> that was adopted to estimate 5-year survival for patients diagnosed 2005-2009 in  
4 the CONCORD-2 study<sup>3</sup> could only have been used to estimate 5-year survival by stage for  
5 patients diagnosed during 2004-2009 if stage data had also been available for patients  
6 diagnosed in 2000. We therefore adopted the complete approach. In this approach, more  
7 information is available to estimate survival in the early years of follow-up than later years.  
8 Only patients diagnosed in 2004 had the potential to be followed up for 5 years by Dec 31,  
9 2009; only patients diagnosed during 2004 and 2005 had the potential to contribute to the  
10 conditional survival probabilities between 4 and 5 years after diagnosis; and so on. This leads  
11 to some increased variation around the 5-year survival estimates for 2004-2009 compared  
12 with those for 2001-2003. This is reflected in the confidence intervals, and slightly lower  
13 precision, seen in the funnel plots for 2004-2009 in some of the site-specific articles.  
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18 This is the most extensive analysis of 5-year population-based cancer survival in the US to  
19 date, with survival trends for 10 common cancers in 37 states that include 80% of the US  
20 population. Here, we have focused on variations in survival by race and stage at diagnosis for  
21 patients diagnosed during 2001-2009.  
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26 Population-based cancer survival is a key measure of the overall effectiveness of the health  
27 system in dealing with cancer. The high quality of the data from the US cancer registries,  
28 implementation of the most up-to-date and unbiased estimator of net survival, combined with  
29 the use of state- and race-specific life tables, all help to ensure that these cancer survival  
30 estimates are robust and comparable. We believe they can be confidently used by policy-  
31 makers to identify inequities in cancer survival by race in each state and for the US as a  
32 whole, and to plan cancer control strategies that promote equal opportunity for the best  
33 possible outcomes after a cancer diagnosis.  
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## Legends for Tables and Figures

### Table 1 Definition of malignancies

### Table 2 Data quality indicators for patients diagnosed during 1995–2009, by US state (all solid cancers combined)

Table 2 footnotes:

<sup>a</sup> *In situ* malignancy (ICD-O-3 behavior code 2): some registries do not register *in situ* cancers; other registries did not submit them. Other: records with incomplete data, or for tumors that are benign (behavior code 0), of uncertain behavior (1), metastatic from another organ (6), or unknown if primary or metastatic (9); or for patients with age outside the range 15-99 years (adults).

<sup>b</sup> DCO: tumors registered from a death certificate only (DCO), or detected solely at autopsy. Other: vital status or sex unknown; invalid sequence of dates; inconsistency of sex-site, site-morphology, age-site, age-morphology, or age-site-morphology.

<sup>c</sup> MV: microscopically verified. Non-specific morphology (solid tumors only): ICD-O-3 morphology code in the range 8000-8005. Censored: patients diagnosed during 1995-2004, with last known vital status "alive", but less than five years of follow-up.

<sup>d</sup> P=Passive ("presumed alive") method; P&A=Passive and Active ("reported alive") methods; see text.

### Table 3: Population coverage and number of patients diagnosed during 1995–2009, by US state

Table 3 footnotes:

<sup>a</sup> Data are from the UN Population Division for 2009

<sup>b</sup> Acute lymphoblastic leukemia, children (0-14 years) only

### Table 4: Age-standardized 5-year net survival (NS, %) for adults (15-99 years) diagnosed with one of 10 common malignancies and children (0-14 years) diagnosed with acute lymphoblastic leukemia (ALL) during 2004-2009, by race and sex: United States<sup>a</sup>

Table 4 footnotes:

<sup>a</sup> Population coverage represents 80.6 % of the US population in 2009 (UN Population Division)

<sup>b</sup> A negative value means that males have lower survival than females

<sup>c</sup> A negative value means that blacks have lower survival than whites

<sup>d</sup> Acute lymphoblastic leukemia, children (0-14 years) only

### Figure 1: 5-year age-standardized net survival for women (15-99 years) diagnosed with breast cancer in 2004-2009, by state and race

Figure 1 footnote: Each data point represents the survival estimate for a US state, either for blacks (28 states) or whites (37 states; see text).

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