Temporal trends in population-level cure of cancer: the Australian context

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Running title

Statistical cure of cancer in Australia

Conflict of interest statement

The authors declare no potential conflicts of interest.
Abstract

**Background:** With the improvements in cancer diagnosis and treatment, more cancer patients are surviving for longer periods than before. This study aims to quantify the proportion cured and median survival time for those who are not cured for major cancers in Australia.

**Methods:** Australian population-based cohort of 2,164,172 cases aged 15-89 years, whose first cancer diagnosis between 1982 and 2014 was one of 22 leading cancers, were followed up to December 2014. Flexible parametric cure models were used to estimate the proportion cured and median survival time for those uncured by age, sex and spread of disease, and temporal trends in these measures.

**Results:** Cure estimates could be generated for 19 of the 22 cancer types. The unadjusted proportion cured ranged from 5.0% for pancreatic cancer to 90.0% for melanoma. Median survival time for those uncured ranged from 0.35 years for pancreatic cancer to 6.05 years for prostate cancer. Cancers were divided into four groups according to their proportion cured in 1980s and the degree of improvement over 28 years. Oesophageal, stomach, pancreatic, liver, gallbladder, lung, and brain cancer had lower proportion cured and smaller improvements over time.

**Conclusions:** For cancers with poor survival where little has changed over time either in prolonging life or achieving statistical cure, efforts should be focused on reducing the prevalence of known risk factors and earlier detection, thereby enabling more effective treatment.

**Impact:** Cure models provide unique insights into whether survival improvements are due to prolonging life, or through curing the disease.
Introduction

With cancer being one of the leading causes of death in the world (1), cancer survival is a widely used measure of the success of cancer control efforts. Most population-based cancer survival estimates use relative survival ratio that provides information about the hypothetical situation where people can only die from their diagnosed cancer (2). Other measures utilising the relative survival framework include conditional survival (3), crude probability of death (4), and loss of life expectancy (5). In recent decades, cancer patients, especially those diagnosed with treatable cancers, have survived their initial diagnosis and remained tumour-free for longer periods than before (6). This favourable trend in cancer prognosis has inspired the development of novel statistical methods to evaluate long-term outcomes, such as the proportion of cases who are cured and the median survival time of patients who are not considered cured (7).

Medical cure is when all signs of cancer have been removed for a patient. However, the individual-level clinical information required to determine medical cure is rarely available at a population level. The population-level equivalent to medical cure is known as population (or statistical) cure (7). Population cure is when the mortality rate associated with a cancer diagnosis returns to the same level as that expected within the general population, or equivalently, when the excess mortality approaches zero. In practice, population cure is the point at which the relative survival curve appears to plateau.

Cure models are used to estimate population cure. They assume that there is a proportion of people diagnosed with cancer who will never die from their cancer. Thus, the cancer cohort can be split into two groups: cured and ‘uncured’ patients. These types of analyses help answer the questions about “what proportion of patients are cured of this cancer?” and “what happens to uncured patients?” (8). Considering changes in the proportion of patients cured, and the survival distribution of the uncured group provide additional insights into cancer survival than can be obtained through estimating relative survival alone.

Estimates of population-level cure can provide practical indicators to monitor the effectiveness of early detection strategies and the quality of clinical care and cancer management in the long-term. While several European studies (8-13) have reported the proportion cured among cancer cohorts for some types of cancer, there remains limited information about the population cure for many other types, and none for Australian cancer patients. The objective of this study was to provide national-level benchmarks for the...
proportion of patients who are considered cured (referred to as “proportion cured” in the text below) and the median survival time for the uncured, and the temporal trends in these estimates for common cancer types in Australia.

Materials and Methods

Ethical approval was obtained from the Queensland University of Technology Human Research Ethics Committee (1600000868), NSW Population & Health Services Research Committee (2016/HRE1203), and ACT Human Research Ethics Committee (ETHLR.16.228). De-identified data were obtained from the Australian Cancer Database (ACD) held by the Australian Institute of Health and Welfare (AIHW). Notification of cancer diagnoses to all state and territory-based cancer registries is required by law, so the ACD is considered to include all cancers (excluding keratinocyte cancers) diagnosed among Australians since its inception in 1982 (14).

Data sources

Data were obtained for 22 of the most frequently diagnosed cancers (see Table 1 for ICD10 codes) for all Australian patients diagnosed from 1982 to 2014 (1982-2013 for New South Wales (NSW)) with mortality follow-up information to December 2014. Mortality status is determined through routine annual linkage of cancer records with the Australian National Death Index.

We restricted the cohort to the first primary cancer diagnosed during the study period (n=2,254,973). Only those aged 15-89 years at diagnosis (n=2,199,431) were included due to the different classification of childhood cancers (15) and the higher bias in relative survival estimates among older people (16). Cases diagnosed based on death certificates only (n=23,950, 1.1%), and who survived no more than one day (n=11,309, 0.5%) were also excluded (Supplementary Figure S1).

Following these selection criteria, 2,164,172 cases were included for 22 cancers diagnosed between 1982 and 2014. For the temporal trends, we further restricted the study cohort to those diagnosed during 1982-2009 (n=1,730,014) to ensure that each case had at least five years of potential follow up, consistent with a previous study reporting changes in proportion cured (9). Information on spread of disease at diagnosis, which is a broad categorisation of how far a cancer has spread from its point of origin (17), was only available for solid tumours diagnosed in NSW during 1982-2013 (n=651,401, Supplementary Table S1).
Relative survival

For each type of cancer, relative survival by year of follow-up (0 to 33 years) was calculated by sex, using the Ederer II method for expected survival (18). The expected population mortality rates were stratified by sex, age, and calendar year. To facilitate temporal trend analyses, the cohort approach was used (19). We constrained the long-term relative survival ratio so that any increases over the follow-up interval were replaced with constant relative survival estimates (20).

The type-specific relative survival curves were used to see whether the survival curve had plateaued within the 33-year study period (Supplementary Figure S2). Cure models were fitted to only those cancers with survival curves that had plateaued (21).

Cure models

Estimates of proportion cured and median survival time for the uncured and their temporal trends were generated using flexible parametric cure models (7) which use splines, defined by constrained piecewise polynomials joined at “knots”, to estimate the underlying hazard function. The number of knots specified to create the splines determines the number of parameters used to model the hazard function (22). “Statistical” cure is estimated by restricting the underlying hazard function to have zero slope after the last knot. The models have been shown to perform at least as well as the other approaches such as mixture or non-mixture cure models, and better when there is high mortality soon after diagnosis (e.g. for the oldest age group) (21).

A key assumption for the cure models is that the relative survival curves plateau at some point during the observed follow up interval (21). Since the relative survival curves for Hodgkin lymphoma and testicular cancer did not plateau after 33 years, they were excluded from the analysis (Supplementary Figure S2). For each cancer that met the cure model assumption, a series of cure models adjusting for sex, age group at diagnosis (15-49, 50-69, 70-89 years), period of diagnosis (1982-1989, 1990-1999, 2000-2014) and, for NSW data only, spread of disease, were used to predict proportion cured and the median survival time for the uncured by sex, age group, and spread of disease for the combined study time period. For temporal trend estimation, age at and year of diagnosis were modelled as continuous time-varying covariates with restricted cubic splines. We used four degrees of freedom (df) for the baseline hazard function and two df for the time-dependent effects. Due to difficulties
with model convergence for thyroid cancer, this cancer was excluded from the cure model analyses.

To eliminate the influences of changing age distribution over time on the temporal trends in proportion cured and the median survival time of the uncured, the predicted measures were then standardised by age group using the study cohort (Supplementary Table S2) as standard population. Comparisons across cancer types for the combined study time period were also standardised by period of diagnosis or age group and period of diagnosis.

Consistent with a previous study, the differences in proportion cured and median survival time for the uncured between sexes, and among age groups and spread of disease were compared based on their 95% confidence intervals (23). The direction, magnitude and significance of linear trends in proportion cured and median survival for the uncured over time were quantified using simple linear regression models, in which the outcome variable was the year-specific age-standardised proportion cured/median survival for the uncured, and year of diagnosis was an explanatory variable.

Cancers were divided into two groups based on the average annual change of age-standardised proportion cured from 1982 to 2009. Cancers with proportion cured increased by < 0.75% per year were defined as “Group I – smaller increase”, otherwise they were defined as “Group II – larger increase”. Age-standardised proportion cured and median survival for the uncured for the 1982-1989 cohort were also estimated using cure models. Cancers with proportion cured < 20% during the 1980s were categorised as “Group A – lower cure”, otherwise they were defined as “Group B – higher cure”. By combining information about the baseline proportion cured for the 1980s cohort and the trends in proportion cured over time, cancers were grouped into four categories: (Group A & Group I) lower cure-smaller increases, indicating the lack of effective diagnostic and treatment options over time; (A, II) lower cure-larger increases, indicating substantial improvements in diagnosis and/or treatment over time; (B, I) higher cure-smaller increase, indicating efficient diagnosis and/or treatment in 1980s that did not significantly improve over time; and (B, II) higher cure-larger increases, indicating good initial cancer management and substantial improvement over time.

All statistical analyses were performed using Stata/SE version 15 (StataCorp, TX, USA). Flexible parametric cure models were fitted using the stpm2 package (24,25).
Results

As discussed above, three cancers (testicular cancer, thyroid cancer, and Hodgkin lymphoma) were excluded (n= 65,249), leaving 19 cancers (n= 2,098,923) for analysis.

The association between proportion cured and median survival time for the uncured cases for each cancer type reflected the differences in severity (Figure 1). The size of the bubble represents the number of incident cases with the cancers. Those located closer to the lower left corner, such as pancreatic cancer, had a lower proportion cured and shorter median survival time for the uncured; while those located closer to the upper right corner, including prostate and breast cancer, had higher proportion cured and longer median survival time for the uncured cases.

Proportion cured and temporal trends

After adjusted for age and year of diagnosis, males had significantly lower proportion cured than females for all the non-sex specific cancers, based on their not overlapped 95% confidence intervals (95% CI) (Table 1). The highest proportion cured was seen for melanoma survivors where 83.2% of males and 90.3% of females were considered statistically cured. The lowest proportion cured was observed for pancreatic cancers where the proportions cured were 6.1% and 7.0% for males and females, respectively.

The age-specific patterns (Table 2) showed that for most types (except female breast and prostate cancer), proportion cured were higher for people diagnosed when younger compared with older patients. The biggest differences (in absolute terms) were seen for ovarian, cervical, and brain cancer, where the proportion cured were 47.5%, 45.5%, and 38.7% lower, respectively between patients diagnosed aged 15-49 and 70+ years. Of note, for breast cancer, while women diagnosed when aged 70+ years still had the lowest proportion cured (69.3%), those diagnosed aged 50-69 years (76.4%) had a higher proportion cured than those aged 15-49 years (73.8%). Similarly, for prostate cancer, the proportion cured was lowest for men aged 70+ years (72.1%), while men aged 50-69 had a higher proportion cured than those aged 15-49 years (80.4% vs. 76.8%).

The proportion cured generally decreased with each known spread of disease category especially for kidney cancer, melanoma, and prostate cancer, with an absolute decrease of 80.0%, 78.9%, and 78.7%, respectively between localised and distant disease (Table 3).
Between 1982 and 2009, the age-standardised proportion cured increased significantly for all types (Figures 2 & 3), although most of the cancers were grouped as “smaller increase” (Group I, annual increase < 0.75%), with an absolute growth less than 20% over 28 years. According to the 1980s baseline proportion cured and its average annual change, cancers of oesophagus, stomach, pancreas, liver, gallbladder, lung, and brain were categorised as Group AI (lower cure-smaller increases); myeloma as AII (lower cure-larger increases); head and neck, ovarian, uterine, and cervical, along with melanoma as BI (higher cure-smaller increase); and prostate, breast, kidney, colorectum, leukaemia, and NHL as BII (higher cure-larger increases).

**Median survival time for uncured cases and temporal trends**

For the subgroup of uncured patients who will die from the diagnosed cancer, breast and prostate cancer patients had the highest median survival time (more than 5 years), while those with pancreatic cancer had the lowest median survival time of less than 0.4 years for both males and females (Table 1). For most types, there was no significant difference in the median survival for the uncured by sex, except for oesophageal and lung cancer where males had significantly lower median survival time than females.

For most types the median survival time for the uncured cases reduced as age group at diagnosis increased (Table 2). The biggest differences were seen for myeloma, where the median survival time for patients aged 15-49 years was 1.7 years higher than for those aged 70-89 years.

The median survival for the uncured cases generally reduced by the known spread of disease categories except uterine, prostate, and brain cancer which did not show a significant difference (Table 3). The impact of spread of disease on the median survival time was greatest for prostate, breast, and head and neck cancer, where the median survival time for the uncured cases with distant disease was 2.7, 2.5, and 1.9 years lower respectively than those with localised disease.

The median survival time for the uncured cases increased over time for most types except cervical cancer, which experienced a small decrease between 1982 and 2009 (Figures 2 & 3). Although statistically significant, the increase in median survival time for the uncured was less than six months (increase <0.02 years, annually) over 28 years for most types (Figure 3), except prostate (1.9 years), myeloma (1.3), breast (0.9), kidney (0.7), leukaemia (0.7), and NHL (0.7).
Sensitivity analysis

The comparison between observed and predicted relative survival curves using flexible parametric cure models showed very good model fit for most cancer types (Supplementary Figure S2), however there was evidence of slight overestimation of survival for some other cancers, particularly prostate cancer, after ten years of follow-up.

Discussion

By fitting cure models, we estimated population proportion cured and the median survival time for the uncured for the 19 most frequently diagnosed cancers in Australia. To the best of our knowledge, this is the first time these have been reported for Australia, and for several cancers, the first cure estimates reported anywhere. There has been a general increase over time in the proportion of cancer patients who can be considered cured, and in the median survival time for those people who will die from their cancer during the study period.

The common survival estimate, relative survival, refers to the percentage of patients who can survive up to a certain amount of time, in a hypothetical situation where they can only die from cancer. In recent decades, with the developments in cancer screening and treatment, an increasing number of cancer cases have become curable. Like relative survival, quantifying the proportion of the cancer population who reach ‘statistical cure’ and the time to survival for those who are not cured, provides important additional insights into the effectiveness of health care systems in diagnosing and treating cancer patients. Using breast cancer as an example, rather than reporting that 90.2% of the breast cancer patients survived for five years in the hypothetical world when breast cancer is the only reason for death (26), the results from the cure models would show that among all Australian women diagnosed with breast cancer, 72.2% of them were cured of this disease; and for those who died from breast cancer, their median survival time was 5.4 years.

The proportion cured and median survival time for the uncured decreased with the spread of disease for all types, emphasising the importance of the screening programs for early diagnosis. In contrast to most other cancers where the older patients had lower cure proportion, those diagnosed with breast or prostate cancers when age 15-49 years had lower proportion cured than those aged 50-64, consistent with studies in European countries (10,27). Possible reasons include the lower prevalence of cancer screening among younger age groups, and the biological differences between early-onset and late-onset disease (28,29).
Based on the proportion cured in 1980s and its temporal change over 28 years, oesophageal, stomach, pancreatic, liver, gallbladder, lung, and brain cancer were categorised as Group AI. Notably this comprised most of the major gastro-intestinal cancers. This is consistent with European studies that have also reported low proportion cured and median survival time for the uncured and small improvements for these gastro-intestinal cancers (9, 10, 13, 27). While still low, the proportion cured for lung cancer in Australia was slightly higher than that for many European countries (9, 10), however there was a consistent lack of increase in cure proportion over time. International comparisons for brain cancer were not available, with one European study reporting results for cancer of the central nervous system, with a much higher proportion cured (~60%) and median survival time for uncured patients (1.2-5.9 years) (9). As this study also included spinal cord cancer, which has shown to have a better survival than brain cancer (30, 31), the results may not be directly comparable.

Only myeloma was categorised as AII. The proportion cured and median survival time of uncured increased substantially over time, possibly associated with improvements in treatment (32). Notably, the ratio between median survival time for the uncured and proportion cured for myeloma is higher than most of the other studied cancers, suggesting that the treatment prolongs life rather than cures this disease (32, 33).

The small number of AII cancers highlights the challenge in the underlying reasons for the “lower cure” of the Group A cancers such as difficulty in diagnosing them early and ineffective treatments remain. This phenomenon emphasises the importance of reducing the prevalence of preventable risk factors for these cancers given the lack of treatment options. For example, given the compelling evidence for smoking as the predominant causal factor for lung cancer (34), strategies for reducing the prevalence of smoking could be an effective approach in eventually reducing the burden of lung cancer.

Head and neck, ovarian, uterine, and cervical cancers, along with melanoma, were categorised as Group BI, indicating good overall proportion cured and the median survival time for the uncured but little improvement over time. International comparisons for cancers in this group were not available, with only one European study reporting results for mouth and pharynx cancers [8], however this is a subset of the head and neck cancer group reported in our study.

In the context of a halving of the incidence and mortality rates since the introduction of the National Cervical Screening Program in 1991 (35), the proportion cured for cervical cancer
have remained constant. This is reflective of the differing intent of the cervical screening program compared to prostate specific antigen (PSA) testing for prostate cancer (36) and mammograms for breast cancers (37), in that it is designed to detect and treat high-grade abnormalities before they progress to cervical cancer. It is also reflective of the difficulty in treating cervical cancer (38), highlighting the importance of primary prevention for this disease through human papillomavirus (HPV) vaccination (39) and secondary prevention through participating in cervical screening (35).

Cancers of prostate, breast, kidney, colorectum, leukaemia, and NHL were categorised as BII, highlighting their relatively favourable cure in the 1980s and large improvements over time. Previous studies that reported statistical cure was not achieved for breast and prostate cancers followed up the cancer cases for 15-16 years (9,10). Our study found that, in the Australian population, prostate cancer plateaued after 17 years and breast cancer after 20 years of follow-up respectively (Supplementary Figure S2), which is consistent with a previous study suggesting that longer follow-up time (25 years versus 10 years) significantly increased the reliability of cure estimation for breast cancer (40).

Based on our study, the proportion cured and median survival time for the uncured for prostate cancer has increased dramatically over past 28 years. A large contributor to this result may be the increasing use of PSA testing in Australia over the study period (36), as PSA testing detects cancers earlier than would otherwise be detected, thus increasing the observed survival (41), and as demonstrated by the stage-specific estimates in our study, thus increasing the proportion cured and median survival for uncured patients. Women diagnosed with breast cancer also experienced a large improvement in proportion cured and the median survival time for the uncured. In a similar way to PSA testing for prostate cancer, it is likely that the improvements over time for breast cancer can, at least partially, be attributed to the impact of mammography screening through the Australian BreastScreen Program that started in 1991 (37).

Similar improvements for kidney and colorectal cancers and leukaemia have been reported in other European countries (8-10,42). These improvements are likely due to earlier diagnosis and improved treatment, especially with the increased use of abdominal ultrasound and CT for early detection of kidney cancer (43), the introduction of total mesorectal excision for colorectal cancer (44), and the development of new chemotherapy treatments for leukaemia (45).
While, to our knowledge, proportion cured and the median survival time for the uncured for NHL have not been reported before, our results are consistent with other reports of improvements in survival for NHL, attributed to improvements in chemotherapy treatments (46). It is not clear why the Australian cure estimates for colorectal cancer are higher than those reported for most European countries during a similar time period (10,42). Although the rollout of the Australian National Bowel Cancer Screening Program started in mid-2006 (47) and aims of full coverage of 50-74 years old by 2019, the lack of a deviation in trend around this time makes it unlikely that this has played a role in this difference.

Study strengths include the use of national high-quality population-based cancer registration and mortality data. In addition, this study followed up cancer cases for maximum 33 years, which made it possible to report proportion cured and median survival time for the uncured for breast and prostate cancer. Third, the use of flexible parametric cure models means that cancer types which could not be modelled using either mixture or non-mixture cure models could be modelled in our study (7). Also, we were able to report some information about the impact of spread of disease at diagnosis on proportion cured and median survival time for the uncured using NSW data.

Limitations include the lack of data on potential confounders such as treatment (48), comorbidities (49), and lifestyle factors (50), which limits the insights into reasons for the observed patterns. Also, population mortality rates were only stratified by sex, age, and calendar year, without lifestyle factors such as smoking, socioeconomic class, or general health status which are strongly associated with general population mortality. While it has been suggested that smoking-related cancers can be problematic in that people diagnosed with these cancers have a higher all-cause mortality even when excluding the cancer-related mortality (51), it has been previously shown that for lung cancer (52), the bias in relative survival estimates due to the exchangeability assumption was negligible. In addition, the cure estimates are relevant for the population of cancer patients; this is conceptually different to ‘clinical cure’, so does not convey the likelihood of an individual patient being cured.

**Conclusion**

Advances in cancer diagnostic and treatment procedures have been shown to improve cancer survival, however these cure models provide unique insights into whether these improvements are due to prolonging life, or through curing the disease. Notably, there remain some cancers (oesophageal, stomach, pancreatic, liver, gallbladder, lung, and brain) for
which survival is low, and little has changed over time either in prolonging life or achieving statistical cure. In addition to reducing the prevalence of known risk factors, it remains a priority to improve efforts to detect these cancers earlier, thereby enabling treatment efforts to be more effective.

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Table 1 Estimated proportion of cured cases and median survival time for uncured cases\textsuperscript{a} for 19 cancer types by sex, Australia, 1982-2014.

| Cancer type (ICD-10 codes) | Males          | Females         |
|-----------------------------|----------------|-----------------|
|                             | Number of cases | Proportion cured in % (95% CI) | Median survival in years (95% CI) | Number of cases | Proportion cured in % (95% CI) | Median survival in years (95% CI) |
| Head & neck (C00-14, C30-32) | 73,634         | 50.8 (49.8-51.8) | 2.60 (2.52-2.67) | 24,747         | 55.4 (54.3-56.5) | 2.72 (2.64-2.80) |
| Oesophageal (C15)            | 18,526         | 13.9 (12.9-14.8) | 0.64 (0.62-0.65) | 9,200          | 18.1 (16.9-19.3) | 0.69 (0.67-0.71) |
| Stomach (C16)                | 35,047         | 23.3 (22.5-24.2) | 0.62 (0.61-0.63) | 18,322         | 25.4 (24.4-26.3) | 0.64 (0.63-0.66) |
| Colorectal (C18-20)          | 174,095        | 56.4 (55.9-56.9) | 1.39 (1.37-1.41) | 146,265        | 58.0 (57.5-58.5) | 1.41 (1.39-1.43) |
| Liver (C22)                  | 15,988         | 11.1 (10.3-11.9) | 0.43 (0.41-0.45) | 5,869          | 11.9 (10.9-13.0) | 0.44 (0.42-0.46) |
| Gallbladder (C23)            | 2,263          | 15.9 (13.8-18.2) | 0.40 (0.37-0.42) | 5,407          | 16.5 (14.6-18.6) | 0.40 (0.38-0.43) |
| Pancreatic (C25)             | 26,273         | 6.1 (5.7-6.6)    | 0.38 (0.37-0.39) | 24,031         | 7.0 (6.5-7.5)    | 0.40 (0.39-0.41) |
| Lung (C33-34)                | 152,831        | 10.2 (9.9-10.4)  | 0.54 (0.53-0.55) | 76,443         | 12.9 (12.5-13.2) | 0.59 (0.58-0.60) |
| Melanoma (C43)               | 135,591        | 83.2 (82.5-83.9) | 3.15 (3.05-3.25) | 108,586        | 90.3 (89.8-90.7) | 3.25 (3.15-3.35) |
| Breast (C50)                 | NI\textsuperscript{d} | -                | -                | 318,582        | 72.5 (70-73.1)   | 5.05 (4.99-5.11) |
| Cervical (C53)               | 0              | -                | -                | 28,028         | 51.3 (49.5-53.0) | 1.76 (1.69-1.83) |
| Uterine (C54-55)             | 0              | -                | -                | 44,724         | 74.5 (73.2-75.8) | 2.22 (2.08-2.36) |
| Ovarian (C56)                | 0              | -                | -                | 32,180         | 28.7 (27.6-29.7) | 1.50 (1.46-1.54) |
| Prostate (C61)               | 351,576        | 75.8 (75.0-76.6) | 5.02 (4.90-5.14) | 0              | -                | -                |
| Kidney (C64)                 | 33,056         | 54.6 (53.4-55.8) | 1.36 (1.29-1.43) | 18,522         | 56.7 (55.4-58.0) | 1.40 (1.32-1.47) |
| Brain (C71)                  | 20,076         | 8.5 (8.1-8.9)    | 0.60 (0.59-0.62) | 14,657         | 9.1 (8.7-9.6)    | 0.62 (0.61-0.64) |
| NHL\textsuperscript{b} (C82-86) | 50,291        | 48.1 (47.2-49.0) | 1.94 (1.87-2.00) | 41,513         | 51.7 (50.8-52.7) | 2.03 (1.96-2.10) |
| Myeloma (C90)                | 16,594         | 19.5 (18.3-20.7) | 3.00 (2.91-3.09) | 13,172         | 20.7 (19.5-22.0) | 3.07 (2.98-3.16) |
| Leukaemia (C91-95)           | 37,220         | 39.1 (38.0-40.1) | 1.40 (1.35-1.45) | 25,614         | 39.5 (38.5-40.6) | 1.41 (1.36-1.46) |
| Testicular cancer\textsuperscript{c} (C62) | 17,685 | -                | -                | 0              | -                | -                |
| Hodgkin lymphoma (C81)       | 7,001          | -                | -                | 5,705          | -                | -                |
| Thyroid cancer (C73)         | 8,592          | -                | -                | 26,266         | -                | -                |

Note: a. Proportion cured and median survival time for the uncured were estimated using cure models (including sex, age group, and period of diagnosis as covariates) and standardised by age and period of diagnosis using 1982-2014 Australian cancer cohort (n=2,098,923) as the standard population. b. NHL – non-Hodgkin lymphoma. c. Testicular, Hodgkin lymphoma, and thyroid cancer were not included in the study cohort due to reasons listed in the text. d. NI - Due to their small number, male breast cancer cases were not included in the study cohort.
Table 2 Estimated proportion of cured cases and median survival time for uncured cases\textsuperscript{a} for 19 cancer types by age group, Australia, 1982-2014.

| Cancer type | Number of cases | Proportion cured in % (95% CI) | Median survival in years (95% CI) | Number of cases | Proportion cured in % (95% CI) | Median survival in years (95% CI) | Number of cases | Proportion cured in % (95% CI) | Median survival in years (95% CI) |
|-------------|----------------|--------------------------------|----------------------------------|----------------|--------------------------------|----------------------------------|----------------|--------------------------------|----------------------------------|
| Head & neck | 18,627         | 74.5 (73.6-75.3)              | 3.19 (3.09-3.29)                 | 50,803         | 50.8 (49.8-51.7)                | 2.62 (2.54-2.69)                 | 28,951         | 45.8 (44.6-47.0)               | 2.48 (2.41-2.55)                 |
| Oesophageal | 1,612          | 21.2 (19.2-23.2)              | 0.74 (0.71-0.77)                 | 12,394         | 17.5 (16.5-18.5)                | 0.69 (0.68-0.71)                 | 13,720         | 10.4 (9.6-11.2)                | 0.59 (0.57-0.60)                 |
| Stomach     | 4,870          | 32.9 (31.5-34.3)              | 0.72 (0.70-0.74)                 | 21,221         | 27.6 (26.7-28.5)                | 0.67 (0.66-0.69)                 | 27,278         | 17.0 (16.3-17.7)               | 0.56 (0.54-0.57)                 |
| Colorectal  | 28,465         | 63.2 (62.6-63.9)              | 1.47 (1.45-1.49)                 | 141,467        | 60.6 (60.2-61.1)                | 1.45 (1.43-1.46)                 | 150,428        | 52.0 (51.5-52.6)               | 1.35 (1.33-1.37)                 |
| Liver       | 2,370          | 21.0 (19.3-22.8)              | 0.60 (0.57-0.64)                 | 10,565         | 12.8 (11.9-13.6)                | 0.47 (0.45-0.49)                 | 8,922          | 6.2 (5.7-6.8)                  | 0.33 (0.32-0.35)                 |
| Gallbladder | 360            | 27.0 (22.6-31.7)              | 0.50 (0.46-0.54)                 | 2,976          | 17.6 (15.8-19.6)                | 0.42 (0.40-0.44)                 | 4,334          | 11.2 (9.8-12.6)                | 0.35 (0.33-0.37)                 |
| Pancreatic  | 3,024          | 16.3 (15.1-17.6)              | 0.57 (0.55-0.59)                 | 20,455         | 6.8 (6.4-7.3)                   | 0.41 (0.40-0.42)                 | 26,825         | 2.5 (2.3-2.7)                  | 0.30 (0.30-0.31)                 |
| Lung        | 12,264         | 19.6 (18.9-20.3)              | 0.71 (0.70-0.72)                 | 107,197        | 12.4 (12.1-12.7)                | 0.59 (0.59-0.60)                 | 109,813        | 6.7 (6.5-6.9)                  | 0.47 (0.47-0.48)                 |
| Melanoma    | 81,016         | 92.1 (91.7-92.4)              | 3.29 (3.18-3.39)                 | 98,830         | 88.0 (87.5-88.5)                | 3.23 (3.13-3.34)                 | 64,331         | 83.6 (82.8-84.4)               | 3.17 (3.07-3.27)                 |
| Breast      | 83,346         | 73.8 (73.4-74.3)              | 5.11 (5.04-5.17)                 | 156,215        | 76.4 (76.0-76.8)                | 5.16 (5.10-5.22)                 | 79,021         | 69.3 (68.5-70.0)               | 5.01 (4.95-5.06)                 |
| Cervical    | 15,299         | 80.1 (79.1-81.0)              | 2.15 (2.06-2.24)                 | 8,470          | 56.9 (55.2-58.5)                | 1.87 (1.79-1.94)                 | 4,259          | 34.6 (32.4-36.8)               | 1.52 (1.46-1.58)                 |
| Uterine     | 5,371          | 85.6 (84.4-86.8)              | 2.39 (2.23-2.54)                 | 25,543         | 81.7 (80.7-82.6)                | 2.33 (2.19-2.48)                 | 13,810         | 63.4 (61.6-65.2)               | 2.07 (1.95-2.20)                 |
| Ovarian     | 6,706          | 59.2 (57.8-60.6)              | 2.10 (2.04-2.16)                 | 14,655         | 33.6 (32.5-34.7)                | 1.67 (1.63-1.71)                 | 10,819         | 11.8 (11.0-12.6)               | 1.11 (1.08-1.14)                 |
| Prostate    | 6,073          | 76.8 (74.9-78.5)              | 5.07 (4.94-5.21)                 | 176,903        | 80.4 (79.9-80.9)                | 5.16 (5.04-5.28)                 | 168,600        | 72.1 (71.4-72.8)               | 4.95 (4.84-5.06)                 |
| Kidney      | 8,157          | 71.9 (70.6-73.2)              | 1.65 (1.56-1.74)                 | 25,416         | 60.8 (59.7-62.0)                | 1.47 (1.40-1.55)                 | 18,005         | 43.9 (42.5-45.4)               | 1.19 (1.13-1.24)                 |
| Brain       | 10,365         | 39.1 (37.9-40.3)              | 1.26 (1.23-1.29)                 | 14,975         | 6.0 (5.5-6.5)                   | 0.64 (0.62-0.66)                 | 9,393          | 0.5 (0.4-0.5)                  | 0.34 (0.33-0.35)                 |
| NHL\textsuperscript{b} | 17,482    | 68.2 (67.3-69.0)              | 2.43 (2.35-2.51)                 | 38,776         | 57.5 (56.6-58.3)                | 2.19 (2.12-2.26)                 | 35,546         | 35.0 (34.0-36.0)               | 1.60 (1.55-1.66)                 |
| Myeloma     | 2,246          | 40.2 (37.8-42.6)              | 4.01 (3.90-4.12)                 | 12,914         | 23.7 (22.5-25.0)                | 3.37 (3.28-3.46)                 | 14,606         | 8.5 (7.8-9.3)                  | 2.32 (2.24-2.41)                 |
| Leukaemia   | 11,330         | 52.5 (51.3-53.7)              | 1.72 (1.66-1.79)                 | 23,986         | 46.9 (45.9-48.0)                | 1.60 (1.54-1.66)                 | 27,518         | 26.2 (25.3-27.2)               | 1.09 (1.05-1.13)                 |

Note: a. Proportion cured and median survival time for the uncured were estimated using cure models (including sex, age group, and period of diagnosis as covariates) and standardised by period of diagnosis using 1982-2014 Australian cancer cohort (n=2,098,923) as the standard population. b. NHL – non-Hodgkin lymphoma.
Table 3 Estimated proportion of cured cases and median survival for uncured cases\(^a\) for 16 solid tumours\(^b\), by spread of disease, New South Wales, 1982-2013 (n=632,662).

| Cancer type | Localised | Regional | Distant | Unknown |
|-------------|-----------|----------|---------|---------|
|             | Proportion cured in % (95% CI) | Median survival in years (95% CI) | Proportion cured in % (95% CI) | Median survival in years (95% CI) | Proportion cured in % (95% CI) | Median survival in years (95% CI) | Proportion cured in % (95% CI) | Median survival in years (95% CI) |
| Head & neck | 68.0 (66.3-69.6) | 3.18 (3.02-3.34) | 32.1 (30.2-34.0) | 2.16 (2.05-2.27) | 11.3 (9.8-13.0) | 1.31 (1.23-1.40) | 56.8 (54.6-58.9) | 2.90 (2.75-3.05) |
| Oesophageal | 25.8 (23.2-28.4) | 0.81 (0.77-0.84) | 16.2 (14.0-18.5) | 0.69 (0.65-0.72) | 2.2 (1.6-2.9) | 0.39 (0.37-0.42) | 17.3 (14.9-19.8) | 0.70 (0.67-0.74) |
| Stomach | 53.0 (50.8-55.1) | 1.05 (1.01-1.09) | 27.8 (26.0-29.7) | 0.82 (0.78-0.85) | 3.4 (2.9-4.0) | 0.40 (0.38-0.42) | 25.3 (23.1-27.5) | 0.79 (0.75-0.82) |
| Colorectal | 86.3 (85.7-86.9) | 2.09 (2.04-2.13) | 60.1 (59.1-61.0) | 1.82 (1.78-1.85) | 7.8 (7.2-8.4) | 0.80 (0.78-0.83) | 63.0 (61.6-64.3) | 1.85 (1.81-1.89) |
| Liver | 19.8 (17.6-22.1) | 0.55 (0.51-0.59) | 9.6 (7.7-11.9) | 0.39 (0.35-0.43) | 3.1 (2.4-4.0) | 0.24 (0.22-0.27) | 12.0 (10.3-13.9) | 0.43 (0.39-0.47) |
| Gallbladder | 48.2 (40.2-54.1) | 0.87 (0.77-0.97) | 18.3 (14.1-22.8) | 0.58 (0.51-0.64) | 2.5 (1.4-4.1) | 0.29 (0.25-0.33) | 22.5 (16.8-28.6) | 0.63 (0.54-0.71) |
| Pancreatic | 15.6 (14.0-17.3) | 0.57 (0.55-0.60) | 11.0 (9.8-12.3) | 0.50 (0.48-0.52) | 1.7 (1.4-2.1) | 0.28 (0.26-0.29) | 11.5 (10.3-12.9) | 0.51 (0.49-0.53) |
| Lung | 28.1 (27.1-29.1) | 0.99 (0.97-1.01) | 15.4 (14.7-16.2) | 0.78 (0.76-0.80) | 1.5 (1.4-1.7) | 0.37 (0.36-0.38) | 12.6 (11.9-13.3) | 0.73 (0.71-0.74) |
| Melanoma | 94.5 (94.0-94.9) | 2.97 (2.81-3.13) | 57.1 (54.2-59.8) | 2.44 (2.31-2.57) | 15.6 (13.6-17.7) | 1.45 (1.36-1.54) | 83.7 (81.5-85.6) | 2.84 (2.69-2.99) |
| Breast | 87.4 (86.7-87.9) | 5.37 (5.26-5.49) | 62.6 (61.4-63.8) | 4.86 (4.76-4.96) | 13.3 (12.2-14.4) | 2.87 (2.78-2.96) | 69.7 (68.2-71.1) | 5.02 (4.92-5.13) |
| Cervical | 74.3 (71.5-76.8) | 2.31 (2.16-2.46) | 40.5 (37.0-44.0) | 1.81 (1.68-1.93) | 7.1 (5.5-9.1) | 0.90 (0.81-0.99) | 59.2 (54.7-63.4) | 2.11 (1.97-2.25) |
| Uterine | 89.8 (88.3-91.1) | 2.47 (2.22-2.72) | 61.6 (57.9-65.1) | 2.10 (1.90-2.30) | 19.1 (15.8-22.6) | 1.25 (1.13-1.37) | 74.2 (70.5-77.4) | 2.28 (2.05-2.50) |
| Ovarian | 71.6 (68.9-74.2) | 2.71 (2.58-2.84) | 29.1 (26.5-31.7) | 1.86 (1.76-1.97) | 13.2 (11.8-14.7) | 1.32 (1.25-1.40) | 38.6 (35.1-42.1) | 2.10 (1.98-2.23) |
| Prostate | 90.3 (89.3-91.2) | 5.13 (4.88-5.38) | 73.2 (70.6-75.7) | 4.80 (4.57-5.03) | 11.6 (9.9-13.5) | 2.43 (2.29-2.58) | 79.5 (77.9-81.0) | 4.93 (4.69-5.16) |
| Kidney | 83.9 (82.2-85.3) | 2.37 (2.17-2.57) | 49.5 (46.2-52.7) | 1.82 (1.67-1.97) | 3.8 (3.0-4.8) | 0.55 (0.50-0.60) | 48.2 (44.7-51.7) | 1.79 (1.64-1.95) |
| Brain | 9.3 (8.5-10.1) | 0.63 (0.60-0.66) | 7.5 (6.3-9.0) | 0.57 (0.53-0.62) | 6.0 (4.5-7.8) | 0.52 (0.45-0.58) | 11.3 (10.3-12.5) | 0.69 (0.65-0.73) |

Note: a. Proportion cured and median survival time for the uncured were estimated using cure models (including sex, age group, period of diagnosis, and spread of disease as covariates) and standardised by age and period of diagnosis using 1982-2014 Australian cancer cohort (n=2,098,923) as the standard population. b. Non-Hodgkin lymphoma, myeloma, and leukaemia were not included in the table because of different staging methods.
Figure legends

Figure 1 Bubble plot of proportion cured and median survival time for uncured cases for 19 cancer types, Australia, 1982-2014, 15-89 years at diagnosis, persons.

Note: a. Proportion cured and median survival time for the uncured were estimated using cure models (including sex, age group, and period of diagnosis as covariates) and standardised by age and period of diagnosis using 1982-2014 Australian cancer cohort (n=2,098,923) as the standard population. b. The area of the bubbles represents the number of cancer cases diagnosed in the study cohort.

Figure 2 Trends in proportion cured and median survival time for the uncured cases for 19 cancer types, Australia, age at diagnosis 15-89 years, 1982-2009, with follow-up to 2014.

Note: Proportion cured and median survival time for the uncured were estimated using cure models (including sex, age group, and year of diagnosis as covariates) and standardised by age of diagnosis using 1982-2014 Australian cancer cohort (n=2,098,923) as the standard population.

Figure 3 The 1980s baseline (upper) and 1982-2009 temporal change (lower) of proportion cured and median survival time for the uncured for 19 cancer types, Australia, age at diagnosis 15-89 years.

Note: a. The 1980s baseline measures were estimated based on cancer cases diagnosed in 1980-1989 using cure models (including sex, age group, and year of diagnosis group as covariates) and standardised by age group using 1982-2014 Australian cancer cohort. Group A – lower cure, defined as proportion cured < 20%; Group B – higher cure, proportion cured ≥ 20%. b. Temporal changes were estimated using linear regression models (dependent variable is the 1982-2009 year-specific proportion cured /median survival for the uncured; independent variable is year of diagnosis). Group I – smaller increase, defined as proportion cured increased by < 0.75% per year; Group II – larger increase, defined as proportion cured increased by ≥ 0.75% per year.
Figure 2: Trends in standardized cure proportion and median survival time for various cancers from 1980 to 2010.
Temporal trends in population-level cure of cancer: the Australian context

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