Cancer incidence and mortality in Australia from 2020 to 2044 and an exploratory analysis of the potential effect of treatment delays during the COVID-19 pandemic: a statistical modelling study

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Summary

Background Long-term projections of cancer incidence and mortality estimate the future burden of cancer in a population, and can be of great use in informing the planning of health services and the management of resources. We aimed to estimate incidence and mortality rates and numbers of new cases and deaths up until 2044 for all cancers combined and for 21 individual cancer types in Australia. We also illustrate the potential effect of treatment delays due to the COVID-19 pandemic on future colorectal cancer mortality rates.

Methods In this statistical modelling study, cancer incidence and mortality rates in Australia from 2020 to 2044 were projected based on data up to 2017 and 2019, respectively. Cigarette smoking exposure (1945–2019), participation rates in the breast cancer screening programme (1996–2019), and prostate-specific antigen testing rates (1994–2020) were included where relevant. The baseline projection model using an age-period-cohort model or generalised linear model for each cancer type was selected based on model fit statistics and validation with pre-COVID-19 observed data. To assess the impact of treatment delays during the COVID-19 pandemic on colorectal cancer mortality, we obtained data on incidence, survival, prevalence, and cancer treatment for colorectal cancer from different authorities. The relative risks of death due to system-caused treatment delays were derived from a published systematic review. Numbers of excess colorectal cancer deaths were estimated using the relative risk of death per week of treatment delay and different durations of delay under a number of hypothetical scenarios.

Findings Projections indicate that in the absence of the COVID-19 pandemic effects, the age-standardised incidence rate for all cancers combined for males would decline over 2020–44, and for females the incidence rate would be relatively stable in Australia. The mortality rates for all cancers combined for both males and females are expected to continuously decline during 2020–44. The total number of new cases are projected to increase by 47·4% (95% uncertainty interval [UI] 35·2–61·3) for males, from 380 306 in 2015–19 to 560 744 (95% UI 514 244–613 356) in 2040–44, and by 54·4% (95% UI 40·2–70·5) for females, from 313 263 in 2015–19 to 483 527 (95% UI 439 069–534 090) in 2040–44. The number of cancer deaths are projected to increase by 36·4% (95% UI 15·3–63·9) for males, from 380 306 in 2015–19 to 560 744 (95% UI 514 244–613 356) in 2040–44, and by 54·4% (95% UI 40·2–70·5) for females, from 313 263 in 2015–19 to 483 527 (95% UI 439 069–534 090) in 2040–44. The example COVID-19 pandemic scenario of a 6-month health-care system disruption with 16-week treatment delays for colorectal cancer patients could result in 460 (95% UI 338–595) additional deaths and 437 (95% UI 314–570) deaths occurring earlier than expected in 2020–44.

Interpretation These projections can inform health service planning for cancer care and treatment in Australia. Despite the continuous decline in cancer mortality rates, and the decline or plateau in incidence rates, our projections suggest an overall 51% increase in the number of new cancer cases and a 36% increase in the number of cancer deaths over the 25-year projection period. This means that continued efforts to increase screening uptake and to control risk factors, including smoking exposure, obesity, physical inactivity, alcohol use, and infections, must remain public health priorities.

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Introduction Cancer control programmes implemented today will have an effect on the burden of cancer over future decades. Long-term projections of national cancer incidence and mortality therefore provide essential information for policy makers, helping to inform health
Evidence before this study

Long-term projections of national cancer incidence and mortality provide essential information for policy makers and can help inform health service planning. We searched MEDLINE, Embase, and PreMEDLINE on Aug 6, 2021, for articles published in English from Aug 6, 2011, that used statistical methods to project national incidence and mortality rates for all cancers combined, and for individual cancers for at least 20 years beyond the period for which rates were used to obtain the projections, using the terms “cancer$ or neoplasm$ or tumo$” and “incidence” and “mortality or death$” and “rate$” and “projection$ or forecast$ or predict$ or extrapolate$” and “population”. We found two studies reporting projections for incidence or mortality for all cancers for 20 or more years, but neither of these directly integrated key cancer-specific factors. The challenges of modelling the future cancer burden have been further complicated by the COVID-19 pandemic, the direct effects and outcomes of which remain to be determined. Currently the most apparent effects include delays in cancer detection, diagnosis, and treatment, which have been reported in several countries, including Australia. We searched MEDLINE, Embase, and PreMEDLINE using the terms “cancer$ or neoplasm$ or tumo$” and “death$ or mortality” and “treatment$ or surgery$ or therapy” and “delay$ or disruption$” and “COVID$ or SARS-CoV-2 or coronavirus”, for articles published in English up until Aug 6, 2021, and did not identify any studies estimating the potential long-term effect of treatment delays on colorectal cancer mortality at a national level.

Added value of this study

We report long-term projections of incidence and mortality to 2044 for all cancers combined and for 21 individual cancer types in Australia. Our approach explicitly integrates selected crucial cancer-specific factors, including cigarette smoking exposure for lung cancer, prostate-specific antigen testing rates for prostate cancer, and screening participation rates for breast cancer. These baseline projections based on the recent pre-pandemic trends can serve as a benchmark against which the effect of the COVID-19 pandemic or other future cancer control interventions can be measured. As an example of a potential application, we conducted an exploratory analysis using the baseline projections as a benchmark to estimate the potential long-term cancer mortality effects of cancer treatment delays due to the COVID-19 pandemic under different delay scenarios, considering colorectal cancer as an example.

Implications of all the available evidence

Our baseline projections can inform prioritisation of cancer control programmes, and health service planning for future cancer care and treatment in Australia. Despite declining rates in cancer incidence and mortality, this study suggests that the total numbers of cancer cases and deaths in Australia will continue to be substantial. Thus, continued efforts to control relevant risk factors must remain a high public health priority. This study also highlighted the urgent need for real-time data on treatment disruptions during the COVID-19 pandemic and for insights into tools and policies that could potentially lessen the disruption to cancer treatment in any future health crises. More detailed modelling is needed to estimate the effect of COVID-19 restrictions and plan for the resulting demand for cancer services over the coming years.
long-term impact of treatment delays on cancer mortality in Australia.

The primary aim of this study was to use pre-pandemic data to estimate Australian incidence and mortality rates for all cancers combined and for 21 cancer types individually, and to estimate the numbers of new cases and deaths from all cancers for the period of 2020 to 2044 (hereafter referred to as baseline projections). These baseline projections assume that the recent pre-pandemic trends in underlying factors will continue into the future and were constructed as a benchmark against which the effect of the COVID-19 pandemic or other future cancer control interventions can be measured. To illustrate how the baseline projections could be used as a benchmark against which to assess the effect of the COVID-19 pandemic, a secondary aim of this study was to conduct an exploratory analysis estimating the potential long-term effect on cancer mortality of cancer treatment delays due to the COVID-19 pandemic under different delay scenarios, using colorectal cancer as an example. We estimated the number of excess colorectal cancer deaths for 2020–44 under a range of potential scenarios. Colorectal cancer was selected as it was the second most common cause of cancer death in Australia in 2019, most patients would have received surgical treatment under the pre-pandemic status quo, and a recent meta-analysis robustly quantified the mortality risk for seven cancers including colorectal cancer due to delayed treatment.10

**Methods**

This study includes two separate analyses: baseline projections of cancer incidence and mortality, and estimating the number of excess deaths from colorectal cancer due to delayed treatment during the COVID-19 pandemic. All age-standardised rates presented in the main results of this paper were standardised to the Segi World standard population. All statistical analyses were performed using Stata version 17.

**Data sources**

For the baseline projections, we obtained tabulated data from the Australian Institute of Health and Welfare (AIHW) and the World Health Organization’s Mortality Database on the numbers of new cancer cases (1982–2017) and deaths (1955–2019) in Australia for all cancers combined and for 21 individual cancer types (appendix pp 7–9) by sex, age, and year. Other tabulated data used in this study include the amounts of cigarette smoking exposure (1945–2019),11 participation rates in the breast cancer screening programme (1996–2019), and prostate-specific antigen (PSA) testing rates (1994–2020; appendix pp 9–11).11 Although PSA testing is not considered to be a suitable population-level screening test, the PSA testing rate is a strong predictor for the prostate cancer incidence rate and was therefore included in the projection model. Australian population data and projections (1955–2044) were obtained from the Australian Bureau of Statistics. These data predict an increasing population size (from 24·6 million in 2017 to 35·0 million by 2044), and an ageing population (eg, percentage of the Australian population aged 65 years and older is estimated to increase from 15·4% in 2017 to 18·3% in 2044).13,15

To assess the effect of treatment delays during the COVID-19 pandemic on colorectal cancer mortality, we obtained data on incidence and survival by sex, age group, and stage at diagnosis from the AIHW.9 Sex-specific prevalence data were also obtained from the AIHW and sex-age-specific prevalence data were obtained from the Global Cancer Observatory database.17 Because we did not have access to sex-age-stage-specific cancer treatment data for Australia, we estimated treatment use for new colorectal cancer cases for other high-income countries using data from the International Cancer Benchmarking Partnership (ICBP) SurvMark-2 project (appendix pp 48–49),18,19 and used this as a proxy for Australian treatment patterns to estimate the proportion of cancer patients who would have received treatment in the absence of the COVID-19 pandemic. For recurrent cancers, the proportion of patients who would have received surgery and other treatment was estimated using the mean proportion of patients with recurrent cancers who received curative surgical treatment as reported in the literature.20 To understand the duration of health-care system disruption during the pandemic, we examined available health service data on the total number of colorectal surgeries and elective surgeries before and during the COVID-19 pandemic in 2020.12,21

The term health system disruptions in this study refers to any changes in how services were delivered during the COVID-19 pandemic, including the suspension of non-urgent elective surgery, the reduction in health service capacity, and the reduction in seeking of health services by cancer patients due to the COVID-19 pandemic. The relative risks of death due to system-caused treatment delays were derived from the systematic review by Hanna and colleagues.21 More details on the data sources used in this study are in the appendix (pp 46–53).

This study used existing, routinely collected data on cancer incidence, mortality, survival, prevalence, smoking intensity, and breast cancer screening released by the AIHW, the Medicare Benefits Schedule claims data on PSA testing, and colorectal cancer surgery released by Services Australia. As such, ethics approval was not required to use these aggregated data.

**Statistical analysis**

**Projection models for the baseline projections**

For each of the 21 cancer types (16 separately for females and males, plus five sex-specific sites) and the remaining cancer types grouped as other cancers, the selection of the most appropriate statistical projection model for each cancer type was based on the Bayesian Information...
Model validation and comparison with other studies

Model validation provides information on the performance and reliability of the projection model. We validated our approach by withholding the most recent 10 years of observed incidence data and the most recent 15 years of mortality data from the model fitting and then comparing the projected rates for those years with the actual observed rates. Validations for all cancers combined and for 21 individual cancer types showed that the uncertainty intervals of projected rates generally captured the observed rates, with only small absolute differences (median 0.3 [range 0.0–8.6] cases per 100,000 population for incidence and 0.2 [0.0–2.4] deaths per 100,000 population for mortality), suggesting that the approach provides valid 10-year projections for incidence and 15-year projections for mortality (appendix pp 19–21). Baseline projections for cancer mortality rates were compared with previously published projections reported in the global study by Foreman and colleagues.26 Estimating the number of excess colorectal cancer deaths due to treatment delays during the COVID-19 pandemic

This outcome consists of two separate components: additional colorectal deaths due to delayed treatment for patients who would not have died from colorectal cancer with timely treatment, and colorectal deaths occurring earlier than expected due to delayed treatment for patients who would have died from colorectal cancer by 2044 even with timely treatment. Due to the scarcity of available real-time Australian data on the average duration of treatment delays experienced by patients and the proportion of patients who would have had delayed treatment during the COVID-19 pandemic, we explicitly modelled a number of hypothetical scenarios based on the combination of three parameters: (1) duration of health-care system disruption (3, 6, and 12 month disruptions to the health-care system), (2) average duration of the treatment delay experienced by patients at the population level (4, 8, 12, 16, and 26 weeks delay), and (3) the assumption that 100% of patients would have had delayed treatment but after the delay eventually all would receive treatment as planned. Some potential parameter choices were informed by the available data, as described in the appendix (pp 50–51). The death rate for each treatment delay scenario was calculated using the proportion of patients having delayed treatment and the corresponding relative risk of death due to the specific delay duration, with relative risks calculated using the formula proposed by Hanna and colleagues (appendix pp 51–52). We defined the UI as the estimated excess colorectal cancer deaths based on the confidence intervals of the relative risks of death due to treatment delay.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

The age-standardised incidence rate for all cancers combined for males is projected to decline by 9.1% (95% UI –17.5 to 0.7) over the period 2015–19 to 2040–44 (figure 1A), dropping from 360.5 to 327.8 (95% UI 297.3 to 363.1) per 100,000 (appendix pp 23–24). For females, the incidence rate for all cancers combined is expected to slightly decrease by 1.1% over the same period (figure 1B), from 293.3 to 290.1 (95% UI 261.7 to 323.0) per 100,000 (appendix pp 23–24). Incidence rates for the age groups aged 50 years and older for males decline steadily from the late-2000s to 2044 (figure 1A), and the incidence rates for the age groups aged 60 years and older for females are expected to slightly decrease after 2020 (figure 1B). Due to population growth and ageing, during 2020–44 it is estimated that the number of new cancer cases will increase by 47.4% (95% UI 35.2 to 61.3) for males, from 380.306 in 2015–19 to 560.744 (95% UI 514.244 to 613.356) in 2040–44, and by 54.4% (95% UI 40.2 to 70.5) for females, from
313,263 in 2015–19 to 483,527 (95% UI 439,069 to 534,090) in 2040–44 (appendix pp 23–24).

The observed and predicted incidence rates and numbers of new cases for 21 selected cancer types plus other cancers as a group are presented in figure 2 and the appendix (pp 23–24, 27–28). It is expected that prostate cancer and female breast cancer will remain the most commonly diagnosed cancers, with prostate cancer projected to account for 133,917 (23.9%) of 560,744 new cases for males and breast cancer projected to account for 137,776 (28.5%) of 483,527 new cases for females in 2040–44 (appendix pp 23–24, 32).

Melanoma is projected to remain the second most commonly diagnosed cancer for males, followed by colorectal cancer and lung cancer. For females, colorectal cancer is projected to remain the second most commonly diagnosed cancer after breast cancer, followed by melanoma and lung cancer (appendix p 32). In 2040–44, cancers of the prostate, lung, colorectum, and female breast and melanoma are projected to account for 564,089 (54.0%) of all 1,044,271 cancer cases (298,006 [53.1%] of 560,744 for males and 266,083 [55.0%] of 483,527 for females) in Australia (appendix pp 27–28, 31).

For both males and females, the age-standardised mortality rates for all cancers combined are projected to continuously decline over the period 2015–19 to 2040–44 (figure IC, D), by 21.5% (95% UI –36.0 to –1.1) for males from 106.3 to 83.4 (95% UI 68.0 to 105.1) per 100,000 males, and by 20.6% (95% UI –35.0 to 0.1) for females from 73.4 to 58.3 (95% UI 47.7 to 73.5) per 100,000 females (appendix pp 25–26). The mortality rates for age groups aged younger than 60 years showed a steady decline from the 1980s, and the decline in the mortality rate started 10–20 years later for age groups 60 years and older (figure IC, D). Due to population growth and ageing, the actual numbers of cancer deaths are projected to increase by 36.4% (95% UI 15.3 to 63.9) for males, from 132,440 in 2015–19 to 180,663 (95% UI 152,719 to 217,126) in 2040–44, and by 36.6% (95% UI
Mortality rates for most cancer types are expected to decrease from 2020 to 2044 for both males and females, except for cancers of the liver, thyroid, uterus, and testis.
Prostate cancer is expected to replace lung cancer as the most common cause of cancer death for males in 2040–44, followed by lung, colorectal, and liver cancers. Lung cancer is estimated to remain the most common cause of cancer death for females in 2040–44, followed by breast, colorectal, and pancreatic cancers (appendix p 33). In 2040–44, lung, prostate, female breast, colorectal, liver, and pancreatic cancers are projected to account for 174660 (54·6%) of all 320145 cancer deaths (97249 [53·8%]...
of 180,663 for males and 77,411 [55·5%] of 139,482 for females) in Australia (appendix pp 29–31).

For a cohort of prevalent colorectal cancer patients, including newly diagnosed patients and people living after a colorectal cancer diagnosis during the COVID-19 pandemic in 2020, it is estimated that there would be a total of 19,975 colorectal cancer deaths (12,025 males and 7,950 females) during the period of 2020 to 2044 in the absence of the COVID-19 pandemic effects. Under a mild scenario whereby health-care system disruptions lasted for 3 months in 2020 and each colorectal cancer patient had a treatment delay of 4 weeks, we estimated that there would be a total of 49 (95% UI 25·7–74) additional colorectal cancer deaths (29 [95% UI 15–43] males and 20 [95% UI 10–31] females), and 48 (95% UI 22–73) deaths (26 [95% UI 13–39] males and 22 [95% UI 9–34] females) that would occur earlier than expected (table). More prolonged delays, such as in a scenario whereby disruptions lasted for 6 months and patients had a treatment delay of 16 weeks, could result in 460 (95% UI 338–593) additional deaths and 437 (95% UI 314–570) deaths occurring earlier than expected. The most extreme scenario, with disruptions lasting 12 months and patients’ treatments being delayed by 26 weeks, could result in a total of 1,719 (95% UI 1,333–2,151) additional deaths and 1,626 (95% UI 1,243–2,050) deaths occurring earlier than expected. These estimates are equivalent to 0·2–8·6% of the estimated total number of colorectal cancer deaths under the pre-pandemic status quo (appendix p 57).

Discussion

The results of our baseline statistical projections suggest that the mortality rates for all cancers combined for both males and females in Australia will continue to decline over the period of 2020–44. The overall incidence rate for all cancers combined for males is projected to continuously decline over the period of 2020–44, and for
females the projected incidence rate is relatively stable. The overall numbers of new cancer cases and deaths are predicted to continue to increase substantially over the period of 2020–44, which is largely a result of the ageing population and increasing population size. As these baseline projections are made under the assumption that recent trends will continue and do not consider any of the possible effects of the COVID-19 pandemic on future cancer rates, we also explored how treatment delays might affect future outcomes for colorectal cancer patients, as an example. We illustrated that a 6-month health-care system disruption with a 16-week delay to cancer treatment is estimated to result in 460 additional cancer deaths and 437 deaths occurring earlier than expected during 2020–44. Given that the number of excess colorectal cancer deaths due to delayed treatment strongly depends on the duration of system disruptions and the resulting delays experienced by individual patients, the negative effect of treatment delays in more serious pandemic situations would be even worse. Also, due to the non-linear relationship between duration of treatment delay and cancer outcome, even if a 12-month treatment delay is experienced by only a small proportion of colorectal cancer patients this could still result in a substantial number of excess colorectal cancer deaths.

This study reported long-term baseline projections of both incidence and mortality rates for all cancers, and explicitly incorporated age-specific PSA testing rates for prostate cancer, cancer screening participation rates for breast cancer, and cigarette smoking exposure for lung cancer. Previous work by Foreman and colleagues reported long-term projections of mortality rates for 195 countries (including Australia) based on the Global Burden of Diseases Study (GBD) 2016 estimates. For most cancer types with decreasing trends, projections from Foreman and colleagues generally overestimated the true rate in 2015–19, with notable differences for colorectal, kidney, lung, oesophagus, and prostate cancers, and melanoma and non-Hodgkin lymphoma. The exception is liver cancer, which was underestimated in the GBD projections (appendix p 34). Due to lags in reporting, GBD 2016 estimates for Australia are a combination of observed data to 2014 and model estimates for the most recent years (2015–16). The discrepancies between these estimated recent data and the observed data probably contributed to the differences between their projections and the observed rates for 2015–19. In general, the absolute differences between the projected and observed rates in 2015–19 for the GBD projections (eg, for all cancers combined, the median of absolute differences was 6–1 [range 3–1–11–9] deaths per 100 000 population) were higher than those for our 15-year model validation (0–9 [0–1–2–4] deaths per 100 000 population; appendix p 21). These differences are likely to be due to the different observed data periods and methods used in the two studies (appendix p 35).

Although the GBD studies provide important insights into the distribution of global health issues, their standardised modelling approach might not explicitly capture the trends of individual cancers in a specific population. Cancer is a diverse group of diseases, with each individual cancer type having unique characteristics in terms of risk factors, natural disease history, treatment, and survival, and, as our study confirmed, different patterns of incidence and mortality rates. A detailed discussion of the results for individual cancer types is provided in the appendix (pp 35–38). For several cancer types, decreasing incidence trends were observed and projected for both males and females, including bladder, colorectal, larynx, lung, oesophageal, and stomach cancers and melanoma, which are likely to be related to changes in behavioural factors including smoking and alcohol consumption, as well as the effect of cancer prevention and screening programmes. However, our projections also suggest increases in incidence rates for kidney, liver and pancreatic cancers for both males and females, which might be attributable to diabetes and obesity, physical inactivity, and hepatitis infection (appendix pp 37–38). Future research focusing on the increases in incidence rates for these cancers and their prioritisation for cancer control efforts are warranted.

Our exploratory analysis of the effect of health-care disruptions on colorectal cancer mortality emphasises the importance of balancing the potential risks and benefits of postponing treatment for cancer patients in response to the COVID-19 pandemic, and highlights the urgent need for real-time health service data to quantify the effect of the pandemic on cancer outcomes. Treatment delays during the COVID-19 pandemic can be due to multiple factors, including a shortage of hospital resources and workforce, or due to patients choosing to limit their potential exposure to SARS-CoV-2. In practice, the delays will probably differ between jurisdictions. For example, a study from England reported a 31% relative reduction in the number of people receiving colorectal cancer surgery in April 2020 compared with monthly data for 2019, which was a larger reduction than that observed in Australia. It is unlikely that the most severe scenarios used in our exploratory analysis occurred in Australia in 2020. However, as Australia and many other countries had new outbreaks of COVID-19 in 2021 due to the delta variant (B.1.617.2), our findings might potentially be more relevant if health services are disrupted for an extended period of time before a substantial rate of vaccination is achieved in the population. It is also important to acknowledge that treatment delays are only one of the many potential negative effects of the COVID-19 pandemic on cancer patients, including possible delays in diagnosis and a subsequent shift in stage towards more advanced disease, which is likely to result in additional excess...
Deaths (a broader discussion of this can be found in the appendix [pp 58–59]). For example, a modelling study published in 2021 estimated that a 6-month disruption in colorectal cancer screening would result in almost 2000 additional colorectal cancer deaths in Australia due to delayed diagnosis.\textsuperscript{22} Thus, it is important to assess the combined effects of disruptions to screening programmes, diagnostic and treatment delays, and any long-term risk behaviour changes, and to determine the best methods for counteracting these effects and aiding recovery. The COVID-19 and Cancer Global Modelling Consortium has been established to address these issues and help countries minimise the effect of COVID-19 on cancer patients in the longer term. More detailed modelling across all major cancer types will be conducted in Australia and other countries.\textsuperscript{13} Comparisons of the effects of the COVID-19 pandemic between Australia and countries with similar health systems that had greater disruption from the pandemic will be important for future policy decisions regarding responses such as border closures and virus elimination strategies.

As with all modelled projections, this study does have some limitations which should be considered when interpreting the results (appendix pp 22, 54–55). For the baseline projections, the main limitation is their dependence on the assumptions made in the modelling, including that the age effect will remain unchanged over time and reflects the general level of cancer risk in the population, that for cancers other than lung cancer the future cohort and period effects will be the same as those for the most recent observed cohort and period,\textsuperscript{32} and that for prostate and breast cancers the most recent trends in the rates of PSA testing and breast cancer screening participation will continue into the future. The models do not capture recent changes in cancer control that might have a large effect on future patterns, including the changes in cervical cancer screening, the full roll-out of the colorectal cancer screening programme, and advances in immunotherapy treatment. Moving forward it might be important to update projections at regular intervals to allow for the incorporation of the most recent trends. However, appropriate adjustment to the data to accommodate the effect of the COVID-19 pandemic will be necessary. The main limitation in our estimation of excess colorectal cancer deaths due to treatment delays during the COVID-19 pandemic is that we do not have real-time clinical data on actual treatment delays experienced by cancer patients, so the current modelling in this study relies on hypothetical scenarios. Also, the proportion of colorectal cancer patients who would have received surgical treatment with or without other therapy was estimated using the ICBP SurvMark-2 data, although we believe this estimate is acceptable as it has been shown that the overall proportion of patients in that dataset who received surgical treatment is generally consistent with that reported for Australia.\textsuperscript{24}

Despite these limitations, this study also has many strengths. First, the long-term observed data used in this study are known to be of high quality and have high population coverage.\textsuperscript{15,16} Second, where relevant and possible, this study took into account detailed data on cancer screening, cigarette consumption, and PSA testing rates when projecting incidence and mortality rates. Third, for other cancer types, age, period, and cohort effects were used, so this study might implicitly capture the effect of factors which contribute to cancer incidence and mortality at a population level, as the age, period, and cohort effects can reflect a range of factors that are related to cancer risk, cancer diagnosis, and treatment.\textsuperscript{25} Furthermore, the models were validated using observed data (appendix pp 19–21), which demonstrated that our projection models were sensible, and that the projections reported are reliable in the short term and adequately reflect cancer outcomes under the current cancer control situation in the absence of any pandemic impacts. The methods used in this study might be applicable elsewhere.

This study provides previously unavailable information on projections of cancer incidence and mortality in Australia to 2044, for all cancers combined as well as for 21 individual cancer types. These projections can help inform health service planning to meet the requirements for future cancer care in Australia. These results can also serve as benchmarks against which to measure the impact of future cancer prevention and intervention initiatives, and we have illustrated a method to use the baseline projections as a benchmark to assess the impact of different hypothetical or real scenarios of delayed treatment during the COVID-19 pandemic. Despite the continuous decline in cancer mortality rates, and the decline or plateau in the incidence rates, our projections suggest an overall 51% increase in the number of new cancer cases and a 36% increase in the number of cancer deaths over the 25-year projection period. This means that continued efforts to increase screening uptake and to control risk factors, including smoking exposure, obesity, physical inactivity, alcohol use, and infections, must remain public health priorities.

Contributors
KC conceived the study. QL, DLO, JS, and KC designed the study. QL did the literature search, study design, statistical projections analyses, and the analyses of cancer treatment delays. JS and CJC analysed the SurvMark-2 data. XQY, MC, FP, PS, IS, DLO, JS, and KC advised on statistical analyses and methods. QL, CK, and XQY verified the data. QL interpreted results and drafted the manuscript with input from CK, DLO, JS, and KC. PBG and SA provided advice on policy implications. All authors contributed to the interpretation of the results, critically revised the manuscript, and read and approved the final manuscript. All authors had full access to the verified data and had final responsibility for the decision to submit for publication.

Declaration of interests
KC is co-principal investigator of an investigator-initiated trial of cervical screening, Compass, run by the Australian Centre for Prevention of Cervical Cancer (ACPPC), which is a government-funded not-for-profit
charity; the ACPC has received equipment and a funding contribution from Roche Molecular Diagnostics, and operational support from the Australian Government. KC is also co-principal investigator on a major investigator-initiated implementation programme Elimination of Cervical Cancer in the Western Pacific (ECCWP) which will receive support from the Minderoo Foundation, the Frazer Family Foundation, and equipment donations from Cepheid. Neither KC nor her institution on her behalf receives direct funding from industry for any project. MC is an investigator on an investigator-initiated trial of cytology and primary human papillomavirus screening in Australia (Compass; ACTRN12613001207707 and NCT02328872), which is conducted and funded by the Australian Centre for the Prevention of Cervical Cancer, a government-funded health promotion charity. The Australian Centre for the Prevention of Cervical Cancer has received equipment and a funding contribution for the Compass trial from Roche Molecular Systems and operational support from the Australian Government. However neither MC nor his institution on his behalf (the Daffodil Centre, a joint venture between Cancer Council NSW and The University of Sydney) receive direct funding from industry for Compass Australia or any other project. All other authors declare no competing interests.

Data sharing
The tabulated data on cancer incidence, mortality, survival, prevalence, and cancer screening are available from the Australian Institute of Health and Welfare at https://www.aihw.gov.au/. The Medicare Benefits Schedule data are available at https://www.servicesaustralia.gov.au/. Access restrictions apply to the National Drug Strategy Household Surveys data on smoking behaviour. Approved release of these data can be obtained through an application to the Australian Institute of Health and Welfare.

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