ACT Asbestos Health Study: Data Linkage Study on the Risk of Mesothelioma and Other Cancers in Residents of Affected Properties in the ACT

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A report prepared for the ACT Government

June 2017

Australian National University

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Abbreviations

ACT	Australian Capital Territory
AIHW	Australian Institute of Health and Welfare
ANU	The Australian National University
ARP	Affected residential property
CI	Confidence interval
DISC	Data Integration Services Centre
IA	Integration Authority
IC	International Classification of Diseases
NSW	New South Wales
Qld	Queensland
NT	Northern Territory
SA	South Australia
SIR	Standardised incidence ratio
Tas	Tasmania
Vic	Victoria
WA	Western Australia

Summary

The Australian Capital Territory (ACT) Government commissioned the Australian National University to undertake a study to improve understanding of the health risks of loose-fill asbestos insulation, which was installed in over one thousand Canberra residences between 1968 and 1979. These affected residential properties (ARPs) are commonly referred to as 'Mr Fluffy' houses. This report concerns the fourth and final component of the *ACT Asbestos Health Study*.

Asbestos is a naturally occurring fibrous mineral that causes mesothelioma, a form of cancer of the lining of the lungs or abdominal cavity. Epidemiological studies have also demonstrated an association between exposure to asbestos and a range of other cancers, including lung, ovarian, laryngeal, pharyngeal, stomach and colorectal cancers. Most of these studies have been conducted in occupational settings where exposure to asbestos has been very high.

This study examined whether the rates of mesothelioma and other cancers were higher in people who have lived at an ARP than in residents who have not lived at an ARP. To do this, Medicare enrolment data on residents of the ACT between November 1983 and December 2013 were linked to the ACT Asbestos Response Taskforce register of ARPs. These data were then linked to Australian Cancer Database and the National Death Index. An *a priori* decision was made to estimate these rates separately in males and females because of likely differences in their exposure to asbestos.

A total of 1 035 578 individuals registered with Medicare had one or more ACT addresses between November 1983 and December 2013, and 17 248 (1.67%) had lived at an ARP. During this study period there was a total of 285 people diagnosed with mesothelioma in this cohort, 133 of whom were diagnosed in the ACT. Seven people diagnosed with mesothelioma had lived at an ARP during the study period and before the mesothelioma was diagnosed. After taking into account age and time of diagnosis, the rate of mesothelioma in males who had lived at an ARP was two and a half times that in males who had not lived at an ARP (standardised incidence ratio [SIR] = 2.54, 95% confidence interval [CI]: 1.02–5.24). This equated to four additional cases of mesothelioma over the number expected from the mesothelioma rate in men who had not lived at an ARP. There were no cases of mesothelioma in females who had lived at an ARP during the study period. In addition, colorectal cancer rates were elevated in ARP residents (SIR for men = 1.32, 95% CI: 0.99–1.73; SIR for women = 1.72, 95% CI: 1.29–2.26), as were rates of prostate cancer (SIR = 1.29, 95% CI: 1.07–1.54).

These findings should be interpreted with the study limitations in mind, which include: absence of data prior to November 1983; some inaccuracy in Medicare address registrations; incomplete cancer registrations (particularly prior to 1994); lack of information on other possible explanatory factors such as occupational history of asbestos exposure; and statistical uncertainty due to small numbers of some cancers, including mesothelioma.

For mesothelioma, the association with living in an ARP was considerably weaker than that typically observed for asbestos exposure in occupational settings. However, the finding cannot be ignored. Higher rates of mesothelioma in men could have been due to their greater frequency of entry into the roof space of their house, where the loose-fill asbestos at ARPs had been placed, or of making renovations to their house.

The association between living at an ARP and subsequently developing colorectal cancer was somewhat surprising given the relatively modest association we observed for mesothelioma. Other studies have overall found weak associations between asbestos exposure and colorectal cancer. We did not expect to observe an association between ARP exposure and prostate cancer; prior evidence of an association between asbestos exposure and prostate cancer is very weak. Therefore, other explanations for these associations should be considered (e.g. greater healthcare seeking behaviour in men who were living or had lived at an ARP and perhaps, therefore, more frequent testing for prostate cancer than average). On the other hand, the health effects of residential exposure to loose-fill asbestos have not previously been studied, so there is no direct basis for expectations as to the range of cancers it might cause. It would be useful to extend this study in future years to include more years of data and potentially expand it to other affected Australian jurisdictions.

Background

The Australian Capital Territory (ACT) Government commissioned the Australian National University (ANU) to undertake a study to improve understanding of the health risks of loose-fill asbestos insulation, which was installed in over one thousand Canberra residences between 1968 and 1979. This data linkage study is the fourth and final component of the *ACT Asbestos Health Study*.

Loose-fill asbestos insulation in the ACT

Between 1968 and 1979, D. Jansen & Co. Pty Ltd and its successor firms—commonly and collectively referred to as 'Mr Fluffy'—insulated homes in the ACT and southern New South Wales (NSW) by blowing loose-fill asbestos, mainly amosite, into roof spaces. Over time this material migrated to other areas such as wall cavities, underfloor spaces, cupboards, heating/cooling ducts and vents, living areas and bedrooms. [1]

Between 1988 and 1993, a joint Commonwealth and ACT Government program visually checked some 65 thousand houses in the ACT for the presence of this loose-fill asbestos insulation. More than one thousand houses, hereafter referred to as affected residential properties (ARPs), were identified as containing this insulation. An extensive remediation program was undertaken to remove loose-fill asbestos from the roof spaces of these properties. However, this program did not completely remove the loose-fill asbestos insulation. The issue re-emerged as a prominent community concern in 2012 when asbestos fibres were found in living spaces of a house that was missed in the remediation program, and subsequently in some other houses that had been remediated. [1]

In June 2014, the ACT government established The Asbestos Response Taskforce to respond to the impacts of loose-fill asbestos insulation on affected residents and the broader ACT community. The Taskforce provided advice to the ACT Government on the longer-term management of this issue in the Territory and has subsequently administered the ACT Government's voluntary Loose Fill Asbestos Insulation Eradication Scheme, comprising the Buyback, Demolition and Sales Programs. [2]

The potential health risks of loose-fill insulation are a concern for many past and present residents, as well as tradespeople and the wider ACT community. In a recent survey of current and recent residents of ARPs, over one third reported they were 'extremely' or 'very concerned' about the health effects of living in a 'Mr Fluffy house'. [3]

Asbestos exposure and the risk of cancer

There is sufficient evidence in humans for the carcinogenicity of all forms of asbestos—chrysotile, crocidolite, amosite, tremolite, actinolite and anthophyllite. The predominant route for exposure is inhalation of fibres, but fibres can also be ingested. The risk of cancer increases with intensity, duration and frequency of exposure. [4]

There is a strong causal association between asbestos exposure and mesothelioma, with asbestos and some other fibrous minerals the only known causes of the disease. Causal associations have also been established for cancer of the lung, ovary and larynx, although

asbestos is not the predominant cause of these cancers. The epidemiological evidence for other cancer sites is more limited, but positive associations have also been observed between exposure to asbestos and cancer of the pharynx, stomach and colon and rectum in a range of studies. [4] There is weak or no evidence on the associations between asbestos exposure and other cancers.

Importantly, estimates of cancer risk associated with asbestos exposure have largely been based on high-level exposures in occupational settings, including mining, manufacturing and construction industries. [4] Risks have also been established for members of occupationally-exposed workers' families [5] and communities living near asbestos-related industries. [6, 7] Far less is known about the risk of exposure in the domestic or household setting. [8] In particular, there is no scientific evidence on the risk of cancer associated with living in a house containing loose-fill asbestos insulation.

Objectives of the study and hypotheses

The purpose of this study was to examine if rates of mesothelioma and other asbestos-associated cancers were higher in people who have lived at an ARP than in those who have not lived at an ARP in the ACT.

The objectives of this study were to estimate in the study period (1984–2013) the relative rates for residence at an ARP of:

1. mesothelioma;
2. other asbestos-associated cancers, including lung, ovarian, laryngeal, pharyngeal, stomach and colorectal cancer; and
3. cancers for which there is very weak or no evidence of an association with asbestos, of which we included bladder cancer, kidney cancer, melanoma and prostate cancer.

An *a priori* decision was made to estimate relative rates separately for males and females, given that male and female residents are likely to have had different levels of asbestos exposure—both within an ARP (particularly relating to entering the roof spaces and making renovations [3]) and non-ARP asbestos exposure (particularly related to occupational history). We also took into account differences in age and year of diagnosis between ARP and non-ARP residents, and lags between exposure and onset of disease.

If living at an ARP increases the risk of cancer, we would expect, by extrapolation from studies of other asbestos-exposure circumstances, to observe higher rates of mesothelioma in males, and to a lesser extent females, who had lived at an ARP than in people who had not lived at an ARP. Similarly, we might expect relative rates of other asbestos-associated cancers to be elevated, but not as much as those for mesothelioma, and possibly not at all, given the likely low average level of asbestos exposure in this setting (compared to occupational settings). We would expect rates of the other cancers to be the same in ARP and non-ARP residents.

Method

Study population and data sources

The study population was drawn from the Australian Medicare enrolment file. We included all people on the file with an ACT address at any time between November 1983 (when Medicare registrations began) and 2013 (last year of data available for this study). For this population, individual-level data from the Medicare file were linked to the ACT Asbestos Response Taskforce register of ARPs, the Australian Cancer Database and the National Death Index.

Medicare enrolment file

Medicare is Australia's universal health insurance provider, which is open to all Australian and New Zealand citizens and Australian permanent residents living in Australia. Medicare is administered by the Australian Government Department of Human Services, which collects and stores personal details—including name, sex, date of birth and address—for each registered individual. There are potentially multiple address records per person, as the address file is updated when a person notifies the Department of a change of details, which can occur by phone, online or in person. A *start date* is included with every change, which is the date the Department was notified of the change.

Medicare data were supplied to the Australian Institute of Health and Welfare's (AIHW) data linkage unit for approved record linkage studies. The Department of Human Services collects both residential and mailing addresses for the Medicare enrolment file. However, residential addresses are non-mandatory and only mailing addresses were provided to the AIHW. People eligible to receive Medicare-subsidised health services are recorded on a Medicare card, which is issued to a card contact. Multiple members of one family may be recorded on one Medicare card. The mailing address on a Medicare card is the address nominated by the card contact to which mail relating to that Medicare card should be sent. While mailing and residential addresses are the same for the vast majority of Australians, a proportion of addresses on the AIHW Medicare database are non-residential addresses, including post office box addresses.

ACT Asbestos Response Taskforce register of ARPs

The list of ARP addresses used in this study contains the 1089 ARP addresses known to the ACT Government. This comprises the addresses of the 1023 properties on the Affected Residential Premises Register, established under the *Dangerous Substances Act 2004*, and addresses of 66 properties that were completely demolished after the conclusion of the original remediation program in 1993, and before commencement of the eligibility criteria for assistance under the Loose Fill Asbestos Insulation Eradication Scheme.

The Australian Cancer Database

The Australian Cancer Database is a collection of all primary malignant neoplasms (cancers) diagnosed and registered in Australia since 1982. It is compiled at the AIHW from cancer data

provided by state and territory cancer registries through the Australasian Association of Cancer Registries. Reporting of cancers newly diagnosed has been mandatory in most jurisdictions since at least 1982[1], but in the ACT only since 1994. At the time of this study, the Australian Cancer Database included all registrations up to and including December 2013, except for New South Wales (NSW), which included registrations up to December 2012.

Standard data items are listed in Appendix 1. Data items used for linking included full name, sex, date of birth and postcode. Data items accessed by the researchers for the analysis were: age, sex, date of diagnosis, exact age at diagnosis and International Classification of Diseases (ICD) code. Further information on the Australian Cancer Database is available at: http://www.aihw.gov.au/australian-cancer-database.

The National Death Index

The National Death Index, housed at the AIHW, contains records of all deaths occurring in Australia since 1980. The data are provided by the Registries of Births, Deaths and Marriages, the Australian Bureau of Statistics and the National Coroners Information System. Request to access these data is made directly to the AIHW. Further information on the National Death Index can be found at: http://www.aihw.gov.au/national-death-index.

For this study, data included all registrations up to and including December 2013. Data items used included full name, sex, date of birth and postcode for data linkage, and date of death for the censoring in the analysis.

Data linkage

The AIHW Data Linkage Unit—a Commonwealth-accredited data integration authority—linked all study datasets. Formal guidelines for integrating Commonwealth data for research projects were endorsed by the Commonwealth Secretaries Board in 2010. Full details, including how to apply for access to Medicare data for research purposes, are available on the Australian Government National Statistical Service website at: http://statistical-data-integration.govspace.gov.au.

The AIHW Data Linkage Unit performed three separate linkages for this study. They linked the Medicare enrolment file for the ACT (November 1983 to December 2015) to: (1) the ACT Asbestos Response Taskforce register of ARPs; (2) the Australian Cancer Database (January 1982 to December 2013); and (3) the National Death Index (January 1980 to June 2016). For linkage of Medicare to the Australian Cancer Database and National Death Index, data were matched probabilistically using full name, sex, date of birth and postcode of residence; linkage to the National Death Index also included all historical addresses for the entity (person). Further details regarding the linkage can be found in Appendix 2.

[1] Mandatory reporting in: ACT—1994; NSW—1972; NT—1991; Qld—1982; SA—1977; Tas—1992; Vic—1982; WA—1981

Study variables

Cancer outcomes

The selection of cancer outcomes for this study was based on the International Agency for Research on Cancer review of evidence on the cancer risks associated with asbestos exposure. [4] Cancer diagnoses for the cohort, which were classified according to the International Classification of Diseases version 10 (ICD-10) code, were ascertained through linkage to the Australian Cancer Database. Mesothelioma (ICD-10 code C45) was the main cancer of interest, given its strong relationship with asbestos exposure. The other asbestos-associated cancers were: lung (includes bronchus, lung and trachea, C33 and C34), ovarian (C56), laryngeal (C32), pharyngeal (C09-C14), stomach (C16) and colorectal (C18-C20) cancer. Other cancers for which there is very weak or no evidence, used as 'negative controls', were four non-rare cancers: bladder cancer (C67), kidney cancer (C64), melanoma (C43) and prostate cancer (C50).

ARP exposure

We classified exposure as residence at an ARP (exposed) or not known to have resided at an ARP (unexposed). ARP exposure was ascertained through linkage of the Medicare enrolment file to the Taskforce list of ARPs. Any Medicare address that was matched to an address on the Taskforce list was flagged as an ARP. Demolished ARPs were reclassified as non-ARP residences after the date of demolition. Addresses such as post office boxes were by default classified as non-ARP (see sensitivity analyses for alternate assumptions and analyses). Individuals recorded as living at an ARP were only classified as at risk of cancer as a result of living there after allowing for a lag of 10 years (see analysis section below). This lag was varied in sensitivity analyses.

Analysis

Main analysis

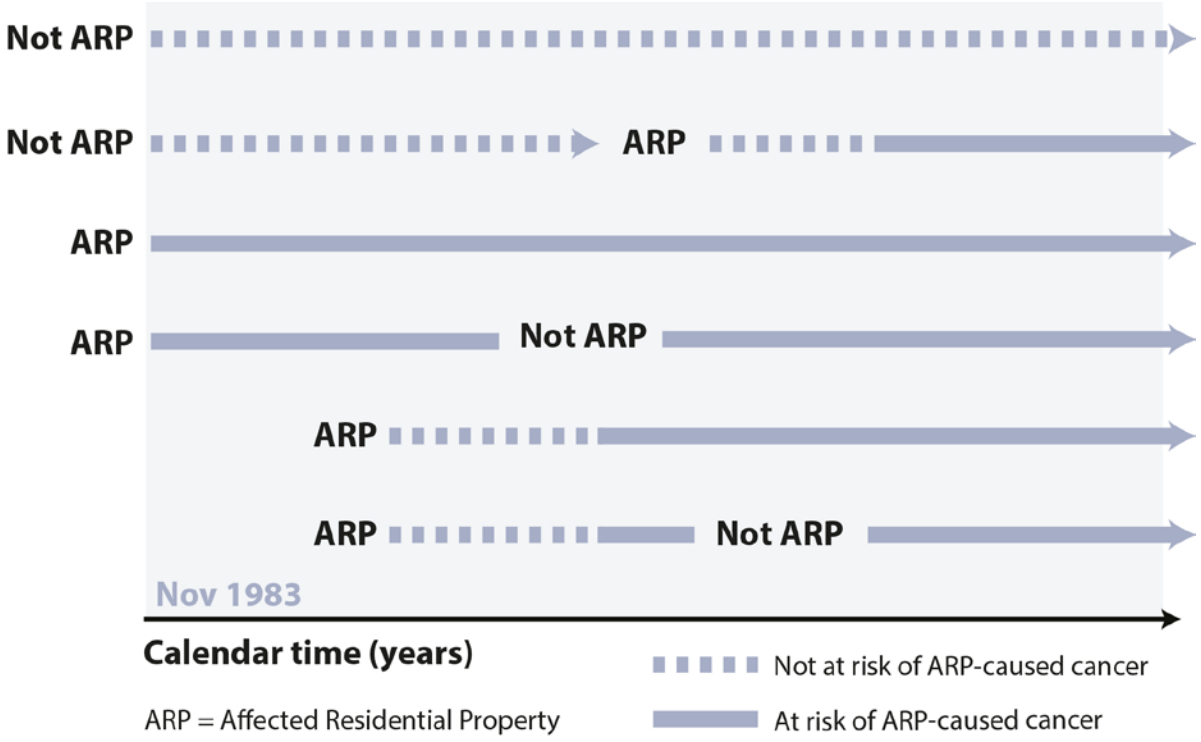
Calculation of event numbers and person-years

For each member of the cohort, entry into the study was the start date of their first Medicare registration, regardless of which state/territory of Australia they were registered in. For each cancer outcome, total person-years were calculated from entry into the study until the date of diagnosis, death from any cause, age 100 years or 31 December 2013, whichever came first. We excluded participants if their date of birth was missing or their death date was before entry into the study (presumed invalid link).

Any person with an ARP address was classified as exposed from the earliest ARP address start date in the Medicare file for that person. However, because of the application of a lag between exposure and diagnosis of a cancer potentially attributable to exposure, we attributed cancers diagnosed and person-years during the first 10 years of follow-up from the earliest ARP address start date to the time not at risk of cancer from living at an ARP, recognising that there were delays between change of address and its registration with Medicare so the true lag period was, on average, longer than this (Figure 1). Person time and

cancers diagnosed following the end of the lag period were considered, respectively, to be time at risk of cancer, and cancer, potentially attributable to ARP exposure. We did not apply this lag to people who were at an ARP address at the start of the study period, i.e. where their earliest Medicare registration was at an ARP address and that registration was before 1985, as we assumed they had been living there for at least 10 years. Alternate assumptions were made in a sensitivity analysis (see below). For the remaining cohort members—all those registered as having only non-ARP residential addresses—all person-time was not at risk and cancers diagnosed were not potentially attributed to ARP exposure. We excluded person-time and cancer diagnoses from all analyses relevant to a particular type of cancer if the person had already been diagnosed with that cancer prior to the start of the period for that exposure (i.e., if the diagnosis date for that cancer was earlier than their earliest start date for that exposure).

Figure 1. Diagram of attribution of person-years, with application of lag period



Calculation of standardised incidence ratios

For each cancer, we calculated crude rates in relation to ARP exposure, separately for males and females. For mesothelioma, we also estimated rates in relation to calendar period (5 year intervals), age standardised to the 2001 Australian population (age groups: <35, 45–54, 55–65, 65–74, 75–84 and 85 years and older), using the direct method.

For each cancer outcome, we used indirect standardisation to generate standardised incidence ratios (SIR) and exact Poisson 95% confidence intervals. These were estimated

separately for males and females, and adjusted for age group and calendar period of diagnosis. The indirect approach to standardisation was used because of the small number of outcomes for some cancers, in particular mesothelioma. Using this approach, the age-sex-period specific rates (number of diagnoses/person-years) for each cancer type in the unexposed were first calculated. These rates were then applied to the exposed population to generate the expected number of cases for each cancer type. The SIR is the total number of observed cases in the exposed divided by the expected number in the exposed. An SIR>1 means cancer rates are higher in the exposed than the unexposed, an SIR <1 means rates are lower in the exposed than the unexposed, and an SIR=1 means there is no difference in rates between the exposed and unexposed. Results were considered statistically significant if the 95% confidence interval did not include an SIR of 1.

Analyses were performed in the AIHW secure data laboratory, using Stata version 12.1 and SAS version 7.1.

Sensitivity analyses

We conducted the following sensitivity analyses:

Variation in lag: (a) We varied the lag period for the exposed from 10 years in the main analysis to 5 years and to 15 years; and (b) we applied the 10-year lag to all people including those who were originally exempted from this lag, i.e., those where their earliest Medicare registration was at an ARP address and that registration was before 1985.

Exclusion of participants with post office box addresses: Rather than assuming participants with post office box addresses were unexposed, we excluded them from the analysis. Specifically, we excluded any participant with only a post office box mailing address registered at any particular time during the study period (1983–2013), unless they had already been classified as exposed at the time of their first post office box address date. We did this because we could not rule out ARP exposure during the study period for these people.

Censoring: We censored all participants at age 85 years instead of 100 years.

Ethics approvals

Ethics approvals were required, and obtained from, the following Committees[2]:

1. ANU Human Research Ethics Committee
2. AIHW Ethics Committee
3. ACT Human Research Ethics Committee
4. NSW Population and Health Services Research Ethics Committee
5. SA Health Human Research Ethics Committee
6. Human Research Ethics Committee (Tasmania) Network
7. WA Department of Health Human Research Ethics Committee

[2] Note host institutional ethics committee (in this case ACT Human Research Ethics Committee) approvals were sufficient to access Qld, Vic and NT data.

Privacy and waiver of consent issues

The study is compliant with all Australian Privacy Principles (APP) except APP6 (use or disclosure of personal information). As this project was conducted without consent, which would breach APP6, a waiver of consent pursuant to Section 95 of the Privacy Act 1988 was sought and granted by the relevant ethics committees.

Secure data management

Data were linked, analysed and stored at the AIHW. Under the Commonwealth's data integration arrangements, the AIHW utilises secure data access modes. The AIHW has met stringent criteria covering project governance, capability, data management, and the protection of privacy and confidentiality. For this project, data were stored on the physically separate Integration Authority (IA) network. Only Data Integration Services Centre (DISC) staff and the Systems Manager had access to this network. The IA network is separated from the general AIHW Information Technology environment and there is no connection to the internet. DISC staff members are located in a physically secure facility within AIHW's premises. The separation principle employed at AIHW meant that no one working with the data could view both the linking (identifying) information (such as name, address or date of birth) together with the merged analysis (content) data (such as clinical information) in an integrated dataset.

Once the data were linked, DISC staff confirmed that the dataset: (1) only contained variables agreed with the data custodian, and (2) had had 'first level' confidentiality protection applied (e.g. collapsing values on certain variables) as agreed with data custodians. It was then moved to the Data Laboratory and usage restricted to the approved researchers. All output was stored in a temporary work area for the duration of the session. When the researcher was confident of the output, the data were moved to a checking area where it became available to an AIHW user who ensured that the data were confidentialised and suitable for release.

A separate storage location was used for the project, with access limited to specific users. This architecture determines who can access what data at any time and access was therefore predetermined and logged. In addition, work logs were generated when code was run against the data; these provided basic information about who ran the job and when. These were stored as part of the audit trail.

At the completion of the project, and in line with the data retention date, AIHW will use Sdelete (Microsoft) to remove all files relating to the project from hard disk. In line with DISC data retention/backup cycle procedures, data are overwritten on a 4 weekly cycle. Data are also encrypted as part of the archival process using Commvault.

Results

Description of the study population

The Medicare enrolment file (November 1983 to December 2015) contained 1 068 520 individuals ever registered with Medicare with an ACT address. A total of 1 035 578 of these individuals were included in the study as they had one or more ACT address start dates recorded between November 1983 and December 2013 (the study period).

The total number of individuals on the Medicare file in any one year whose most recent address start date was for an ACT address grew from 186 173 in 1984 (76% of the ABS estimated mid-year ACT population for that year) to 234 459 (93% of the ACT population) in 1985, suggesting almost complete identification by Medicare of the ACT resident population by the end of Medicare's first two years. These numbers and proportions continued to rise in each year over the study period, with the number of people identified in any one year exceeding the estimated ACT mid-year population by the year 1990 (Tables, Appendix 3 and Appendix 4). This discrepancy is probably explained by Medicare enrollees delaying or failing to update their address with Medicare when they moved out of the ACT, people not automatically being removed from Medicare's records once they died, and to a lesser extent, the presence of duplicate records. Two thirds (68%) of the study participants had start dates during the study period for addresses that were outside the ACT (Table, Appendix 3). The age and sex distribution of the ACT's Medicare-enrolled population in each year of the study period was similar to ABS estimates of this distribution, but with increasing over-representation of older people, probably, at least in part, reflecting deceased enrollees remaining on the database (Table, Appendix 4).

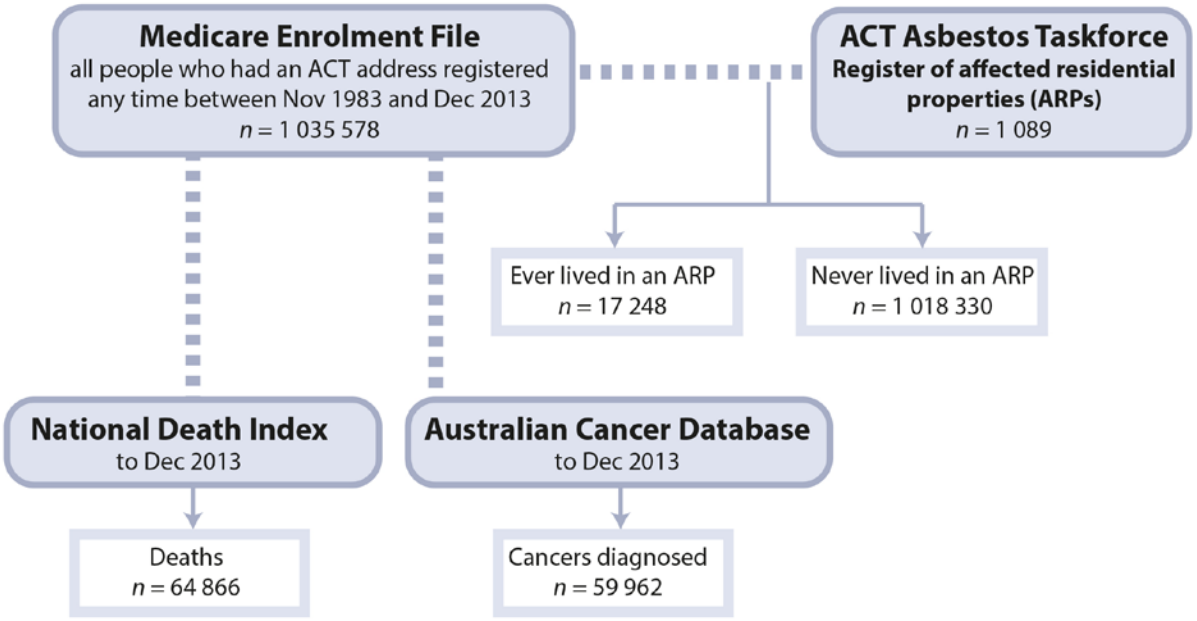
There were 2 741 650 unique address IDs in the data, of which 577 517 (21%) were in the ACT. Because of the issue of multiple address IDs for a single address, and the issue of unreliable end dates, it was not possible to accurately determine the number of unique addresses recorded in any one year. However, the number of unique address IDs recorded in any year gives an upper estimate of this number. This ranged from 75 718 in 1984 to 169 411 in 2013 for ACT addresses, and for addresses outside the ACT, 147 829 in 1984 to 291 244 in 2013 (Appendix, Table 3). Of the 577 517 unique ACT address IDs in the entire sample, 71 584 (12%) were classified as post office box addresses, with 269 203 individuals (26%) having ever had an ACT post office box as their only recorded address at some point during the study period.

Of the 1089 ARPs, 1087 (99.8%) were linked to one or more addresses on the Medicare database. Altogether there were 3305 address IDs for 1089 ARPs. The number of unique ARP address IDs in any one year generally increased from 1984 (1009 IDs) to 1991 (1328 IDs) and generally decreased thereafter (1045 IDs in 2013). In any one year, the number of individuals recorded as living at an ARP ranged from 2667 (in 1984) to 3476 (in 2012) (Appendix, Table 3).

Among the 1 035 578 people registered with Medicare who had an ACT Medicare address date during the study period, there were 17 248 (1.67%) who had ever had an ARP address.

There were 54 771 /1 035 578 (5.3%) people in the study population with at least one linkage to the Australian Cancer Database to December 2013, with 59 962 cancers diagnosed in total. There were 64 866/1 035 578 (6.3%) people with a death recorded in the NDI during the study period (Figure 2). Further linkage results can be found in Appendix 2.

Figure 2. Data sources and linkage results for the study population



Mesothelioma

After exclusions, a total of 1 034 059 people (99.9%) were included in the sample for the main mesothelioma analysis (Table 1).

Table 1. Final sample for main analysis for mesothelioma (10-year lag)

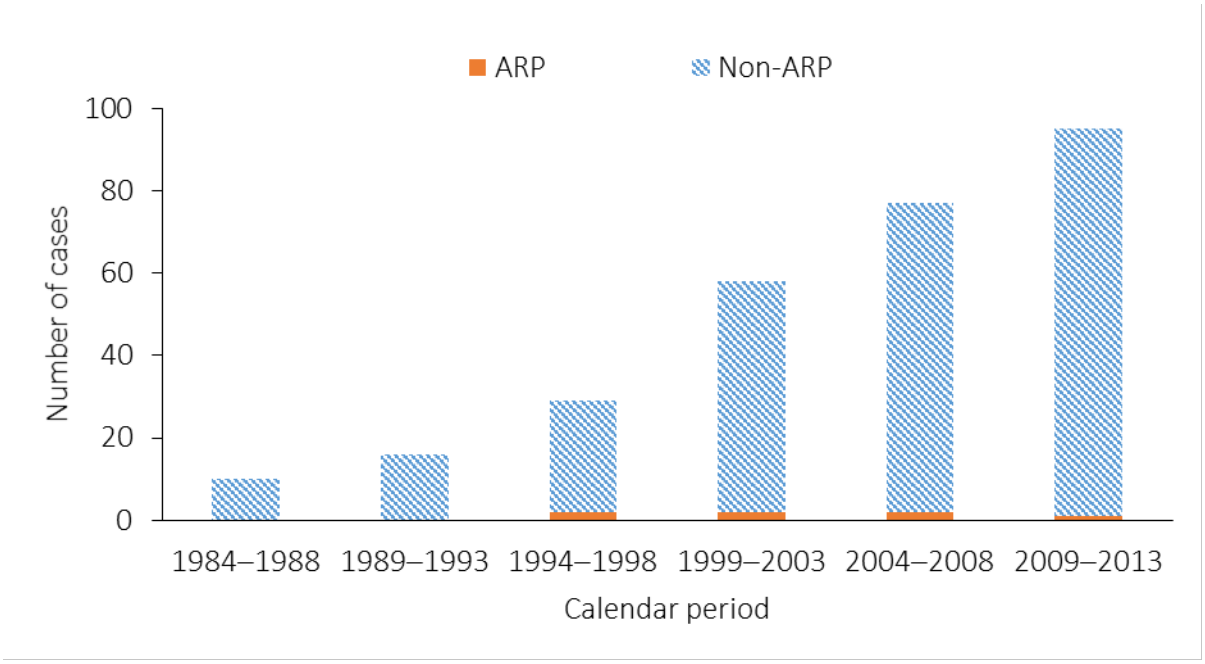
	n	Cumulative exclusions*
Individuals registered with Medicare with an ACT address any time between 1 Nov 1983 and 31 Dec 2013	**1 035 578**	
Exclusions		
Date of birth missing	268	268
Date of birth > exit date	124	392
Entry date>exit date†	1212	1514
Mesothelioma diagnosis before entering study	7	1519
Final sample	**1 034 059**	

**Cumulative exclusions<total n for exclusions as exclusions not mutually exclusive.*
†After accounting for 10-year lag, and including invalid death dates where death date preceded study entry date.

There was a total of 285 cases of mesothelioma, of which just under half (133/285, 46.7%) were registered in the ACT, the remainder being registered in other Australian jurisdictions. Nine of the 285 cases were diagnosed in people who had ever lived at an ARP, but two of these were in people whose mesothelioma diagnoses occurred before they were registered as living at an ARP (0.45 and 5.7 years before) so these cases were automatically attributed to non-ARP exposure. The remaining seven cases in residents who had ever lived at an ARP were attributed to the exposed person-years in the main analysis, all of which occurred after an assumed or actual 10-year lag. All seven of these cases were pleural mesothelioma.

There was a gradual increase in the total number of mesothelioma cases diagnosed over time, from 10 reported in 1984–1988 to 95 in 2009–2013 (Figure 3). The first identified ARP-associated case did not occur until 1996. All 7 of the ARP (exposed) cases and 239/278 (86%) of the non-ARP (unexposed) cases were in men. The average age of diagnosis was 67.2 years (median 67.8) , with a mean of 58.1 years (median 57.1) in the exposed and 67.4 years (median 68.0) in the unexposed (Table 2). The median time between the first ARP exposed address date and mesothelioma diagnosis was 15.0 years (interquartile range: 9.70; range 12.8–24.9 years). In at least 5 of the 7 ARP cases, the estimated time between exposure and diagnosis is a minimum as these cases were registered as living at an ARP at the start of the study period (Dec 1983–Jan 1984).

Figure 3. Number of mesothelioma cases by period, 1984 to 2013



Note. ARP=affected residential property

Table 2. Description of mesothelioma cases by exposure (ARP and non-ARP)

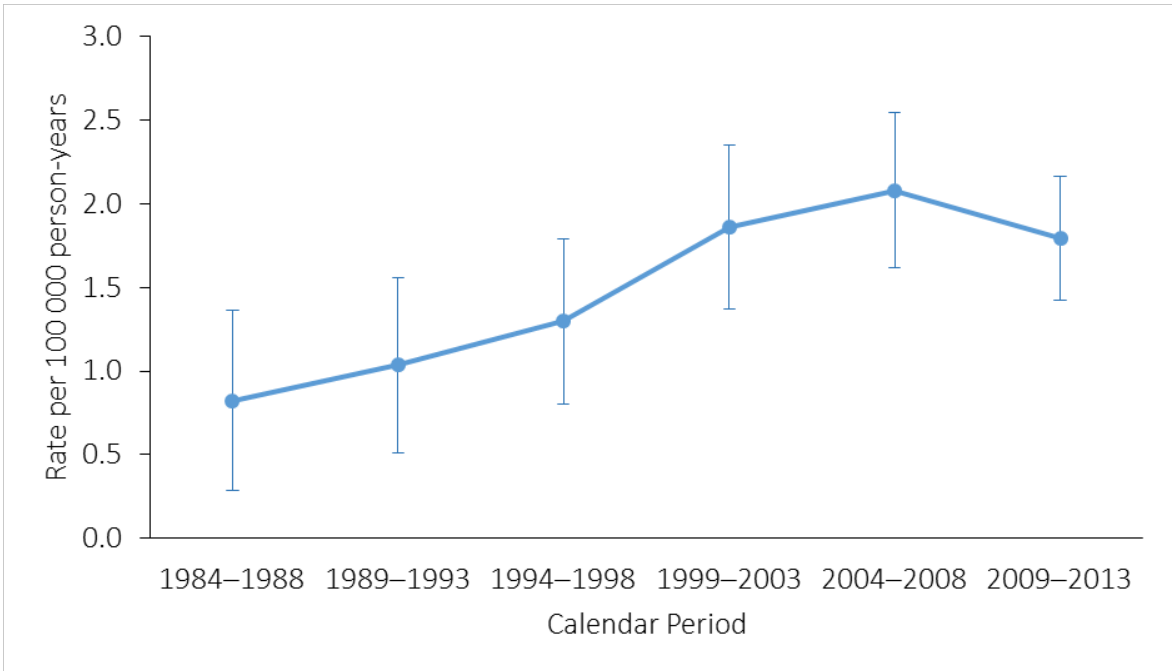
	ARP	Non-ARP	Total
Number of cases			
Male	7	239	246
Female	0	39	39
Total	7	278	285
Age at diagnosis			
Mean (SD)	58.1 (15.4)	67.4 (12.1)	67.2 (12.3)
Median (IQR)	57.1 (26.8)	68.0 (14.9)	67.8 (15.4)
Range	36.6–80.4	30.9–92.6	30.9–92.6
Diagnosis Dates (year)			
Earliest	1996	1984	1984
Latest	2011	2013	2013

Note. ARP=affected residential property; SD=standard deviation; IQR=interquartile range

Mesothelioma rates by sex and by period

The 285 mesothelioma cases occurred over a total of 21.9 million person-years of follow-up, an overall crude incidence rate of 1.30 (95% CI: 1.15–1.46) per 100 000 person-years, 2.30 (95% CI: 2.02–2.60) per 100 000 person-years in males, and 0.35 (95% CI: 0.25–0.47) per 100 000 person-years in females. Overall, age-standardised rates increased over time (Figure 4).

Figure 4. Age-standardised mesothelioma rates, by period, 1984 to 2013



Note: Directly age-standardised to the Australian 2001 population. Vertical bars represent 95% CIs around point estimates for the incidence rate in each period.

Mesothelioma rates and ARP exposure

Among males, crude mesothelioma rates were 2.25 (95% CI: 1.97–2.56) per 100 000 person-years in the unexposed and 8.26 (95% CI: 3.32–17.0) per 100 000 person-years in the exposed. After taking into account age and period, the rate of mesothelioma in ARP-exposed males was two and a half times that in unexposed males (SIR=2.54, 95% CI: 1.02–5.24). There were an estimated 4.2 (95% CI: 0.06–11.7) excess cases of mesothelioma (observed cases minus expected cases) in male ARP residents between 1984 and 2013. Among females, the crude rate of mesothelioma was 0.35 (95% CI: 0.25–0.48) per 100 000 person-years in the unexposed, with no cases in the exposed (<1 case expected). The two-sided 95% CI for the SIR in females was from 0 to 9.37, which is a wide interval due to few events in the unexposed and exposed populations. Statistically, the SIRs in males and females were not different (p=0.39).

Other cancers

The SIRs for all cancers, including mesothelioma, are shown in Figure 5. Final sample sizes, number of people diagnosed, person-years of follow-up and crude rates are in Appendix 5.

Of the other asbestos-associated cancers, colorectal cancer rates were elevated in ARP-exposed residents compared to unexposed residents among males (SIR=1.32, 95%CI: 0.99–1.72) and females (SIR=1.73, 95%CI: 1.29–2.26). Statistically, these SIRs are no different between males and females (p=0.17). For the remaining asbestos-associated cancers—lung, ovarian, laryngeal, pharyngeal and stomach—rates did not differ significantly between the exposed and the unexposed.

Rates of three of the four other cancers—bladder, kidney and melanoma—did not differ significantly between the exposed and the unexposed. The rate of prostate cancer was significantly higher in the ARP-exposed than in the unexposed population (SIR=1.29, 95% CI: 1.07–1.54).

Sensitivity analyses

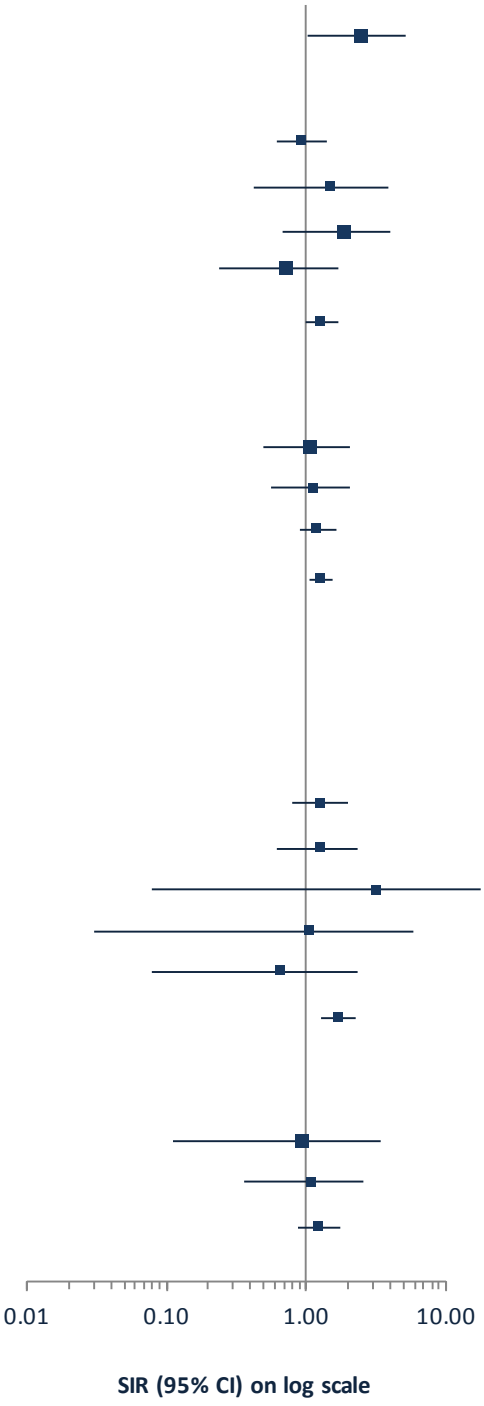
Varying the lag period from 10 to 5 and to 15 years (Table, Appendix 6), and applying the 10-year lag to all people including those who were originally exempted from this lag (Table, Appendix 7), essentially did not change the direction of the findings. However, with a lag of 15 years, there was considerable uncertainty in the SIR for mesothelioma (Male SIR=1.78, 95% CI: 0.48–4.55). This was due to small numbers, with only four observed cases in males after a 15-year lag. Three of the cases attributed to the exposed in the main analysis were diagnosed between 10 and 15 years after the first recorded ARP exposure and hence were attributed to the unexposed person-years in the 15-year lag analysis.

Excluding participants with post box mailing addresses at any time during the study period (n=269 203, 26%) did not change the direction of the findings, but introduced more uncertainty in the results. If anything, effect sizes were smaller, and the association with prostate cancer was weak (SIR=1.10, 95% CI: 0.91–1.31) (Table, Appendix 8).

Censoring at age 85 had no material effect on the results (Table, Appendix 9).

Figure 5. Cancer outcomes: Total number of cases, observed (O) and expected (E) cases in the exposed and standardised incidence ratios (SIRs) with 95% CI, by sex

	Total cases	O / E	SIR (95% CI)
MALES			
Mesothelioma	246	7/2.75	**2.54 (1.02–5.24)**
Other asbestos-associated cancers			
Lung	2455	25/26.2	0.96 (0.62–1.41)
Laryngeal	254	4/2.60	1.54 (0.42–3.93)
Pharyngeal	292	6/3.21	1.87 (0.69–4.07)
Stomach	654	5/6.81	0.73 (0.24–1.71)
Colorectal	3788	54/40.9	1.32 (0.99–1.72)
Other cancers			
Bladder	831	9/8.37	1.07 (0.49–2.04)
Kidney	860	11/9.58	1.15 (0.57–2.05)
Melanoma	3636	46/37.6	1.23 (0.90–1.63)
Prostate	8208	121/94.0	**1.29 (1.07–1.54)**
FEMALES			
Mesothelioma	39	0/0.39	(0–9.37)*
Other asbestos-associated cancers			
Lung	1577	21/16.0	1.31 (0.81–2.01)
Ovarian	762	10/7.77	1.29 (0.62–2.37)
Laryngeal	33	1/0.31	3.25 (0.08–18.1)
Pharyngeal	85	1/0.94	1.07 (0.03–5.95)
Stomach	343	2/3.04	0.66 (0.08–2.37)
Colorectal	3186	53/30.7	**1.73 (1.29–2.26)**
Other cancers			
Bladder	241	2/2.13	0.94 (0.11–3.40)
Kidney	444	5/4.48	1.12 (0.36–2.60)
Melanoma	3049	37/29.4	1.26 (0.89–1.74)



*Notes. *one-sided 97.5% confidence interval (CI)*
1. SIR is the rate in exposed (ARP) compared to rate in non-ARP, standardised for age and period. SIRs are plotted on a log scale and are represented with squares, with 95% CIs indicated by horizontal lines.
2. Diagnoses are based on ICD-codes: Mesothelioma, C45; Lung–includes bronchus, lung and trachea–C33 and C34; ovarian, C56; laryngeal, C32; pharyngeal, C09-C14; stomach, C16; colorectal, C18-C20; bladder cancer, C67; kidney cancer, C64; melanoma, C43; and prostate cancer, C50.

Discussion

Summary of the findings

Rates of mesothelioma were around two and a half times (154%) higher in males who had lived at an ARP than in males who had not lived at an ARP, equating to an estimated 4 excess cases of mesothelioma in male ARP residents between 1984 and 2013. The SIR for mesothelioma remained elevated across multiple sensitivity analyses. There were no cases of mesothelioma in exposed females.

Of the other six cancers known to be associated or potentially associated with asbestos exposure, only colorectal cancer rates were significantly elevated in ARP residents compared to non-ARP residents—32% higher in males and 73% higher in females. SIRs remained elevated across multiple sensitivity analyses.

Of the four other cancers, those not expected to be associated with ARP exposure, three were not elevated in ARP residents, but prostate cancer rates were. They were 29% higher in male ARP residents.

Interpretation of the findings in the light of previous studies

There are no previous studies that have estimated the risks of cancer among people who have lived at properties with loose-fill amosite asbestos insulation, nor among workers who installed it. In the United States, vermiculite contaminated with asbestos (ore estimated to be 21–26% asbestos by weight) was used extensively in loose-fill attic insulation, which remains in millions of homes in the United States, Canada, and other countries. [9] Workers who mined, milled, and processed the vermiculite in Libby, Montana, have substantially higher mortality rates of asbestos-related respiratory diseases than the general population, including mesothelioma, lung cancer and asbestosis. [10] Rates of asbestos-associated diseases have also been found to be elevated in the Libby community, although at substantially lower levels than in people occupationally exposed to asbestos-containing vermiculite. [11] However, we are not aware of any studies examining the health risks in people living in the houses with the loose-fill asbestos-contaminated insulation.

Estimates of cancer risks associated with asbestos have, for the most part, involved people with occupational or para-occupational exposure to asbestos, with mesothelioma consistently shown to have the strongest association with exposure of any cancer. [4] Our study findings are in line with this evidence in that mesothelioma had the strongest association with ARP exposure of the cancers examined, at least in men. However, the magnitude of the association with ARP exposure was substantially weaker than that generally reported for other asbestos exposures. This is not surprising given the bulk of prior epidemiological evidence is based on cohorts with relatively heavy asbestos exposure. For example, among amosite asbestos miners in Tyler USA, standardised mortality rates for peritoneal mesothelioma were 21.5 (95% CI 8.62–44.2), and for pleural mesothelioma 222 (12.7–361); [12] and in asbestos textile workers in Italy they were 29.1 (21.5–38.6) and 33.7 (25.7–43.4), respectively. [7] Similarly, very high mesothelioma rates have been observed in in crocidolite miners in Wittenoom in WA. [13]

The observation that the SIR for mesothelioma was elevated in men but not women is consistent with previous evidence, and could suggest confounding by occupational exposure. However, there is no reason to suspect that ARP residents would be more likely to be occupationally exposed to asbestos than non-ARP residents. Alternatively, the stronger association between exposure and mesothelioma in males may reflect higher average levels of exposure to the loose-fill insulation among men. In a survey of ARP residents, a significantly higher proportion of men reported entering the roof space than women (85% vs 41%, $p<0.001$); with 51% of men who reported entering the roof space reporting that they entered the roof space greater than 10 times, and 15% more than 50 times. Similarly, a higher proportion of men reported entering the underfloor space at the ARP compared to women (86% vs 62%, $p<0.001$). [3]

Previous studies on asbestos exposure and colorectal cancer have produced mixed findings. Elevated risks have been most consistently found in studies with heavy exposure and with long intervals since exposure. [4] In a meta-analysis of cohort studies examining the association between asbestos exposure and colorectal cancer, comparing 'any' versus no exposure, the summary relative risk was 1.15 (95% CI: 1.01–1.31); for studies comparing 'high' versus no exposure, risks were 1.38 (95% CI: 1.14–1.67). The largest excesses of colorectal cancer were observed among the earliest North American insulation workers and British male insulation workers. [14] More recent evidence also supports an association between colorectal cancer and prolonged exposure to high levels of asbestos, but not with lower levels of exposure. [15, 16] Given ARP asbestos exposure is considered to be relatively low, and the relatively weak association between ARP and mesothelioma found in this cohort, the SIRs for colorectal cancer were higher than expected, particularly for women. This might reflect a different type of exposure than for mesothelioma—through ingestion rather than inhalation of fibres. However, while asbestos fibres have been found in living areas of ARPs including kitchen and dining areas, [1, 3] the evidence on ingestion of asbestos and colorectal cancer is weak, [17] making the link between living in a house with loose-fill asbestos insulation and colorectal cancer uncertain. Alternative explanations reflecting limitations in the design of the study rather than causal associations between ARP exposure and colorectal cancer are discussed below.

We did not expect to find an elevated risk of prostate cancer. While the association was relatively weak, there is little prior evidence for such an association. Elevated risks of prostate cancer were reported in a study of Finnish construction workers in an asbestos screening program, [18] and in a cohort study of former residents of the mining town of Wittenoom. [19] However, these elevated rates may well have been due to ascertainment bias, i.e. exposed men more likely than the general male population to be tested for prostate cancer. Such a possibility cannot be ruled out in this study of residents of ARPs. Thus, while a causal association between ARP and prostate cancer is plausible, [20] further evidence is needed before any conclusions can be drawn about this observation. As with colorectal cancer, there are possible alternative explanations, as outlined in the next section.

Study strengths and limitations

This study has several strengths, including:

- use of the Medicare enrolment file to assemble the cohort, allowing virtually complete coverage of the ACT population over the study period and use of an internal rather than external reference population;
- access to a complete address list of ARPs to capture exposure; and
- linkage to cancer registry data and death data nationally, ensuring near-complete follow-up of health outcomes.

However, there are several aspects of the study design, including limitations with the data, which need to be kept in mind when interpreting the results.

The role of chance

The role of random error in explaining the findings cannot be ruled out. It is possible the significant SIRs, indicating an association between ARP exposure and cancer, were merely chance findings. This is more likely to be the case where the lower 95% confidence bound is close to one (the value one is indicative of no association), and in the context of multiple analyses. Also, true associations between ARP exposure and cancer could have been missed. This is more likely to be the case where there is low power to detect an association due to a small number of cancer diagnoses, as with pharyngeal and laryngeal cancer. The rarer the cancer, the more uncertain the resulting estimates.

Inaccuracy in exposure measurement

We relied on linkage of the Taskforce register of ARPs to the Medicare enrolment file to classify whether a person lived at an ARP or not. While the Taskforce register is considered a complete list of affected properties, the reliance on Medicare data to identify individuals who had lived at these properties is limited for a number of reasons, any of which may have affected the accuracy of the findings, as follows.

- Medicare registrations only began in November 1983, and there was incomplete enrolment at least in the first 2 years of the Program. Given exposure was possible as early as 1968, anyone in the study who was at an ARP prior to Medicare enrolment but not after entering into the study would have been misclassified as unexposed. The extent of such misclassification is unknown, but is likely to have biased results toward the null (i.e., if there really is an association between ARP exposure and cancer the SIR would be underestimated). In addition, anyone who prior to November 1983 lived at an ARP and moved out of the ACT permanently or died would not have been captured in this study.
- While start and end dates are provided when people change their address details on the Medicare database, these are not necessarily the dates at which people actually change their addresses. For many people, there is likely to be a delay between moving residence and registering the change of address. End dates in particular are deemed by Medicare to be unreliable. This was reflected in our data, with the number of people registered in the ACT in any one year eventually exceeding the total ACT population, suggesting many people move from the ACT without registering this change or at least not until sometime

later. The main effect of this is that the estimates of person-years in both the exposed and unexposed will be inaccurate. However, this is likely to be non-differential with respect to the exposure, so while estimates of absolute cancer rates may be inaccurate, relative estimates, i.e. the SIRs, may not be biased.

- Addresses on the Medicare database are not always residential addresses. Of particular note is that around ten percent of ACT addresses on the AIHW Medicare database were post box rather than house addresses. Given exposure was assigned as non-ARP in these cases, anyone with a post box address who was living at an ARP would have been misclassified as unexposed. In the sensitivity analysis where we excluded those with post box addresses, relative rates of mesothelioma remained elevated, but uncertainty increased.

Another limitation of the exposure measurement is that we were unable to measure dose. We did not have actual measurements of fibre counts in the houses. Also, we could not measure the intensity of exposure indirectly, such as whether residents entered roof spaces, nor could we measure duration of exposure given that exposure data were only available from November 1983 and the start and end dates were not necessarily accurate.

Finally, we relied on linkage to the NDI to ascertain deaths, to enable calculation of person time at risk. Linkage to the early NDI is subject to quality issues due to incomplete reporting of deaths, particularly affecting earlier years (more details in Appendix 3). However, any biases this introduces into calculation of rates will be non-differential with respect to ARP exposure.

Incomplete ascertainment of cancer outcomes

A strength of the study is the use of Australia-wide cancer registry data to ascertain cancer outcomes. However, while cancer registries date back to before the start of the study period and reporting of cancers has been mandatory since this time, reporting has only been mandatory in the ACT since 1994. Thus, there is likely to be under-ascertainment of cases before 1994. Near-complete ascertainment is likely since 1994, although there may have been some cases that were missed, as registry data do not include people with unconfirmed cancer or cases involving residents who lived away from Australia at the time of their diagnosis. Any under-ascertainment is likely to be non-differential with respect to ARP exposure. However, missing a case in the exposed would have a much greater effect than missing a case in the unexposed, particularly for the less common cancers. For example, while missing a mesothelioma case in the unexposed would have virtually no effect on the SIR, one additional mesothelioma case in the exposed males would increase the SIR point estimate from 2.54 to 2.90 (95% CI: 1.26–5.73), and in exposed females just one case would produce an SIR of 2.54, albeit with considerable uncertainty (95% CI: 0.06–14.2).

In addition, cancer data were only available for this study up until December 2013 (2012 for NSW-registered cases). Given the lag between exposure to asbestos and cancer diagnosis, and this is longer at lower exposure levels, [13] it is possible that there are ARP-associated cancers that have since been diagnosed and/or are yet to be diagnosed.

Finally, we restricted the number of types of cancer investigated in this study *a priori*, to limit the possibility of finding significant associations between ARP exposure and disease just by chance. Consequently, we cannot rule out the possibility that other cancers not investigated in this study are associated with ARP exposure. However, given prior knowledge about the health risks of asbestos derived from multiple scientific studies and involving much heavier exposure than that experienced by people with living in ARPs on average, this is unlikely.

Potential confounding

A major limitation of using administrative data is the lack of information on the characteristics of participants (beyond age and sex), hence limited ability to control for potential confounding. Confounding will be present if there are characteristics of ARP residents that are different from those of non-ARP residents and these characteristics are associated with an increased risk of cancer. Potential confounders vary depending on the particular cancer, but include, for example, smoking, occupational exposure to asbestos, obesity and alcohol consumption. For prostate cancer incidence, a potential confounder is prostate-specific antigen testing, where ARP-exposed men may have been more likely to seek cancer screening leading to higher prostate cancer detection rates.

With regard to mesothelioma, occupational history of asbestos exposure is particularly important, as this has been the most important source of asbestos exposure up to the present time. [4, 21] We cannot rule out the possibility that the higher mesothelioma rate in the ARP residents was due to occupational exposure to asbestos rather than ARP exposure but, on the other hand, we have no evidence that they were. Smoking does not increase the risk of mesothelioma; however, smoking is a potential cofounder (and effect modifier) in the relationship between ARP exposure and some of the other cancers investigated in this study, such as lung, colorectal and bladder cancers. [22] There is no way of quantifying the extent of uncontrolled confounding, if any, in this study. However, we have no certain basis for believing that any potential confounding factors were differentially distributed in ARP and non-ARP residents.

Conclusion

In this study, we examined the association between living in a house containing loose-fill asbestos and subsequently developing mesothelioma and other cancers. Despite the widespread use of asbestos-containing materials to insulate houses, this is the first study to examine the relationship between this type of exposure and possibly asbestos-related cancers. The study was novel in using Medicare data to identify anyone who had lived in the ACT during the study period. We observed elevated rates of mesothelioma in men who had lived at an ARP, which may reflect a higher likelihood of exposure to asbestos while entering the roof space of houses or renovating. There was considerable uncertainty in the estimates of elevated risk, however, given the rarity of mesothelioma. There were no cases of mesothelioma in women living in these houses during the study period. We observed higher rates of colorectal cancer in men and women, and prostate cancer in men, who had lived at an ARP. These results were somewhat unexpected and chance, bias and confounding cannot

be ruled out as explanations for them. It would be useful to extend this study in future years to include more years of data and potentially expand it to other affected Australian jurisdictions. These results have important implications for the ACT community, along with Australian and international public health agencies.

Terminology used in this report

Affected residential property (ARP): An ARP is a property in the ACT that was insulated with loose-fill asbestos insulation, between 1968 and 1979.

Confidence interval (CI): Expresses the degree of statistical uncertainty in a result. The 95% confidence interval can be interpreted to mean that one can be 95% confident that the true value of the estimate lies within that interval.

Confounding: Confounding is a distortion of the association between an exposure and an outcome that occurs when the exposed and non-exposed groups differ with respect to other factors that influence the outcome. In this study, confounding will be present if there are characteristics of ARP residents that are different from those of non-ARP residents and these characteristics are associated with an increased risk of cancer.

Exposed and unexposed: In epidemiology, the term 'exposure' can be broadly applied to any factor that may be associated with an outcome of interest. Participants are exposed if they have experienced the exposure (in this study, lived at an ARP), and unexposed if they have not.

Incidence rate: The number of new cases of disease per person-years of follow. A **crude incidence rate** is the incidence rate unadjusted for any other factors, such as age. An **age-adjusted rate** minimises the effects of differences in age composition in comparing rates for different populations (see also *standardisation*).

Person-years (py): An estimate of the actual time-at-risk observed for participants in a study. Participants contribute person-years so long as they do not yet have the health outcome under study (in this study, cancer) and have not died, and, therefore, are still at risk of developing the outcome. Knowing the number of new cases of cancer and the person-time-at-risk allows cancer incidence rates to be calculated.

Relative rate (RR): The ratio of two rates.

Standardisation: A set of techniques, based on weighted averaging, to remove as much as possible the effects of age, sex or other factors when comparing rates for two or more populations.

Standardised incidence ratio [SIR]: The ratio of the observed number of cases in the exposed to number that would be expected if the exposed had the same incidence rates as the unexposed population. SIRS can be standardised for age, sex and other factors.

Funding & Governance

The ACT Asbestos Health Study was funded by the ACT Government. The study was overseen by the ACT Asbestos Health Study Steering Committee. The ACT Chief Health Officer chaired the Steering Committee, which was comprised of staff of ACT Health, the Asbestos Response Taskforce, NSW Health and the ACT Asbestos Health Study team.

Role of the funding agency

The ACT Asbestos Health Study team was solely responsible for developing the methodology for this study, collecting and analysing data and interpreting the findings. The ACT Asbestos Health Study Steering Committee provided comments on the methodology and the final report. The Steering Committee did not make decisions about data to include, analyses to carry out or interpretation of the results, nor the decision to submit the final report.

References

1. ACT Government Asbestos Response Taskforce [Internet]: **Long term management of loose fill asbestos insulation in Canberra homes**; 2014 [cited 2017 April 26]. Available from: www.asbestostaskforce.act.gov.au.
2. ACT Government Asbestos Response Taskforce [Internet]: **Buyback, Sale and Rebuild;** 2016 [cited 2017 April 26]. Available from: www.asbestostaskforce.act.gov.au.
3. Kirk MD, Batterham PJ, Clements MS, Armstrong BK, Trevenar SM, Welsh JA, Korda RJ: **ACT Asbestos Health Study: Cross Sectional Survey Report;** 2016 [cited 2017 April 26]. Available from: http://nceph.anu.edu.au/research/projects/act-asbestos-health-study.
4. IARC Working Group on the Evaluation of Carcinogenic Risks to Humans: **Arsenic, metals, fibres, and dusts**. *IARC monographs on the evaluation of carcinogenic risks to humans / World Health Organization, International Agency for Research on Cancer* 2012, **100**(Pt C):11-465.
5. Goswami E, Craven V, Dahlstrom DL, Alexander D, Mowat F: **Domestic asbestos exposure: a review of epidemiologic and exposure data**. *Int J Environ Res Public Health* 2013, **10**(11):5629-5670.
6. Reid A, Heyworth J, de Klerk N, Musk AW: **The mortality of women exposed environmentally and domestically to blue asbestos at Wittenoom, Western Australia**. *Occup Environ Med* 2008, **65**(11):743-749.
7. Pira E, Romano C, Violante FS, Farioli A, Spatari G, La Vecchia C, Boffetta P: **Updated mortality study of a cohort of asbestos textile workers**. *Cancer medicine* 2016, **5**(9):2623-2628.
8. Sim M, Benke G, McFarlane E, Kee E: **The management of asbestos in the non-occupational environment**. Report prepared for the Department of Health and Ageing by Monash University. Environmental Health Standing Committee (enHealth); 2014.
9. Spear TM, Hart JF, Spear TE, Loushin MM, Shaw NN, Elashhab MI: **The presence of asbestos-contaminated vermiculite attic insulation or other asbestos-containing materials in homes and the potential for living space contamination**. *Journal of environmental health* 2012, **75**(3):24-29.
10. Sullivan PA: **Vermiculite, respiratory disease, and asbestos exposure in Libby, Montana: update of a cohort mortality study**. *Environ Health Perspect* 2007, **115**(4):579-585.
11. Naik SL, Lewin M, Young R, Dearwent SM, Lee R: **Mortality from asbestos-associated disease in Libby, Montana 1979-2011**. *Journal of exposure science & environmental epidemiology* 2017, **27**(2):207-213.
12. Levin JL, Rouk A, Shepherd S, Hurst GA, McLarty JW: **Tyler asbestos workers: A mortality update in a cohort exposed to amosite**. *Journal of toxicology and environmental health Part B, Critical reviews* 2016, **19**(5-6):190-200.
13. Berry G, Reid A, Aboagye-Sarfo P, de Klerk NH, Olsen NJ, Merler E, Franklin P, Musk AW: **Malignant mesotheliomas in former miners and millers of crocidolite at Wittenoom (Western Australia) after more than 50 years follow-up**. *Br J Cancer* 2012, **106**(5):1016-1020.
14. Institute of Medicine. **Asbestos: Selected Cancers.** Washington, DC: The National Academies Press; 2006 [cited 2017, April 26]. Available from: https://doi.org/10.17226/11665.
15. Offermans NS, Vermeulen R, Burdorf A, Goldbohm RA, Keszei AP, Peters S, Kauppinen T, Kromhout H, van den Brandt PA: **Occupational asbestos exposure and risk of esophageal, gastric and colorectal cancer in the prospective Netherlands Cohort Study**. *Int J Cancer* 2014, **135**(8):1970-1977.
16. Paris C, Thaon I, Herin F, Clin B, Lacourt A, Luc A, Coureau G, Brochard P, Chamming's S, Gislard A *et al*: **Occupational Asbestos Exposure and Incidence of Colon and Rectal Cancers in French Men: The Asbestos-Related Diseases Cohort (ARDCo-Nut)**. *Environ Health Perspect* 2017, **125**(3):409-415.
17. Gamble J: **Risk of gastrointestinal cancers from inhalation and ingestion of asbestos**. *Regul Toxicol Pharmacol* 2008, **52**(1 Suppl):S124-153.

18. Koskinen K, Pukkala E, Reijula K, Karjalainen A: **Incidence of cancer among the participants of the Finnish Asbestos Screening Campaign**. *Scand J Work Environ Health* 2003, **29**(1):64-70.
19. Reid A, Franklin P, Olsen N, Sleith J, Samuel L, Aboagye-Sarfo P, de Klerk N, Musk AW: **All-cause mortality and cancer incidence among adults exposed to blue asbestos during childhood**. *American journal of industrial medicine* 2013, **56**(2):133-145.
20. Auerbach O, Conston AS, Garfinkel L, Parks VR, Kaslow HD, Hammond EC: **Presence of asbestos bodies in organs other than the lung**. *Chest* 1980, **77**(2):133-137.
21. Australian Mesothelioma Registry: **Australian Mesothelioma Registry 5th Annual Report;** 2016 [cited 2017 May 4]. Available from: https://www.mesothelioma-australia.com /publications-and-data/publications.
22. U.S. Department of Health and Human Services. **The Health Consequences of Smoking—50 Years of Progress: A Report of the Surgeon General**. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health; 2014. [cited 2017 May 5]. Available from: https://www.surgeongeneral.gov /library/reports/50-years-of-progress.

Appendices

Appendix 1. Australian Cancer Database: Standard data items

Australian Cancer Database agreed minimum data set	
Person-level attributes	Tumour-level attributes
Person identification number (assigned by the state/territory)	State/territory of usual residence at diagnosis
Surname	Tumour identification number (assigned by the state/territory)
First given name	Date of diagnosis
Second given name	Date of diagnosis accuracy indicator
Third given name	Age at diagnosis
Sex	ICD-O-3[(a)] topography code
Date of birth	ICD-O-3[(a)] morphology code
Date of birth accuracy indicator	ICD-10[(b)] disease code
Indigenous status	Most valid basis of diagnosis
Country of birth	Statistical local area at diagnosis
Date of death	Postcode at diagnosis
Age at death	Melanoma thickness (Breslow)
Cause of death	Tumour size (breast cancer only)

a. International Classification of Diseases for Oncology, 3rd edition.
b. International Statistical Classification of Diseases and Related Health Problems, 10th revision.

Source: http://www.aihw.gov.au/australian-cancer-database/

EO2015-4-208: ACT Asbestos Health Study

Data Linkage Unit, October 2016

Overview

This report outlines the methodology and results from probabilistic linkages carried out as part of the data linkage component of the ACT Asbestos Health Study. Three separate linkages were undertaken:

1) Linkage between the ACT Asbestos Response Taskforce register of Affected Residential Premises (ARP) to ACT addresses on the Medicare enrolments file,
2) Linkage between the Medicare enrolments file (ACT residents only) and the Australian Cancer Database (ACD), and
3) Linkage between the Medicare enrolments file (ACT residents only) and the National Death Index (NDI).

The probabilistic linkages were carried out by the AIHW Data Linkage Unit at the request of the National Centre for Epidemiology and Population Health, Australian National University.

Description of the data

The ACT Asbestos Response Taskforce register of ARPs contains 1,089 identified addresses affected by loose fill asbestos insulation as of January 2017. Each record contains data on unit number, street number, street name, street type and suburb, as well as alternate street address where one exists.

The Medicare enrolments file contains data on all persons enrolled in Medicare since its inception in November 1983. The cohort data set consists of all persons that ever registered on Medicare with an ACT address (1,068,520 individuals). Each record contains data on name, sex, date of birth, street address, postcode and state. The Medicare enrolments file contains updates in change of details; therefore there are multiple records per person containing all historical changes in name and demographic details, both before and after registration in the ACT.

The NDI is a Commonwealth database that contains records of deaths registered in Australia since 1980. Data comes from Registrars of Births, Deaths and Marriages in each jurisdiction, the National Coronial Information System and the Australian Bureau of Statistics. Similar to the cohort data set, the linkage data available in the NDI include name, sex, date of birth and address at time of death registration. Just under 30% of NDI records are missing data for date of birth and/or month of birth (year of birth is available). The majority of these records relate to death before 2000.

The ACD is a data collection of all primary, malignant cancers diagnosed in Australia since 1982. The ACD is compiled at the AIHW from cancer data provided by state and territory cancer registries through the Australasian Association of Cancer Registries. The linkage data available in the ACD include name, sex, date of birth and postcode of residence at time of cancer diagnosis.

Method

Data checking and cleaning

Substantial cleaning and standardisation methods were carried out on all ACT addresses in the Medicare enrolments register prior to linkage to the ACT Asbestos Response Taskforce register of ARPs.

In both data sets (Medicare enrolments and Taskforce list of ARPs), street address is populated in a single character field. However, all addresses on the Taskforce list of ARPs also had a 'standard' street address format, that is, the address had a unit number (optional), a street number, a street name and a street type. This was not the case for addresses in the Medicare enrolments file, where just over 15% of addresses were post office box addresses, single-word rural properties, institutions, government offices or incomplete/non-meaningful addresses (examples include 'YMCA', 'CANBERRA GIRLS GRAMMAR', 'DFAT' and 'BUILDING 57').

In order to standardise the address structures in both data sets, an approach was undertaken where a pattern search specification was designed to identify Medicare addresses with a 'standard' street address structure. 'Standard' addresses had to contain at a minimum a street number, a street name and a street type. Subsequently, a parsing algorithm was developed to deconstruct these addresses into their component parts, namely a unit number (optional), a street number, a street name and a street type, thus resulting in four additional fields. Only addresses that conformed to this standard structure could be linked probabilistically to the Taskforce list of ARPs. Of all ACT addresses, 84.6% had a standard structure.

For the remaining addresses, a separate pattern search algorithm was developed to identify post office box addresses. These were flagged as 'PO Box' addresses (12.4% of ACT addresses) and the remaining addresses were flagged as 'Non-Standard' addresses (3% of ACT addresses). These addresses were not attempted to be linked to the Taskforce list of ARPs, but were identified to provide the researchers with additional information for analysis.

For the person-level linkages between individuals on the Medicare cohort data set to the ACD and NDI, no project-specific cleaning was performed on the Medicare data. Of the 1,068,520 individuals Medicare cohort members that ever registered on Medicare with an ACT address, there were no individuals with missing address, only 2 individuals with missing postcode, 268 individuals with missing name and birth date information and 1088 individuals with missing given name (surname was available in these records).

Limited additional cleaning was performed on the NDI and ACD data sets as these have been prepared through standard AIHW data cleaning methods during collation.

Data linkage

The various data sets were linked using probabilistic linkage algorithms. In probabilistic linkage, the linkage of records in two files is based on the probabilities of agreement and disagreement between linkage variables. Probabilistic linkage allows for variation in reporting by allowing probabilities of agreement to be less than 1 and probabilities of disagreement to be greater than 0.

The probabilistic linkage procedure involves creating record pairs—one from each data set—by running a series of passes that allow for variation in full name information and demographic data. Each pass consists of deterministic pairwise matching on selected blocking variables and then calculating a comparison weight based on probabilities of agreement and

disagreement for the blocking and match variables for each respective match pair in the block. In this way, the linkage process creates record pairs by combining records from one data set with records from another data set based on similarities in characteristics such as surname, given name(s) and day, month and year of birth.

NB: It should be noted that probabilistic linkage does **not** require an exact match between two records for any given variable. For each record pair, a record pair comparison weight is calculated. This is an index of the degree of similarity between records in a given pair. It can also be used to ascertain the extent to which a given record pair is likely to be the same person. A higher comparison weight suggests that a given record pair is more likely to be the same person than a lower comparison weight.

Clerical review—general description

Clerical review is the name given to the process that involves manually examining available linkage data for proposed match pairs and deciding whether to accept or reject the match. Commonly, in name-based matching two weight cut-offs are set, with weights above a first (higher) cut-off limit assumed to indicate a match and weights below a second (lower) cut-off assumed to indicate a non-match. Clerical review is then used to decide the match status of possible match pairs with weights between the two cut-offs; that is for record pairs in the 'grey zone' defined by the two weight cut-offs. Clerical review may be carried out after each pass, or after all passes.

In full clerical review, multiple passes are run starting from a high number of blocking variables to a low number of blocking variables. During the initial passes, a large number of blocking variables are applied to identify as many obvious true links as possible. Gradually, the number of blocking variables is reduced to allow for more flexible matching (for example, if there is variation in spelling or reported date of birth) to occur. In this way, links with the strongest evidence (highest weights) are identified easily while also allowing true matches with inconsistent data to be identified.

Generally, most links are identified during the initial passes (up to 90%) and few at the end. In the final stages, records are brought together with the least number of blocking variables possible. These final passes allow us to review if there are any more links that were missed as a result of the constraints imposed by the blocking variables. By doing this, we ensure that the search for links is, as far as possible, exhaustive.

Clerical review process for current project

In the current project, clerical review was carried out after each pass, rather than after all passes. As blocking variables were removed, progressively more clerical review was performed to ensure the identification of matches among record pairs with differing linkage information.

Overall, more than 30 passes each were undertaken to create Medicare to NDI record pairs and Medicare to ACD record pairs. Various combinations of the following variables were used as blocking variables:

- Surname
- Given name(s)
- Day, month and year of birth (individual elements)
- Postcode

- First part of address

Additional variables used to assist in clerical review included:

- Date of diagnosis
- Date of death
- State
- Full address

For example, in the first pass (the most restricted pass), record pairs were created by blocking records according to surname, given name(s) and full date of birth. In subsequent passes, the number of blocking variables was reduced; for example, blocking on surname, given name(s), and year of birth in order to allow for variation in day and month of birth.

For the linkage between Medicare addresses and the Taskforce list of ARPs, 13 passes were undertaken to create Medicare address to ARP record pairs. Various combinations of the following variables were used as blocking variables:

- Unit number
- Street number
- Street name
- Street type
- Suburb

In addition to the above variables, postcode and demolition date were used to assist in clerical review.

Because the linkage strategy was a probabilistic process, a small percentage of the identified matches may not be correct, and a small number could have been missed even though full clerical review was carried out. In addition, because people's information can be reported quite differently in different data sets, the clerical review process itself is not 100% accurate. However, it is expected that the numbers of false and missed matches is very small.

Additionally, links were checked for information inconsistencies. For example, the date of death (from the NDI) was compared to the date of cancer diagnosis (from the ACD) to ensure that the *latter* occurred before the former. After clerical review, a number of links with a date of cancer diagnosis occurring after the date of death were retained (see Results section). For the address linkage, demolition date in the ARP was used for consistency checks.

Results

Linkage between the ACT Asbestos Response Taskforce register of Affected Residential Premises (ARP) to the Medicare enrolments file

Overall, 1,087 (99.8%) of the addresses in the Taskforce list of ARPs were linked to the Medicare enrolments file. Other points of interest include:

- Most ARPs (954/1,087) linked to two or more Medicare address IDs. These links were retained as valid as clerical review revealed that these were the same addresses with multiple address IDs on the Medicare data set. People associated with any of these linked addresses are flagged as having lived in an ARP.
- There was a median of 3 links per ARP and a maximum of 13 links per ARP.
- Two ARPs could not be identified on the Medicare enrolments file.

Linkage between the Medicare enrolments file (ACT residents only) and the Australian Cancer Database (ACD)

Overall, 54,796 (5.13%) Medicare cohort members were matched to the ACD database. Other points of interest include:

- There were 61 cohort members that matched to 2 ACD person IDs. These matches have been retained as valid as clerical review suggests these were the same individuals with two different person IDs on the ACD data set.
- The match file contains in excess of 54,857 (54,796 + 61) records due to the fact that an individual on the ACD may have multiple records resulting from multiple diagnoses.
- There are 11 links where the death date (from the NDI) occurs before the diagnosis date (from the ACD). These links were retained as valid as clerical review showed that these links were made on sufficient evidence on the other linkage variables. For these records, it is possible that either the date of diagnosis or the date of death is incorrect. Alternatively, it is possible that the cancer diagnosis was established after the date of death.

Linkage between the Medicare enrolments file (ACT residents only) and the National Death Index (NDI)

Overall, 64,907 (6.07%) Medicare cohort members were matched to the NDI database. Other points of interest include:

- Among the matches there are 11 death dates on the NDI that are missing, incomplete or invalid.
- Where a link is made to an NDI record with missing date of birth information, a flag was created to identify such linkages. In addition to this flag, an indicator of the strength of the comparison weight is also provided, calculated based on other linkage variables besides the day/month of birth.
- The total number of deaths registered in the ACT from the period 1984 to 2014 is 41,247 (Australian Bureau of Statistics, Catalogue No. 3302.2). The likely reason that the number of deaths identified for the Medicare cohort exceeds this number is the identification of death of cohort members who have moved away from the ACT.

Match files

Three separate data tables are provided that reflect each of the linkages performed. These tables are mutually relatable by the variable AIHW_ID. The variables in each data table are listed below.

Match file 1: Medicare enrolments cohort with classification of exposure to ARP

Name: ACT_ADDRESSES (CSV file)

Observations: 7,204,176

Content:

Variable	Source	Description of Variable
AIHW_ID	AIHW derived	Entity identifier
SEX	Medicare	Last recorded sex on Medicare
BIRTH_YEAR	Medicare	Last recorded year of birth on Medicare
AIHW_ADDRESS_ID	AIHW derived	Medicare address identifier
STATE	AIHW derived	State of address. Values are 'ACT' or 'Outside ACT'.
START_DATE	Medicare	Start date at address
END_DATE	Medicare	End date at address
ARP_FLAG	AIHW derived	Flag of whether the address is an Affected Residential Premise (ARP). Values are 'ARP' or missing.
ARP_DEMOLISHED_YEAR	Asbestos Response Taskforce Register of ARPs	Year of demolition of ARP
CO_FLAG	AIHW derived	Flag of whether the address has a C/O character string. Values are 'C/O' or missing.
ADDRESS_TYPE	AIHW derived	Flags whether the address has a 'standard' street address structure. Values are 'Standard', 'Non-Standard', or 'PO Box'.

Match file 2: Medicare enrolments cohort linkage to ACD

Name: ACT_TO_ACD (CSV file)

Observations: 59,989

Content:

Variable	Source	Description of Variable
AIHW_ID	AIHW derived	Entity identifier
SEX	ACD	Sex
DIAGNOSIS_AGE_EXACT	ACD	Age at diagnosis
DIAGNOSIS_DATE	ACD	Date of diagnosis
TOPOGRAPHY	ACD	ICD-0-3 TOPOGRAPHY CODE
HISTOLOGY	ACD	ICD-0-3 MORPHOLOGY CODE
ICD10	ACD	ICD-10 DISEASE CODE
STATE	ACD	STATE/TERRITORY OF USUAL RESIDENCE AT DIAGNOSIS
POSTCODE	ACD	POST CODE OF DIAGNOSIS

Match file 3: Medicare enrolments cohort linkage to NDI

Name: ACT_TO_ACD (CSV file)

Observations: 64,907

Content:

Variable	Source	Description of Variable
AIHW_ID	AIHW derived	Entity identifier
DATE_OF_DEATH	NDI	Date of death
UNDERLYING_CAUSE*	NDI	Primary cause of death
OTHER_CAUSES	NDI	All other causes of death mentioned on the death certificate
LINKAGE_NOTE	AIHW derived	Flags whether the link was made on a limited number of variables. Values are 'Linkage on limited info', or missing.
WEIGHT	AIHW derived	Where the linkage was performed on a limited number of variables, an indicator of comparison weight is provided. Values are 'High', 'Medium' or 'Low'.

* For NDI records with year of registration up to 1997, only the underlying cause of death is available, and this is coded in ICD-9. For records from 1996, both the codes for underlying cause of death and all other causes of death are available, coded in ICD-10.

Appendix 3. Number of individuals and unique addresses included in the study

Number of individuals and unique address IDs registered with Medicare by year, for people who have ever had an ACT address registered with Medicare between 1984 and 2013

Year	Individuals					Unique Address IDs				
	ACT			Outside ACT	Total	ACT			Outside ACT	Total
	ARP	Non-ARP	Total			ARP	Non-ARP	Total		
1984	2 667	183 506	186 173	219 435	405 608	1 009	74 709	75 718	147 829	223 547
1985	3 271	231 188	234 459	251 462	485 921	1 231	93 607	94 838	168 792	263 630
1986	3 227	242 042	245 269	260 112	505 381	1 222	98 592	99 814	174 084	273 898
1987	3 229	252 512	255 741	268 292	524 033	1 227	103 320	104 547	178 990	283 537
1988	3 289	260 853	264 142	277 505	541 647	1 278	107 082	108 360	184 397	292 757
1989	3 332	270 061	273 393	284 717	558 110	1 306	111 280	112 586	188 905	301 491
1990	3 344	280 609	283 953	291 227	575 180	1 312	115 647	116 959	193 013	309 972
1991	3 252	288 753	292 005	292 458	584 463	1 328	121 159	122 487	194 083	316 570
1992	3 193	297 791	300 984	294 156	595 140	1 282	123 026	124 308	194 012	318 320
1993	3 154	308 195	311 349	297 700	609 049	1 259	124 355	125 614	195 258	320 872
1994	3 149	319 223	322 372	303 711	626 083	1 220	126 117	127 337	198 560	325 897
1995	3 223	330 294	333 517	311 306	644 823	1 222	129 146	130 368	202 733	333 101
1996	3 208	341 112	344 320	319 962	664 282	1 202	130 829	132 031	207 861	339 892
1997	3 175	350 219	353 394	328 911	682 305	1 193	131 947	133 140	213 276	346 416
1998	3 142	360 882	364 024	336 323	700 347	1 182	133 639	134 821	218 096	352 917
1999	3 134	373 510	376 644	342 863	719 507	1 173	135 614	136 787	222 887	359 674
2000	3 239	385 110	388 349	349 318	737 667	1 175	137 858	139 033	227 417	366 450
2001	3 215	396 855	400 070	356 093	756 163	1 157	140 033	141 190	232 193	373 383
2002	3 187	403 698	406 885	357 915	764 800	1 098	137 275	138 373	234 201	372 574
2003	3 208	414 194	417 402	366 654	784 056	1 092	139 726	140 818	240 184	381 002
2004	3 168	424 518	427 686	377 117	804 803	1 077	142 068	143 145	246 810	389 955
2005	3 244	435 588	438 832	385 877	824 709	1 096	148 408	149 504	252 723	402 227
2006	3 269	446 857	450 126	393 228	843 354	1 104	151 244	152 348	258 618	410 966
2007	3 209	459 362	462 571	399 714	862 285	1 085	154 544	155 629	264 007	419 636
2008	3 267	475 444	478 711	409 095	887 806	1 056	151 298	152 354	268 364	420 718
2009	3 325	488 754	492 079	416 826	908 905	1 059	156 042	157 101	275 081	432 182
2010	3 418	503 541	506 959	423 266	930 225	1 060	157 105	158 165	279 103	437 268
2011	3 442	521 522	524 964	428 143	953 107	1 061	162 175	163 236	283 795	447 031
2012	3 476	537 038	540 514	432 923	973 437	1 053	164 341	165 394	287 430	452 824
2013	3 408	553 179	556 587	435 667	992 254	1 045	168 366	169 411	291 244	460 655

ARP= affected residential property ACT= Australian Capital Territory

Appendix 4. Comparison of Medicare enrolee population and estimated resident populations for the ACT

Number of individuals enrolled with Medicare with an ACT address and the estimated mid-year resident population (ERP) of the ACT for each year from 1984 to 2013 by age and sex, and proportions within each age-sex group as a percentage of the total population for that year

MALES		0-4	5-14	15-24	25-44	45-64	65-84	85 plus		0-4	5-14	15-24	25-44	45-64	65-84	85 plus
		n	n	n	n	n	n			%	%	%	%	%	%	%
1984	**ERP**	10 641	23 571	21 961	41 885	19 622	4 613	165		4.34	9.62	8.96	17.09	8.01	1.88	0.07
	Medicare	8 373	17 076	16 628	32 864	15 032	2 995	85		4.50	9.17	8.93	17.65	8.07	1.61	0.05
	Ratio	0.79	0.72	0.76	0.78	0.77	0.65	0.52								
1985	**ERP**	10 595	23 536	22 575	43 290	20 378	5 000	175		4.21	9.36	8.98	17.22	8.11	1.99	0.07
	Medicare	9 691	21 165	19 877	41 668	19 437	4 943	218		4.13	9.03	8.48	17.77	8.29	2.11	0.09
	Ratio	0.91	0.90	0.88	0.96	0.95	0.99	1.25								
1986	**ERP**	10 749	23 160	24 391	44 912	20 915	5 000	175		4.16	8.96	9.43	17.37	8.09	1.93	0.07
	Medicare	9 943	21 378	21 310	43 933	20 492	5 430	256		4.05	8.72	8.69	17.91	8.36	2.21	0.10
	Ratio	0.93	0.92	0.87	0.98	0.98	1.09	1.46								
1987	**ERP**	10 828	23 225	24 715	46 296	21 761	5 687	215		4.08	8.75	9.31	17.44	8.20	2.14	0.08
	Medicare	10 084	21 738	22 269	46 330	21 537	5 909	319		3.94	8.50	8.71	18.12	8.42	2.31	0.12
	Ratio	0.93	0.94	0.90	1.00	0.99	1.04	1.48								
1988	**ERP**	10 869	23 294	25 233	47 659	22 535	6 057	247		4.03	8.64	9.36	17.68	8.36	2.25	0.09
	Medicare	10 119	21 978	23 099	47 849	22 513	6 481	385		3.83	8.32	8.75	18.12	8.52	2.45	0.15
	Ratio	0.93	0.94	0.92	1.00	1.00	1.07	1.56								
1989	**ERP**	10 922	23 099	25 725	48 216	23 304	6 485	270		3.95	8.36	9.31	17.44	8.43	2.35	0.10
	Medicare	10 325	22 169	23 933	49 311	23 716	7 096	440		3.78	8.11	8.76	18.04	8.68	2.60	0.16
	Ratio	0.95	0.96	0.93	1.02	1.02	1.09	1.63								
1990	**ERP**	11 175	23 025	26 528	48 926	24 209	6 911	284		3.96	8.16	9.40	17.34	8.58	2.45	0.10
	Medicare	10 453	22 591	24 791	51 015	25 042	7 713	524		3.68	7.96	8.73	17.97	8.82	2.72	0.18
	Ratio	0.94	0.98	0.93	1.04	1.03	1.12	1.85								

MALES		0-4	5-14	15-24	25-44	45-64	65-84	85 plus		0-4	5-14	15-24	25-44	45-64	65-84	85 plus
		n	n	n	n	n	n			%	%	%	%	%	%	%
1991	**ERP**	11 547	23 204	27 529	49 393	25 265	7 400	298		3.99	8.02	9.52	17.07	8.73	2.56	0.10
	Medicare	10 705	22 620	25 028	52 060	26 679	8 384	634		3.67	7.75	8.57	17.83	9.14	2.87	0.22
	Ratio	0.93	0.97	0.91	1.05	1.06	1.13	2.13								
1992	**ERP**	11 650	23 319	27 809	49 554	26 773	7 784	329		3.95	7.91	9.43	16.80	9.08	2.64	0.11
	Medicare	10 755	22 757	25 249	53 045	28 707	9 243	746		3.57	7.56	8.39	17.63	9.54	3.07	0.25
	Ratio	0.92	0.98	0.91	1.07	1.07	1.19	2.27								
1993	**ERP**	11 658	23 349	28 100	49 643	28 136	8 170	372		3.89	7.79	9.37	16.56	9.39	2.73	0.12
	Medicare	10 775	23 220	25 508	54 499	30 489	10 148	862		3.46	7.46	8.19	17.51	9.79	3.26	0.28
	Ratio	0.92	0.99	0.91	1.10	1.08	1.24	2.32								
1994	**ERP**	11 453	23 249	27 987	49 413	29 283	8 534	411		3.79	7.69	9.26	16.35	9.69	2.82	0.14
	Medicare	10 801	23 590	25 621	56 024	32 592	11 034	976		3.35	7.32	7.95	17.38	10.11	3.42	0.30
	Ratio	0.94	1.01	0.92	1.13	1.11	1.29	2.37								
1995	**ERP**	11 437	23 299	27 749	49 621	30 561	8 851	450		3.74	7.62	9.07	16.22	9.99	2.89	0.15
	Medicare	10 820	24 007	25 853	57 468	34 619	12 136	1 123		3.25	7.20	7.75	17.24	10.38	3.64	0.34
	Ratio	0.95	1.03	0.93	1.16	1.13	1.37	2.50								
1996	**ERP**	11 331	23 412	27 207	50 195	31 730	9 285	475		3.66	7.56	8.79	16.21	10.25	3.00	0.15
	Medicare	10 748	24 466	25 755	59 002	36 587	13 222	1 253		3.12	7.11	7.48	17.14	10.63	3.84	0.36
	Ratio	0.95	1.05	0.95	1.18	1.15	1.42	2.64								
1997	**ERP**	11 178	23 262	26 577	50 008	32 762	9 647	506		3.60	7.49	8.56	16.10	10.55	3.11	0.16
	Medicare	10 526	24 650	25 761	59 902	38 543	14 373	1 442		2.98	6.98	7.29	16.96	10.91	4.07	0.41
	Ratio	0.94	1.06	0.97	1.20	1.18	1.49	2.85								
1998	**ERP**	10 945	23 011	26 313	49 698	33 944	10 077	559		3.51	7.39	8.45	15.95	10.90	3.23	0.18
	Medicare	10 439	24 671	26 227	61 117	40 442	15 560	1 648		2.87	6.78	7.21	16.79	11.11	4.28	0.45
	Ratio	0.95	1.07	1.00	1.23	1.19	1.54	2.95								

MALES		0-4	5-14	15-24	25-44	45-64	65-84	85 plus		0-4	5-14	15-24	25-44	45-64	65-84	85 plus
		n	n	n	n	n	n			%	%	%	%	%	%	%
1999	ERP	10 873	22 813	25 984	49 803	34 974	10 545	607		3.46	7.26	8.27	15.85	11.13	3.36	0.19
	Medicare	10 421	24 700	26 778	62 877	42 371	16 732	1 886		2.77	6.56	7.11	16.70	11.25	4.44	0.50
	Ratio	0.96	1.08	1.03	1.26	1.21	1.59	3.11								
2000	ERP	10 687	22 874	25 711	50 002	35 894	10 989	658		3.37	7.21	8.10	15.76	11.31	3.46	0.21
	Medicare	10 341	24 778	27 425	64 684	44 111	17 758	2 127		2.66	6.38	7.06	16.66	11.36	4.57	0.55
	Ratio	0.97	1.08	1.07	1.29	1.23	1.62	3.23								
2001	ERP	10 641	22 817	26 122	50 085	36 823	11 433	745		3.31	7.10	8.12	15.58	11.45	3.56	0.23
	Medicare	10 144	24 921	28 020	66 275	46 073	18 760	2 405		2.54	6.23	7.01	16.57	11.52	4.69	0.60
	Ratio	0.95	1.09	1.07	1.32	1.25	1.64	3.23								
2002	ERP	10 472	22 832	26 344	50 439	37 518	11 756	777		3.23	7.03	8.12	15.54	11.56	3.62	0.24
	Medicare	10 083	24 520	28 021	67 408	47 280	19 819	2 640		2.48	6.03	6.89	16.57	11.62	4.87	0.65
	Ratio	0.96	1.07	1.06	1.34	1.26	1.69	3.40								
2003	ERP	10 402	22 510	27 016	50 534	38 102	12 172	832		3.18	6.88	8.25	15.44	11.64	3.72	0.25
	Medicare	10 047	24 320	28 689	69 065	48 763	20 911	2 917		2.41	5.83	6.87	16.55	11.69	5.01	0.70
	Ratio	0.97	1.08	1.06	1.37	1.28	1.72	3.51								
2004	ERP	10 361	22 172	27 317	50 694	38 600	12 470	873		3.15	6.74	8.30	15.41	11.73	3.79	0.27
	Medicare	10 099	24 201	28 883	70 739	50 335	22 136	3 271		2.36	5.66	6.76	16.54	11.77	5.18	0.77
	Ratio	0.97	1.09	1.06	1.40	1.30	1.78	3.75								
2005	ERP	10 398	21 751	27 633	50 967	39 217	12 852	1 014		3.14	6.56	8.34	15.38	11.83	3.88	0.31
	Medicare	10 319	23 962	29 156	72 246	52 178	23 263	3 764		2.35	5.46	6.65	16.47	11.89	5.30	0.86
	Ratio	0.99	1.10	1.06	1.42	1.33	1.81	3.71								
2006	ERP	10 628	21 340	27 881	51 627	39 985	13 225	1 128		3.17	6.37	8.32	15.40	11.93	3.95	0.34
	Medicare	10 767	23 752	29 401	73 989	53 812	24 314	4 230		2.39	5.28	6.53	16.44	11.96	5.40	0.94
	Ratio	1.01	1.11	1.05	1.43	1.35	1.84	3.75								

MALES		0-4	5-14	15-24	25-44	45-64	65-84	85 plus		0-4	5-14	15-24	25-44	45-64	65-84	85 plus
		n	n	n	n	n	n			%	%	%	%	%	%	%
2007	**ERP**	11 165	21 328	28 524	52 814	40 839	13 724	1 246		3.26	6.22	8.32	15.41	11.92	4.01	0.36
	Medicare	11 200	23 707	29 728	75 698	55 607	25 420	4 717		2.42	5.13	6.43	16.37	12.02	5.50	1.02
	Ratio	1.00	1.11	1.04	1.43	1.36	1.85	3.79								
2008	**ERP**	11 486	21 285	28 966	53 954	41 482	14 183	1 351		3.30	6.11	8.31	15.49	11.91	4.07	0.39
	Medicare	11 707	23 800	30 055	78 118	57 583	27 074	5 346		2.45	4.97	6.28	16.32	12.03	5.66	1.12
	Ratio	1.02	1.12	1.04	1.45	1.39	1.91	3.96								
2009	**ERP**	11 966	21 429	29 458	55 232	42 087	14 708	1 445		3.37	6.04	8.30	15.57	11.86	4.15	0.41
	Medicare	12 268	23 941	30 294	80 022	59 293	28 377	5 944		2.49	4.87	6.16	16.27	12.05	5.77	1.21
	Ratio	1.03	1.12	1.03	1.45	1.41	1.93	4.11								
2010	**ERP**	12 382	21 477	29 941	56 589	42 626	15 296	1 549		3.42	5.94	8.28	15.64	11.78	4.23	0.43
	Medicare	12 707	24 177	30 568	82 191	61 002	29 963	6 603		2.51	4.77	6.03	16.22	12.04	5.91	1.30
	Ratio	1.03	1.13	1.02	1.45	1.43	1.96	4.26								
2011	**ERP**	12 512	21 893	29 916	58 043	42 954	16 032	1 646		3.40	5.95	8.13	15.77	11.67	4.36	0.45
	Medicare	13 128	24 824	30 935	84 799	62 752	32 232	7 291		2.50	4.73	5.89	16.16	11.96	6.14	1.39
	Ratio	1.05	1.13	1.03	1.46	1.46	2.01	4.43								
2012	**ERP**	13 038	22 338	29 559	59 666	43 193	17 074	1 748		3.48	5.95	7.88	15.90	11.51	4.55	0.47
	Medicare	13 679	25 344	31 231	86 911	63 908	34 475	7 990		2.53	4.69	5.78	16.08	11.83	6.38	1.48
	Ratio	1.05	1.13	1.06	1.46	1.48	2.02	4.57								
2013	**ERP**	13 445	22 696	28 912	60 857	43 629	17 913	1 878		3.53	5.96	7.59	15.98	11.45	4.70	0.49
	Medicare	14 110	26 116	31 337	89 301	65 268	36 301	8 746		2.54	4.69	5.63	16.05	11.73	6.52	1.57
	Ratio	1.05	1.15	1.08	1.47	1.50	2.03	4.66								

FEMALES		0-4	5-14	15-24	25-44	45-64	65-84	85 plus		0-4	5-14	15-24	25-44	45-64	65-84	85 plus
		n	n	n	n	n	n			%	%	%	%	%	%	%
1984	**ERP**	10 382	22 616	21 491	42 470	18 861	6 306	528		4.24	9.23	8.77	17.33	7.69	2.57	0.22
	Medicare	8 188	16 410	17 047	33 700	14 416	3 135	211		4.40	8.81	9.16	18.10	7.74	1.68	0.11
	Ratio	0.79	0.73	0.79	0.79	0.76	0.50	0.40								
1985	**ERP**	10 407	22 704	22 198	43 670	19 516	6 737	608		4.14	9.03	8.83	17.37	7.76	2.68	0.24
	Medicare	9 425	20 195	19 896	42 094	18 497	6 678	658		4.02	8.61	8.49	17.95	7.89	2.85	0.28
	Ratio	0.91	0.89	0.90	0.96	0.95	0.99	1.08								
1986	**ERP**	10 402	22 592	23 583	45 120	19 940	7 059	598		4.02	8.74	9.12	17.45	7.71	2.73	0.23
	Medicare	9 580	20 396	21 217	44 076	19 296	7 196	744		3.91	8.32	8.65	17.97	7.87	2.93	0.30
	Ratio	0.92	0.90	0.90	0.98	0.97	1.02	1.24								
1987	**ERP**	10 524	22 492	24 444	46 471	20 658	7 536	625		3.96	8.47	9.21	17.50	7.78	2.84	0.24
	Medicare	9 666	20 742	22 373	45 901	20 199	7 804	833		3.78	8.11	8.75	17.95	7.90	3.05	0.33
	Ratio	0.92	0.92	0.92	0.99	0.98	1.04	1.33								
1988	**ERP**	10 567	22 414	22 731	47 830	21 422	8 041	669		3.92	8.31	8.43	17.74	7.95	2.98	0.25
	Medicare	9 748	20 973	23 126	47 324	21 076	8 499	936		3.69	7.94	8.76	17.92	7.98	3.22	0.35
	Ratio	0.92	0.94	1.02	0.99	0.98	1.06	1.40								
1989	**ERP**	10 627	22 264	25 657	48 431	22 204	8 520	708		3.84	8.05	9.28	17.52	8.03	3.08	0.26
	Medicare	9 808	21 359	23 833	48 949	22 081	9 262	1 068		3.59	7.81	8.72	17.91	8.08	3.39	0.39
	Ratio	0.92	0.96	0.93	1.01	0.99	1.09	1.51								
1990	**ERP**	10 699	22 232	26 191	49 264	23 068	8 948	751		3.79	7.88	9.28	17.46	8.17	3.17	0.27
	Medicare	10 021	21 604	24 643	50 906	23 347	10 053	1 203		3.53	7.61	8.68	17.93	8.22	3.54	0.42
	Ratio	0.94	0.97	0.94	1.03	1.01	1.12	1.60								
1991	**ERP**	10 979	22 240	26 888	50 130	24 128	9 544	775		3.79	7.69	9.29	17.33	8.34	3.30	0.27
	Medicare	10 200	21 606	24 738	52 123	25 000	10 809	1 365		3.49	7.40	8.47	17.85	8.56	3.70	0.47
	Ratio	0.93	0.97	0.92	1.04	1.04	1.13	1.76								

FEMALES		0-4	5-14	15-24	25-44	45-64	65-84	85 plus		0-4	5-14	15-24	25-44	45-64	65-84	85 plus
		n	n	n	n	n	n			%	%	%	%	%	%	%
1992	**ERP**	11 131	22 297	27 270	50 516	25 657	9 963	835		3.77	7.56	9.25	17.13	8.70	3.38	0.28
	Medicare	10 259	21 612	24 939	53 188	27 103	11 801	1 516		3.41	7.18	8.29	17.68	9.01	3.92	0.50
	Ratio	0.92	0.97	0.91	1.05	1.06	1.18	1.82								
1993	**ERP**	11 158	22 327	27 515	50 900	27 055	10 438	932		3.72	7.45	9.18	16.98	9.03	3.48	0.31
	Medicare	10 288	22 011	25 146	54 607	29 195	12 826	1 706		3.31	7.07	8.08	17.54	9.38	4.12	0.55
	Ratio	0.92	0.99	0.91	1.07	1.08	1.23	1.83								
1994	**ERP**	11 134	22 275	27 203	51 019	28 389	10 853	991		3.68	7.37	9.00	16.88	9.39	3.59	0.33
	Medicare	10 432	22 338	25 318	56 557	31 298	13 855	1 871		3.24	6.93	7.86	17.55	9.71	4.30	0.58
	Ratio	0.94	1.00	0.93	1.11	1.10	1.28	1.89								
1995	**ERP**	11 040	22 320	27 007	51 414	29 811	11 211	1 067		3.61	7.30	8.83	16.81	9.75	3.67	0.35
	Medicare	10 359	22 607	25 202	58 495	33 599	15 033	2 105		3.11	6.78	7.56	17.54	10.08	4.51	0.63
	Ratio	0.94	1.01	0.93	1.14	1.13	1.34	1.97								
1996	**ERP**	10 942	22 450	26 563	52 005	31 315	11 569	1 150		3.53	7.25	8.58	16.80	10.11	3.74	0.37
	Medicare	10 313	22 903	25 172	60 293	35 985	16 207	2 321		3.00	6.65	7.31	17.52	10.45	4.71	0.67
	Ratio	0.94	1.02	0.95	1.16	1.15	1.40	2.02								
1997	**ERP**	10 718	22 334	25 675	51 983	32 674	11 952	1 257		3.45	7.19	8.27	16.74	10.52	3.85	0.40
	Medicare	10 131	23 037	24 950	61 681	38 252	17 466	2 585		2.87	6.52	7.06	17.46	10.83	4.94	0.73
	Ratio	0.95	1.03	0.97	1.19	1.17	1.46	2.06								
1998	**ERP**	10 555	22 105	24 947	51 644	34 093	12 318	1 323		3.39	7.10	8.01	16.58	10.94	3.95	0.42
	Medicare	10 096	23 174	25 290	63 162	40 400	18 782	2 923		2.77	6.37	6.95	17.36	11.10	5.16	0.80
	Ratio	0.96	1.05	1.01	1.22	1.18	1.52	2.21								
1999	**ERP**	10 474	22 114	24 664	51 689	35 409	12 775	1 447		3.33	7.04	7.85	16.45	11.27	4.07	0.46
	Medicare	10 058	23 382	26 118	65 157	42 702	20 110	3 263		2.67	6.21	6.94	17.30	11.34	5.34	0.87
	Ratio	0.96	1.06	1.06	1.26	1.21	1.57	2.26								

FEMALES		0-4	5-14	15-24	25-44	45-64	65-84	85 plus		0-4	5-14	15-24	25-44	45-64	65-84	85 plus
		n	n	n	n	n	n			%	%	%	%	%	%	%
2000	**ERP**	10 386	22 011	24 739	51 834	36 690	13 137	1 623		3.27	6.94	7.80	16.34	11.57	4.14	0.51
	Medicare	10 038	23 504	26 842	67 052	44 848	21 105	3 636		2.59	6.05	6.91	17.27	11.55	5.44	0.94
	Ratio	0.97	1.07	1.09	1.29	1.22	1.61	2.24								
2001	**ERP**	10 348	22 057	25 301	51 901	37 908	13 580	1 777		3.22	6.86	7.87	16.14	11.79	4.22	0.55
	Medicare	9 927	23 699	27 560	68 920	46 973	22 271	4 017		2.48	5.93	6.89	17.23	11.74	5.57	1.00
	Ratio	0.96	1.07	1.09	1.33	1.24	1.64	2.26								
2002	**ERP**	10 273	21 933	25 630	52 023	38 837	13 926	1 867		3.16	6.76	7.90	16.03	11.96	4.29	0.58
	Medicare	9 768	23 391	27 651	69 977	48 553	23 279	4 377		2.40	5.75	6.80	17.20	11.94	5.72	1.08
	Ratio	0.95	1.07	1.08	1.35	1.25	1.67	2.34								
2003	**ERP**	10 206	21 573	26 137	51 957	39 685	14 307	1 924		3.12	6.59	7.98	15.87	12.12	4.37	0.59
	Medicare	9 743	23 188	28 310	71 676	50 395	24 505	4 766		2.33	5.56	6.78	17.18	12.08	5.87	1.14
	Ratio	0.95	1.07	1.08	1.38	1.27	1.71	2.48								
2004	**ERP**	9 982	21 270	26 197	51 772	40 538	14 646	2 048		3.03	6.47	7.96	15.74	12.32	4.45	0.62
	Medicare	9 619	23 220	28 475	73 452	52 174	25 766	5 204		2.25	5.43	6.66	17.18	12.20	6.03	1.22
	Ratio	0.96	1.09	1.09	1.42	1.29	1.76	2.54								
2005	**ERP**	9 956	21 016	26 289	51 848	41 294	14 980	2 184		3.00	6.34	7.93	15.65	12.46	4.52	0.66
	Medicare	9 791	23 134	28 647	75 458	54 152	26 811	5 833		2.23	5.27	6.53	17.20	12.34	6.11	1.33
	Ratio	0.98	1.10	1.09	1.46	1.31	1.79	2.67								
2006	**ERP**	10 153	20 819	26 329	52 308	42 096	15 394	2 257		3.03	6.21	7.86	15.61	12.56	4.59	0.67
	Medicare	10 228	22 941	28 955	77 244	56 166	27 782	6 435		2.27	5.10	6.43	17.16	12.48	6.17	1.43
	Ratio	1.01	1.10	1.10	1.48	1.33	1.80	2.85								
2007	**ERP**	10 592	20 809	26 911	53 373	42 974	15 896	2 449		3.09	6.07	7.85	15.58	12.54	4.64	0.71
	Medicare	10 613	22 978	29 369	79 416	58 008	28 889	7 095		2.29	4.97	6.35	17.17	12.54	6.25	1.53
	Ratio	1.00	1.10	1.09	1.49	1.35	1.82	2.90								

FEMALES		0-4	5-14	15-24	25-44	45-64	65-84	85 plus		0-4	5-14	15-24	25-44	45-64	65-84	85 plus
		n	n	n	n	n	n			%	%	%	%	%	%	%
2008	**ERP**	10 852	20 655	27 312	54 312	43 587	16 303	2 640		3.12	5.93	7.84	15.59	12.51	4.68	0.76
	Medicare	11 016	23 068	29 752	82 229	60 163	30 726	7 948		2.30	4.82	6.22	17.18	12.57	6.42	1.66
	Ratio	1.02	1.12	1.09	1.51	1.38	1.88	3.01								
2009	**ERP**	11 008	20 662	27 777	55 307	44 100	16 811	2 795		3.10	5.82	7.83	15.59	12.43	4.74	0.79
	Medicare	11 331	23 099	30 124	84 469	61 988	32 085	8 709		2.30	4.70	6.12	17.17	12.60	6.52	1.77
	Ratio	1.03	1.12	1.08	1.53	1.41	1.91	3.12								
2010	**ERP**	11 451	20 687	28 247	56 521	44 583	17 442	2 975		3.17	5.72	7.81	15.62	12.32	4.82	0.82
	Medicare	11 859	23 305	30 423	86 680	64 003	33 805	9 527		2.34	4.60	6.00	17.10	12.63	6.67	1.88
	Ratio	1.04	1.13	1.08	1.53	1.44	1.94	3.20								
2011	**ERP**	11 620	20 904	28 575	57 566	45 116	18 063	3 145		3.16	5.68	7.77	15.64	12.26	4.91	0.85
	Medicare	12 390	23 801	30 858	89 320	65 986	36 220	10 274		2.36	4.54	5.88	17.02	12.57	6.90	1.96
	Ratio	1.07	1.14	1.08	1.55	1.46	2.01	3.27								
2012	**ERP**	12 157	21 308	28 031	59 412	45 264	19 132	3 263		3.24	5.68	7.47	15.84	12.06	5.10	0.87
	Medicare	12 871	24 316	30 888	91 773	67 259	38 646	11 058		2.38	4.50	5.72	16.98	12.45	7.15	2.05
	Ratio	1.06	1.14	1.10	1.54	1.49	2.02	3.39								
2013	**ERP**	12 648	21 684	27 487	60 596	45 603	20 128	3 438		3.32	5.69	7.22	15.91	11.97	5.28	0.90
	Medicare	13 284	25 036	31 191	94 178	68 686	40 915	11 934		2.39	4.50	5.61	16.93	12.34	7.35	2.14
	Ratio	1.05	1.15	1.13	1.55	1.51	2.03	3.47								

TOTAL PERSONS																	
ERP	**Medicare**	**Ratio**		**ERP**	**Medicare**	**Ratio**		**ERP**	**Medicare**	**Ratio**		**ERP**	**Medicare**	**Ratio**		**ERP**	**Medicare**	**Ratio**
1984				**1985**				**1986**				**1987**				**1988**		
245 112	186 160	0.76		251 389	234 442	0.93		258 596	245 247	0.95		265 477	255 704	0.96		269 568	264 106	0.98
1989				**1990**				**1991**				**1992**				**1993**		
276 432	273 350	0.99		282 211	283 906	1.01		289 320	291 951	1.01		294 887	300 920	1.02		299 753	311 280	1.04
1994				**1995**				**1996**				**1997**				**1998**		
302 194	322 307	1.07		305 838	333 426	1.09		309 629	344 227	1.11		310 533	353 299	1.14		311 532	363 931	1.17
1999				**2000**				**2001**				**2002**				**2003**		
314 171	376 555	1.20		317 235	388 249	1.22		321 538	399 965	1.24		324 627	406 767	1.25		327 357	417 295	1.27
2004				**2005**				**2006**				**2007**				**2008**		
328 940	427 574	1.30		331 399	438 714	1.32		335 170	450 016	1.34		342 644	462 445	1.35		348 368	478 585	1.37
2009				**2010**				**2011**				**2012**				**2013**		
354 785	491 944	1.39		361 766	506 813	1.40		367 985	524 810	1.43		375 183	540 349	1.44		380 914	556 403	1.46

Notes.

1. ERP = estimated resident population; data source: ABS. 3105.0.65.001 Australian Historical Population Statistics, 2014 (for data for years 1984-2011) and 3101.0 Australian Demographic Statistics (for data for years 2012-2013).

2. Ratio = Medicare population/ERP

Appendix 5. Cancer outcomes: crude rates

Sample size, number of people diagnosed, person-years at risk and crude rates by exposure, for males and females separately, allowing for 10-year lag

Cancer diagnosis	Sample size	ARP			Non-ARP		
		n	PY	Crude rate (95% CI)	n	PY	Crude rate (95% CI)
MALES							
Mesothelioma	504 850	7	0.848	8.26 (3.32–17.0)	239	106	2.25 (1.97–2.56)
Other asbestos-associated cancers							
Lung	504 778	25	0.847	29.5 (19.1–43.6)	2430	106	22.9 (22.0–23.8)
Laryngeal	504 840	4	0.848	4.72 (1.29–12.1)	250	106	2.36 (2.07–2.67)
Pharyngeal	504 846	6	0.848	7.08 (2.60–15.4)	286	106	2.69 (2.39–3.03)
Stomach	504 818	5	0.848	5.90 (1.92–13.8)	649	106	6.12 (5.65–6.60)
Colorectal	504 668	54	0.845	63.9 (48.0–83.4)	3734	106	35.3 (34.1–36.4)
Other cancers							
Bladder	504 805	9	0.847	10.6 (4.86–20.2)	822	106	7.75 (7.23–8.30)
Kidney	504 833	11	0.847	13.0 (6.48–23.2)	849	106	8.00 (7.47–8.56)
Melanoma	504 696	46	0.844	54.5 (39.9–72.7)	3590	106	33.9 (32.8–35.1)
Prostate	504 660	121	0.839	144 (120–172)	8087	106	76.6 (74.9–78.3)
FEMALES							
Mesothelioma	529 209	0	0.891	(0–4.14)*	39	112	0.35 (0.25–0.48)
Other asbestos-associated cancers							
Lung	529 173	21	0.890	23.6 (14.6–36.1)	1556	111	14.0 (13.3–14.7)
Ovarian	529 208	10	0.890	11.2 (5.39–20.7)	752	111	6.75 (6.27–7.25)
Laryngeal	529 169	1	0.891	1.12 (0.03–6.26)	32	112	0.29 (0.20–0.41)
Pharyngeal	529 208	1	0.891	1.12 (0.03–6.26)	84	112	0.75 (0.60–0.93)
Stomach	529 191	2	0.891	2.25 (0.27–8.11)	341	112	3.06 (2.74–3.40)
Colorectal	529 057	53	0.888	59.7 (44.7–78.1)	3133	111	28.2 (27.2–29.2)
Other cancers							
Bladder	529 187	2	0.890	2.25 (0.27–8.12)	239	112	2.14 (1.88–2.43)
Kidney	529 196	5	0.891	5.61 (1.82–13.1)	439	111	3.94 (3.58–4.32)
Melanoma	529 058	37	0.885	41.8 (29.4–57.6)	3012	111	27.1 (26.1–28.1)

Notes. ARP=affected residential property
**one-sided 97.5% confidence interval (CI)*
1. PY: Person-years x 100 000. 2. Crude rate: per 100 000 py. 3. Diagnoses are based on ICD-codes: Mesothelioma, C45; Lung–includes bronchus, lung and trachea–C33 and C34; ovarian, C56; laryngeal, C32; pharyngeal, C09-C14; stomach, C16; colorectal, C18-C20; bladder cancer, C67; kidney cancer, C64; melanoma, C43; and prostate cancer, C50.

Appendix 6. Sensitivity analysis: Different lag periods

Total number of observed (O) and expected (E) cases in the exposed and standardised incidence ratios (SIRs) with 95% CI, by sex, for 5-year, 10-year and 15-year lags

Cancer diagnosis	5-year lag		10-year lag (Main analysis)		15-year lag	
	O/E	SIR (95%CI)	O/E	SIR (95%CI)	O/E	SIR (95%CI)
MALES						
Mesothelioma	7/3.21	2.18 (0.88–4.49)	**7/2.75**	**2.54 (1.02–5.24)**	4/2.25	1.78 (0.48–4.55)
Other asbestos-associated cancers						
Lung	27/30.8	0.88 (0.58–1.28)	25/26.2	0.96 (0.62–1.41)	20/21.7	0.92 (0.56–1.42)
Laryngeal	4/3.16	1.27 (0.35–3.24)	4/2.60	1.54 (0.42–3.93)	3/2.17	1.38 (0.28–4.03)
Pharyngeal	6/3.97	1.51 (0.55–3.29)	6/3.21	1.87 (0.69–4.07)	5/2.51	1.99 (0.65–4.65)
Stomach	5/8.14	0.61 (0.20–1.43)	5/6.81	0.73 (0.24–1.71)	2/5.59	0.36 (0.04–1.29)
Colorectal	62/48.7	1.27 (0.98–1.63)	54/40.9	1.32 (0.99–1.72)	**46/33.2**	**1.39 (1.02–1.85)**
Other cancers						
Bladder	10/9.87	1.01 (0.49–1.86)	9/8.37	1.07 (0.49–2.04)	8/6.92	1.16 (0.50–2.28)
Kidney	12/11.5	1.04 (0.54–1.82)	11/9.58	1.15 (0.57–2.05)	10/7.62	1.31 (0.63–2.41)
Melanoma	54/46.3	1.17 (0.88–1.52)	46/37.6	1.23 (0.90–1.63)	37/29.5	1.26 (0.88–1.73)
Prostate	**142/110**	**1.29 (1.09–1.52)**	**121/94.0**	**1.29 (1.07–1.54)**	**100/76.0**	**1.32 (1.07–1.60)**
FEMALES						
Mesothelioma	0/0.47	0.00 (0–7.80)	0/0.39	0.00 (0–9.37)	0/0.32	0.00 (0–11.6)
Other asbestos-associated cancers						
Lung	24/19.0	1.26 (0.81–1.88)	21/16.0	1.31 (0.81–2.01)	17/13.1	1.30 (0.76–2.08)
Ovarian	12/9.51	1.26 (0.65–2.20)	10/7.77	1.29 (0.62–2.37)	8/6.13	1.31 (0.56–2.57)
Laryngeal	1/0.37	2.71 (0.07–15.1)	1/0.31	3.25 (0.08–18.1)	1/0.25	3.93 (0.10–21.9)
Pharyngeal	1/1.16	0.86 (0.02–4.82)	1/0.94	1.07 (0.03–5.95)	1/0.72	1.40 (0.04–7.79)
Stomach	3/3.75	0.80 (0.17–2.34)	2/3.04	0.66 (0.08–2.37)	2/2.46	0.81 (0.10–2.94)
Colorectal	**57/37.0**	**1.54 (1.17–2.00)**	**53/30.7**	**1.73 (1.29–2.26)**	**42/24.9**	**1.69 (1.22–2.28)**
Other cancers						
Bladder	3/2.54	1.18 (0.24–3.45)	2/2.13	0.94 (0.11–3.40)	2/1.73	1.15 (0.14–4.17)
Kidney	6/5.41	1.11 (0.41–2.42)	5/4.48	1.12 (0.36–2.60)	5/3.54	1.41 (0.46–3.29)
Melanoma	50/37.1	1.35 (1.00–1.78)	37/29.4	1.26 (0.89–1.74)	27/22.5	1.20 (0.79–1.75)

*Notes. *one-sided 97.5% confidence interval (CI)*
1. SIR=standardised incidence ratio, which is the rate in ARP compared to rate in non-ARP, standardised for age and period. 2. Diagnoses are based on ICD-codes: Mesothelioma, C45; Lung–includes bronchus, lung and trachea–C33 and C34; ovarian, C56; laryngeal, C32; pharyngeal, C09-C14; stomach, C16; colorectal, C18-C20; bladder cancer, C67; kidney cancer, C64; melanoma, C43; and prostate cancer, C50.

Appendix 7. Sensitivity analysis: 10-year lag applied to all participants

Total number of observed (O) and expected (E) cases in the exposed and SIRs with 95% CI, by sex: main analysis and analysis applying 10-year lag to all participants regardless of start date[1]

Cancer diagnosis	10-year lag, main analysis		10-year lag, no exemptions	
	O/E	SIR (95% CI)	O/ E	SIR (95% CI)
MALES				
Mesothelioma	7/2.75	**2.54 (1.02–5.24)**	7/2.36	**2.97 (1.19–6.12)**
Other asbestos-associated cancers				
Lung	25/26.2	0.96 (0.62–1.41)	23/19.8	1.16 (0.74–1.75)
Laryngeal	4/2.60	1.54 (0.42–3.93)	3/1.75	1.72 (0.35–5.01)
Pharyngeal	6/3.21	1.87 (0.69–4.07)	6/2.64	2.28 (0.84–4.96)
Stomach	5/6.81	0.73 (0.24–1.71)	5/5.22	0.96 (0.31–2.23)
Colorectal	54/40.9	1.32 (0.99–1.72)	47/32.2	**1.46 (1.07–1.94)**
Other cancers				
Bladder	9/8.37	1.07 (0.49–2.04)	9/6.40	1.41 (0.64–2.67)
Kidney	11/9.58	1.15 (0.57–2.05)	8/8.03	1.00 (0.43–1.96)
Melanoma	46/37.6	1.23 (0.90–1.63)	42/30.9	1.36 (0.98–1.84)
Prostate	121/94.0	**1.29 (1.07–1.54)**	105/81.2	**1.29 (1.06–1.57)**
FEMALES				
Mesothelioma	0/0.39	(0-9.37)*	0/0.31	(0–11.8)*
Other asbestos-associated cancers				
Lung	21/16.0	1.31 (0.81–2.01)	18/13.1	1.38 (0.82–2.18)
Ovarian	10/7.77	1.29 (0.62–2.37)	7/6.28	1.12 (0.45–2.30)
Laryngeal	1/0.31	3.25 (0.08–18.1)	1/0.23	4.29 (0.11–23.9)
Pharyngeal	1/0.94	1.07 (0.03–5.95)	0/0.8	(0–4.63)*
Stomach	2/3.04	0.66 (0.08–2.37)	2/2.27	0.88 (0.11–3.19)
Colorectal	53/30.7	**1.73 (1.29–2.26)**	47/24.5	**1.92 (1.41–2.55)**
Other cancers				
Bladder	2/2.13	0.94 (0.11–3.40)	1/1.66	0.60 (0.02–3.36)
Kidney	5/4.48	1.12 (0.36–2.60)	5/3.76	1.33 (0.43–3.10)
Melanoma	37/29.5	1.26 (0.89–1.74)	32/24.1	1.33 (0.91–1.87)

*Notes. *one-sided 97.5% confidence interval (CI)*

1. In the main analysis, the lag was not applied to participants whose earliest Medicare registration was at an ARP address and the registration was before 1985. This was applied in the sensitivity analysis. 2. SIR=standardised incidence ratio, which is the rate in ARP compared to rate in non-ARP, standardised for age and period. 3. Diagnoses are based on ICD-codes: Mesothelioma, C45; Lung–includes bronchus, lung and trachea–C33 and C34; ovarian, C56; laryngeal, C32; pharyngeal, C09-C14; stomach, C16; colorectal, C18-C20; bladder cancer, C67; kidney cancer, C64; melanoma, C43; and prostate cancer, C50.

Appendix 8. Sensitivity analysis: Exclusion of post office box addresses

Total number of observed (O) and expected (E) cases in the exposed and SIRs with 95% CI, by sex: main analysis and analysis excluding participants with post office box addresses[1]

Cancer diagnosis	Main analysis		Excluding participants with post office box addresses	
	O /E	SIR (95% CI)	O/ E	SIR (95% CI)
MALES				
Mesothelioma	7/2.75	**2.54 (1.02–5.24)**	7/3.21	2.18 (0.88–4.50)
Other asbestos-associated cancers				
Lung	25/26.2	0.96 (0.62–1.41)	25/31.3	0.80 (0.52–1.18)
Laryngeal	4/2.60	1.54 (0.42–3.93)	4/3.15	1.27 (0.35–3.25)
Pharyngeal	6/3.21	1.87 (0.69–4.07)	5/3.49	1.43 (0.47–3.34)
Stomach	5/6.81	0.73 (0.24–1.71)	5/8.06	0.62 (0.2–1.45)
Colorectal	54/40.9	1.32 (0.99–1.72)	54/47.5	1.14 (0.85–1.48)
Other cancers				
Bladder	9/8.37	1.07 (0.49–2.04)	8/9.92	0.81 (0.35–1.59)
Kidney	11/9.58	1.15 (0.57–2.05)	11/10.7	1.03 (0.52–1.85)
Melanoma	46/37.6	1.23 (0.90–1.63)	42/40.8	1.03 (0.74–1.39)
Prostate	121/94.0	**1.29 (1.07–1.54)**	118/108	1.10 (0.91–1.31)
FEMALES				
Mesothelioma	0/0.39	(0–9. 37)*	0/0.51	(0–7.24)*
Other asbestos-associated cancers				
Lung	21/16.0	1.31 (0.81–2.01)	21/19.0	1.11 (0.68–1.69)
Ovarian	10/7.77	1.29 (0.62–2.37)	10/8.39	1.19 (0.57–2.19)
Laryngeal	1/0.31	3.25 (0.08–18.1)	1/0.41	2.42 (0.06–13.5)
Pharyngeal	1/0.94	1.07 (0.03–5.95)	1/1.05	0.95 (0.02–5.29)
Stomach	2/3.04	0.66 (0.08–2.37)	2/3.50	0.57 (0.07–2.07)
Colorectal	53/30.7	**1.73 (1.29–2.26)**	52/36.0	**1.44 (1.08–1.89)**
Other cancers				
Bladder	2/2.13	0.94 (0.11–3.40)	2/2.55	0.79 (0.10–2.84)
Kidney	5/4.48	1.12 (0.36–2.60)	5/5.07	0.99 (0.32–2.30)
Melanoma	37/29.5	1.26 (0.89–1.74)	35/31.7	1.10 (0.77–1.53)

*Notes. *one-sided 97.5% confidence interval (CI)*

1. Exclusions: Any participant with a post office box address registered at any time during the study period (1983-2013), unless they had already been classified as exposed at the time of their first post office box address registration. 2. SIR=standardised incidence ratio, which is the rate in ARP compared to rate in non-ARP, standardised for age and period. 3. Diagnoses are based on ICD-codes: Mesothelioma, C45; Lung–includes bronchus, lung and trachea–C33 and C34; ovarian, C56; laryngeal, C32; pharyngeal, C09-C14; stomach, C16; colorectal, C18-C20; bladder cancer, C67; kidney cancer, C64; melanoma, C43; and prostate cancer, C50.

Appendix 9. Sensitivity analysis: Censoring at age 85

Total number of observed (O) and expected (E) cases in the exposed and SIRs with 95% CI, by sex: main analysis and analysis with censoring at age 85 years

Cancer diagnosis	Main analysis		Censoring at age 85	
	O/E	SIR (95% CI)	O/ E	SIR (95% CI)
MALES				
Mesothelioma	7/2.75	**2.54 (1.02–5.24)**	7/2.62	**2.67 (1.07–5.50)**
Other asbestos-associated cancers				
Lung	25/26.2	0.96 (0.62–1.41)	25/25.4	0.99 (0.64–1.45)
Laryngeal	4/2.60	1.54 (0.42–3.93)	3/2.57	1.17 (0.24–3.41)
Pharyngeal	6/3.21	1.87 (0.69–4.07)	5/3.17	1.58 (0.51–3.68)
Stomach	5/6.81	0.73 (0.24–1.71)	5/6.60	0.76 (0.25–1.77)
Colorectal	54/40.9	1.32 (0.99–1.72)	54/39.7	**1.36 (1.02–1.77)**
Other cancers				
Bladder	9/8.37	1.07 (0.49–2.04)	7/7.89	0.89 (0.36–1.83)
Kidney	11/9.58	1.15 (0.57–2.05)	10/9.35	1.07 (0.51–1.97)
Melanoma	46/37.6	1.23 (0.90–1.63)	36/28.8	1.25 (0.92–1.67)
Prostate	121/94.0	**1.29 (1.07–1.54)**	117/92.1	**1.27 (1.05–1.52)**
FEMALES				
Mesothelioma	0/0.39	(0-9. 37)*	0/0.37	(0-10.0)*
Other asbestos-associated cancers				
Lung	21/16.0	1.31 (0.81–2.01)	21/15.4	1.37 (0.85–2.09)
Ovarian	10/7.77	1.29 (0.62–2.37)	10/7.58	1.32 (0.63–2.42)
Laryngeal	1/0.31	3.25 (0.08–18.1)	1/0.30	3.30 (0.08–18.4)
Pharyngeal	1/0.94	1.07 (0.03–5.95)	1/ 0.92	1.09 (0.03–6.09)
Stomach	2/3.04	0.66 (0.08–2.37)	2/2.83	0.71 (0.09–2.55)
Colorectal	53/30.7	**1.73 (1.29–2.26)**	48/29.1	**1.65 (1.22–2.19)**
Other cancers				
Bladder	2/2.13	0.94 (0.11–3.40)	2/1.91	1.05 (0.13–3.79)
Kidney	5/4.48	1.12 (0.36–2.60)	5/4.36	1.15 (0.37–2.68)
Melanoma	37/29.5	1.26 (0.89–1.74)	36/28.8	1.25 (0.88–1.73)

*Notes. *one-sided 97.5% confidence interval (CI)*

1. SIR=standardised incidence ratio, which is the rate in ARP compared to rate in non-ARP, standardised for age and period. 2. Diagnoses are based on ICD-codes: Mesothelioma, C45; Lung–includes bronchus, lung and trachea–C33 and C34; ovarian, C56; laryngeal, C32; pharyngeal, C09-C14; stomach, C16; colorectal, C18-C20; bladder cancer, C67; kidney cancer, C64; melanoma, C43; and prostate cancer, C50.