# Incidence and Mortality from Malignant Mesothelioma 1982-2020 and relationship with asbestos exposure: the Australian Mesothelioma Registry

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**Abstract**

**Objectives:**

Malignant mesothelioma is an uncommon cancer associated with asbestos exposure, predominantly occupational. Asbestos has been banned in Australia since 2003 but mesothelioma has a long latency and incident cases continue to present. The Australian Mesothelioma Registry was incepted to collect systematic data about incidence and mortality alongside asbestos exposure.

**Methods:**

Benefitting from the Australian national system of cancer notification, all incident cases of mesothelioma in all states and territories are fast-tracked and notified regularly. Notified patients are contacted asking for consent to collect exposure information, initially by postal questionnaire and subsequently by telephone interview. Age-standardised annual incidence rates and mortality rates were calculated. Asbestos exposure was categorised as occupational, non-occupational, neither or, both; and as low, or high, probability of exposure.

**Results:**

Mesothelioma incidence appears to have peaked. The age-standardised incidence rates have declined steadily since the early 2000s (peaking in males at 5.9/100,000 and in all-persons at 3.2/100,000), driven by rates in males, who comprise the majority of diagnosed cases. Rates in women have remained fairly stable since that time. Age-standardised mortality rates have followed similar trends. Mesothelioma remains commonest in those aged over 80 years. Nearly all (94%) cases were linked with asbestos exposure (78% occupational in men; 6.8% in women).

**Conclusions:**

With effective control of occupational asbestos use, the decline in age-standardised incidence and death rates has occurred. Incidence rates among women, in whom occupational asbestos exposure is rarely detectable, remain unchanged, pointing to the role of household and /or environmental asbestos exposure.

**Key words: Malignant mesothelioma; asbestos; registry; exposure; incidence; mortality**

**What is already known on this topic**

The majority of cases of malignant mesothelioma occur among men with a history of occupational asbestos exposure. Since asbestos was banned in Australia in 2003, we would anticipate a decline in incident cases and mortality rates.

**What this study adds**

Data from the Australian Mesothelioma Registry show that incidence rates appear to have peaked in the early 2000s among men although they are unchanged in women. Most cases of mesothelioma among men can be associated with historic asbestos exposure. Mortality rates have improved slightly over time.

**How this study might affect research, practice or policy**

Control of occupational asbestos exposure has reduced the cases of mesothelioma amongst men. There has been no change amongst women, reflecting that environmental and household exposure has not been totally eliminated.

### Introduction

Mesothelioma is an uncommon neoplasm typically originating from the mesothelial cells that line serous body cavities, classically the pleura and peritoneum. Exposure to asbestos is implicated in an estimated 86-95% of cases of mesothelioma (1-3) although estimated rates of cases of non-asbestos related mesothelioma vary, likely because of variability in the methodology used for assessing asbestos exposure (4). Despite identification of the principal exposure, the burden caused by this disease remains considerable, with an estimated 23,000 deaths worldwide (95%UR: 22,593-23,615) in 2016 (5-6). Although there have been developments in understanding the aetiology of the disease, including identifying genetic risk factors (7), improvements in diagnosis which permit earlier diagnosis (8) using new biomarkers and a number of clinical trials, the prognosis after diagnosis of mesothelioma remains poor (9-11) with around half of patients dying within a year of diagnosis (12).

The global age-standardised mesothelioma incidence and mortality rates climbed sharply in the 1960s, linked with the vast increase in use of asbestos after World War II. Occupational exposure was particularly high amongst men who were: insulation workers; hazardous materials removal workers; riggers; marine or ship engineers; plumbers; and pipefitters (7). Australia gradually increased the production of asbestos from the late 1880s to the late 1930s but its peak consumption was over 700,000 metric tonnes 1970–1979 (13,14). Australia mined and imported asbestos, which was primarily used in the construction and transport industries because it was durable and resistant to fire and chemicals (15). Asbestos-related regulatory controls were first introduced in Australia in the 1960s but have been significantly tightened over time. Asbestos-containing materials (ACMs) have been banned in Australia since December 2003, and it is now illegal to make, use or import it from another country. However, a large amount of asbestos still remains in older structures and products, potentially exposing workers and/or the public to asbestos if ACMs are disturbed without appropriate control measures. Exposure to asbestos can also occur when naturally occurring geological occurrences of asbestiform minerals are disturbed by building and development works (7).

The Australian Mesothelioma Registry (AMR) was set up in 2011, funded by Safe Work Australia, with specific objectives to: (1) accurately measure the incidence of mesothelioma in the Australian population (total population 25.7 million) for the purposes of monitoring changes and identifying groups most at risk; (2) enable periodic assessment of mesothelioma survival to ascertain whether changes in care are resulting in measurable improvements in survival; (3) document the asbestos and/or other exposure(s) amongst people newly diagnosed with mesothelioma as a form of surveillance for new or changing sources of exposure to asbestos; (4) provide a resource for research into the causes and control of mesothelioma; and (5) to inform the development of policies to best deal with asbestos remaining in the environment. The AMR builds on the foundation of earlier attempts to collect detailed information on all mesothelioma cases in Australia – the Australian Mesothelioma Program, which ran from 1979 to 1985, and the Australian Mesothelioma Register, which ran from 1986 until the mid-2000s (16,17).

This paper describes the AMR methodology and provides information about the age-standardised incidence rates for mesothelioma 1982-2020, and age-standardised mortality rates 1997-2021 and occupational and non-occupational asbestos exposure amongst those diagnosed with mesothelioma 2010-2021.

### Methods

The AMR was established in 2011 by SafeWork Australia, managed initially by Cancer Institute New South Wales and subsequently by the Australian Institute of Health and Welfare (AIHW) since 2017. In Australia, all cases of cancer are notifiable (with the exception of common non-melanoma skin cancers) and data on these cancers are provided annually by each state and territory for inclusion in the Australian Cancer Database. All deaths are registered to the National Death Index and the AIHW holds both of these resources, providing complete national coverage of deaths and notifiable cancers since 1 January 1982.

For the AMR, all jurisdictions fast-track all new cases of mesothelioma, processing and coding them as quickly as possible. Each jurisdiction provides case notifications to the AMR regularly, including patient demographics, diagnosis and death information. After notification of each new case, AMR staff attempt to contact every notified individual to ask for informed consent for them to provide additional asbestos exposure information through a postal questionnaire and telephone interview. The AMR does not collect exposure information from next-of-kin in the event that the patient is too unwell to consent or has died. The postal questionnaire collects information about places of residence and occupational history, as well as any family history of mesothelioma. The place of residence and occupational information are systematically compiled through an online assessment tool called the Occupational Integrated Database Exposure Assessment System (OccIDEAS) (18). Telephone interviews are subsequently carried out with specific questions assigned to each individual based on their responses to the postal questionnaire in order to accurately assess their likelihood (possible or probable) of having been exposed to asbestos (occupational / non-occupational /both) in their lifetime and the likely level of exposure (high/medium/low).

Incidence rates for mesothelioma have been calculated using AMR data since July 2010. However, mesothelioma data are also available from the Australian Cancer Database since 1982. Both of these data sources have been used to estimate annualised incidence rates (number of cases per year) by age and gender for the period 1982-2020. Annual mortality rates (number of deaths per year) due to mesothelioma have been calculated for 1997-2020 by gender. For a sample of participants recruited between 1 July 2010 and 28 February 2019, logistic regression was used to explore the relationship between response to the exposure assessment and: age at diagnosis (categorised as ≤69 years; 70-79 years and 80 years and over); gender; country of birth (Australia; mainly English speaking; all other countries); Aboriginal and/or Torres Strait Islander (yes/no); time from diagnosis to notification to AMR; state/territory of notification; season of diagnosis; laterality, morphology and topography of mesothelioma. Those independent factors that were statistically significant predictors were then taken forwards to a final model. Goodness of fit for this final model was established using the Hosmer-Lemeshow Chi squared test (19), applied with 8 degrees of freedom. Non-parametric significance testing was used to determine whether the distribution of exposure assessment variables differed by the same factors.

### Results

From 1982-2020, a diagnosis of, or death from, mesothelioma in the AMR was five times more common among men than among women. The disease was strongly age-associated, with median age at diagnosis of 75 years.

**Age-standardised rates of new diagnosis and death from mesothelioma**

The age-standardised rates of new diagnoses of mesothelioma from the commencement of data collection in 1982 until 2020 are shown in Figure 1. Among men, the age-standardised incidence rate increased between 1982-2003 (2.3 to 5.9 cases per 100,000), notwithstanding yearly fluctuations. Among women, the rates increased over the same period (from 0.3 to 1.0 cases per 100,000 population), with overall rates (combined for men and women) peaking at 3.2 cases per 100,000 population. After peaking in 2003, the incidence rates in males and all-persons have slowly decreased. As men were diagnosed with mesothelioma much more commonly than women, the overall reduction in incidence of new cases has mostly been driven by a reduction of new diagnoses amongst men. Age-standardised incidence rates amongst women appeared fairly stable throughout.

Age-standardised mortality rates (per 100,000 population) from mesothelioma in the AMR are shown in Figure 2 for the period 1997-2020. The age-standardised mesothelioma mortality rates fluctuated between 2.1 and 2.7 deaths per 100,000 population, peaking in the early 2000s. Mortality rates for men peaked at about 5.0 deaths per 100,000 population in 2001 and 2004 and have fallen fairly steadily since then. Rates for females fluctuated around 0.8 deaths per 100,000 throughout.

Whilst the age-standardised rates of new cases and deaths from mesothelioma peaked in the early 2000s, the total number of new diagnoses (Figure 3) by year and gender, continued to increase at least until 2017; there may have been a reduction since then, but this is uncertain at this stage as full reporting may take several years after the relevant year (Figure 3).

**Mesothelioma survival**

Comparison of age-adjusted mesothelioma survival rates for 1988-92 to 2013-17 suggests that there has been a gradual improvement in rates of survival at 1-year, 3-years and 5-years between the two periods. One-year survival showed the greatest improvement (from 30% to 46%) (Figure 4).

**Rates of completion of exposure assessment**

Between 1 July 2010 and 28 February 2019, 6124 new cases were notified to the registry amongst whom 874 completed the exposure assessment (response rate 14.3%). Respondents and non-respondents were compared. No variation in response was seen by age or gender; reported Aboriginal and/or Torres Strait Islander status; state/territory; season; or tumour descriptors. However, responses were more likely when the delay between diagnosis and notification to AMR was shortest (OR 5.5, 95% confidence interval (CI) 4.1-7.5 for shortest duration vs longest duration). Response rates were better from people born in Australia or English-speaking countries (compared with people born in other countries: OR 1.9, 95% CI 1.5-2.4 and OR 1.4, 95% CI 1.0-1.9 respectively). Finally, responses were more likely among those diagnosed younger: compared with those aged over 80 years, those aged ≤69 years: OR 1.9, 95% CI 1.5-2.3 and those aged 70-79 years: (OR 1.7, 95% CI 1.4-2.1). Whilst these factors were associated with likelihood of completion of exposure information, non-parametric significance testing showed that neither the resultant category of asbestos exposure (occupational, non-occupational, both, neither) nor category of probability of asbestos exposure (possible; probable -low; probable-medium; probable-high) differed by those factors.

### Asbestos exposure among people with mesothelioma

Participation rates in the asbestos exposure assessment remained stable at 14-15% throughout but dipped slightly (12%) during the COVID-19 pandemic. At the end of 2020, 1253 people (1000 men and 253 women) in the AMR had consented to participate in the voluntary asbestos exposure assessments. Of these, 1,098 (867 men and 231 women) completed both the postal questionnaire and telephone interview. Based on the information provided, 1028 (94%) were assessed as having possible or probable exposure to asbestos. The majority of men (78.5%) had identified occupational exposure. Most of these (63.4% of all included men), also had non-occupational exposure. In contrast, amongst women, only a tiny proportion (6.8%) of exposures detected were occupational (Table 1).

### Discussion

The AMR was established in 2010 and has enabled identification of new cases and deaths from mesothelioma in Australia, as well as their association with asbestos exposure, since then. The registry data suggest that the age-standardised incidence rates and mortality rates peaked in the early 2000s and have declined since then. However, the majority of mesothelioma cases have occurred amongst men throughout the observation period and it is the reduction of age-standardised cases amongst men that has driven the overall decline; there is less indication of any change of incidence or death rates amongst women. It is important to note however that diagnosing mesothelioma amongst women has always been difficult and was even in the past controversial for the peritoneal type, because of the difficulty in distinguishing it from ovarian tumours histopathologically. Despite the age-standardised rates reducing, the overall numbers of new diagnoses continued to climb after the early 2000s but may have peaked. In 2020, the age-specific mesothelioma incidence rates increased with age for men up until age 80-84 years and for women until aged 85 and over. Survival rates after diagnosis remain poor (<50% after 1-year) but there has been a small improvement (particularly in 1-year survival) over the past two decades, perhaps as a result of improved treatment, particularly for the non-pleural cases of mesothelioma and amongst carriers of the BAP1 and other germline mutations, which have a much-improved prognosis (20). The majority of cases (94%) were associated with identifiable asbestos exposure, with 78.3% of men having had possible or probable occupational exposure. However, only a small proportion (6.8%) of the cases amongst women could be attributed to occupational asbestos exposure.

These data appear to be consistent with the hypothesis that the majority of incident cases notified to the AMR since 2010 were probably related to occupational exposure which occurred before current occupational asbestos regulations and practices came into effect. There are three reasons for this: firstly, mesothelioma is known to have a long latency period from exposure to development of the disease (typically 30-50 years) (21). Secondly, in Australia, as in many other developed countries, life expectancy is increasing, so that, even if incidence rates were declining, the overall number of new cases and deaths per year would be expected to remain stable, or even increase somewhat, because mesothelioma is primarily a cancer of older people and people are surviving long enough to present with the disease. Thirdly, there have been a relatively small and steady number of cases of mesothelioma diagnosed amongst women throughout this 30-year period, very few of which (6.8%) could be associated with occupational exposure. In contrast, the majority of cases amongst men could be linked with occupational asbestos exposure which typically is of higher frequency, concentration and duration than non-occupational exposure. Thus, the dose incurred by men would be effectively higher than that by women. Therefore, the fact that incidence and death rates have reduced for mesothelioma in men but not women would appear to be most likely explained by better control of occupational asbestos exposure.

This is not the first, or only, mesothelioma surveillance programme or registry: Italy (22), France (23), Germany (24), UK, and New Zealand have all established registries and Canada and the USA have been considering doing so (25). The AMR has been linked with mortality data from inception and most other national registries are likewise linked to mortality data or planning to include such linkage. Some other countries have incorporated patient interviews to better understand exposures, including France, Italy, New Zealand and the surveillance system in South Korea (26,27). Like many other registries, the AMR has relatively limited information about treatment, quality of life, and other patient-centred outcomes including symptoms and pain management. The lack of treatment and outcome information is important, as there is evidence that many patients do not receive recommended treatment (28) and that participation rates in clinical trials for mesothelioma are low (29). Given that a mechanism now exists for more rapid identification and notification of new cases through AMR, the registry could potentially provide a means by which to collect more data about treatment. Certainly, for another uncommon condition with a short survival period after diagnosis (Amyotrophic Lateral Sclerosis (ALS)), establishment of a national registry in the US has provided a mechanism by which to improve recruitment to trials (30). The AMR provides access to both de-identified aggregate data and more detailed unit record data for purposes of research or audit related to mesothelioma (31).

AMR has some limitations. One limitation is the dependence of the registry for notifications from the states and territories, which typically results in delays in reporting. Despite the fast tracking of notifications, the AIHW has found that most notifications are received in the year after diagnosis, partly because of time taken between diagnosis and notification to cancer registries and AMR. Each jurisdiction has its own system for collating mesothelioma cases, with each of the state and territory cancer registries submitting notifications to the AMR on a regular basis. Secondly, notification is dependent upon correct and accurate diagnosis but mesothelioma is challenging to diagnose, for a number of reasons. Firstly, the symptoms are non-specific and common to many other conditions. Consequently, diagnosis may rely on the results of a number of clinical investigations, including clinical examinations, imaging and histo-pathological diagnosis (32). Even with good biopsy material, mesothelioma can be difficult to diagnose, especially the sarcomatoid subtype or mesothelioma arising in unusual anatomical locations (33-35). Moreover, diagnostic and treatment practices for mesothelioma are recognised not to be equally distributed across Australia (31) and the most recent diagnosis and treatment guidelines expired in 2018 so that there are currently no accepted Australian gold standard diagnostic criteria for clinicians. If a mesothelioma diagnosis is uncertain for any reason, the AMR is not notified and the case remains unrecorded, until the diagnosis is confirmed.

Consent for participation in the exposure assessments is obtained for only a relatively small proportion (15%) of patients in the registry. As described above, there is potential for both a delay in diagnosis and subsequent delay in notification to the AMR. Consequently, in some cases, by the time of notification, the individual may be too unwell to complete a questionnaire or interview, or may have died. Moreover, it cannot be ruled out that there is a participation bias such that people who are actively pursuing legal redress are more likely to choose to not participate, perhaps because of advice they receive from legal representatives. Certainly, anecdotally, the team have been made aware by patient advocacy groups that some lawyers advise their clients not to answer questions about jobs or asbestos exposure to any other party, for fear of being detrimental to their legal claim. Counter to this, mesothelioma patients who are pursuing a claim for redress may be better informed in reporting their jobs and exposures relating to asbestos as a result of their legal claim, which would tend to bias the findings of exposure assessments towards a greater proportion of occupational asbestos exposure. It is important to acknowledge that a proportion of non-participants may be people who were not born in Australia or do not speak English as their first language. It is recognised that migrant workers in particular are more likely to be employed in industrial settings and doing high-risk jobs and therefore their non-participation may result in an under-estimation of actual occupational exposure. Additionally, given the small number of cases of mesothelioma among women, this low participation rate in the exposure assessment may have created more scope for over- or under-estiamtion of the occupational exposure to asbestos amongst women. Ideally, exposure information would be collected for all participants. Therefore, in order to comprehensively collect exposure data, enrolment closer to the time of diagnosis would be preferable, maximising the capture of new cases and optimising coverage of new patients and supported by a simplified consent process. The AMR facilitates participation by providing an option for patients to self-notify via the AMR website; disseminating brochures to patients, lawyers and healthcare professionals about the registry and its aims; and working with healthcare professionals who treat mesothelioma (specialist nurses; advocacy organisations) to increase their awareness and understanding of the AMR.

In summary, the AMR shows that incidence of, and deaths from, mesothelioma peaked in Australia in the early 2000s, probably as a result of restrictions on occupational asbestos use from the 1980s. However, there is no obvious change in mesothelioma rates amongst women and non-occupational asbestos exposure appears the most likely explanation.

More information on the AMR is available at <[www.mesothelioma-australia.com/home](http://www.mesothelioma-australia.com/home)>. The report *Mesothelioma in Australia 2019* and previous annual reports are available at <[www.mesothelioma-australia.com/publications-and-data/publications](http://www.mesothelioma-australia.com/publications-and-data/publications)>. People diagnosed with mesothelioma can choose to self-notify by contacting the AMR via email at <amr@aihw.gov.au> or via the toll-free information line on 1800 378 861.

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**Contributorship**

MS, GB, and EM incepted the AMR with colleagues at the AIHW. GB and EM carry out analysis of all exposure assessments. FB, KT and TD were founder members of the Scientific Advisory Board, chaired by TD. The idea for this paper was conceived by all contributors. KWB produced the first draft and all co-authors commented on the draft and approved it for submission. Data analyses were carried out by AIHW staff.

**Competing interests**

All authors confirm that they have no competing interests to declare.

**Data Sharing/data availability**

Data from the AMR are held by the Australian Institute for Health and Welfare. Applications for use of these data would need to be made to this body.

**Ethics approval statement**

Ethical approval for the Australian Mesothelioma registry was received from the AIHW (Ref: EO2017/4/387) and the Monash Research Ethics Committee (Ref:1792).

**Table 1 Summary of number of cases diagnosed 1982-2020 and diagnostic characteristics of those diagnosed between 1/7/2010 and 31/12/2020**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Men****No (%)** | **Women****No (%)** | **Total****No (%)** |
| Total number of mesothelioma cases 1982-2020 | 16456 | 3384 | 19840 |
| Total number of cases 1982-1999 | 4823 | 746 | 5569 |
| Total number of cases 2000-2020 | 11633 | 2638 | 14271 |
|  |  |  |  |
| **Total number of cases July 2010- December 2020** | **6328** | **1498** | **7826** |
| Number of cases by age category |  |  |  |
| <54 years | 169 (2.7) | 102 (6.8) | 271 (3.5) |
| 55-59 years | 231 (3.7) | 78 (5.2) | 309 (3.9) |
| 60-64 years | 470 (7.4) | 145 (9.7) | 615 (7.9) |
| 65-69 years | 889 (14.0) | 218 (14.6) | 1107 (14.1) |
| 70-74 years | 1215 (19.2) | 239 (16.0) | 1454 (18.6) |
| 75-79 years | 1276 (20.2) | 243 (16.2) | 1519 (19.4) |
| * 1. years
 | 1293 (20.4) | 266 (17.8) | 1559 (19.9) |
| >85 years | 785 (12.4) | 207 (13.8) | 992 (12.7) |
| Number of cases by topographic site |  |  |  |
| Pleura NOS | 5994 (94.7) | 1341 (89.5) | 7335 (93.7) |
| Peritoneum NOS | 212 (3.4) | 109 (7.3) | 321 (4.1) |
| Specific parts of the peritoneum | 73 (1.2) | 37 (2.5) | 110 (1.4) |
| Other /unknown primary site | 15 (0.2) | 3 (0.2) | 18 (0.2) |
| Tunica vaginalis | 15 (0.2) | - | 15 (0.2) |
| Pericardium | 7 (0.1) | 4 (0.3) | 11 (0.1) |
| Overlapping lesion of the retroperitoneum | 6 (0.1) | 2 (0.1) | 8 (0.1) |
| Mediastinum NOS | 5 (0.1) | 2 (0.1) | 7 (0.1) |
| Malignant neoplasm of retroperitoneum and peritoneum | 1 (0.0) | 0 (0.0) | 1 (0.0) |
| Morphology |  |  |  |
| Epithelioid mesothelioma | 2893 (45.7) | 824 (55.0) | 3717 (47.5) |
| Mesothelioma malignant | 1812 (28.6) | 436 (29.1) | 2248 (28.7) |
| Fibrous mesothelioma | 930 (14.7) | 139 (9.3) | 1069 (13.7) |
| Biphasic mesothelioma | 693 (11.0) | 99 (6.6) | 792 (10.1) |
| Laterality |  |  |  |
| Right | 2679 (42.3) | 521 (34.8) | 3200 (40.9) |
| Left | 1667 (26.3) | 408 (27.2) | 2075 (26.5) |
| Bilateral | 11 (0.2) | 1 (0.1) | 12 (0.2) |
| N/A | 259 (4.1) | 112 (7.5) | 371 (4.7) |
| Unknown | 1712 (27.1) | 456 (30.4) | 2168 (27.7) |
| **EXPOSURE TO ASBESTOS** |  |  |  |
| Occupational exposure only | 124 (15.1) | 1 (0.5) | 125 (12.2) |
| Non-occupational exposure only | 177 (21.5) | 191 (93.2) | 368 (35.8) |
| Both occupational and non-occupational exposure | 522 (63.4) | 13 (6.3) | 535 (52.0) |
| **Total** | **823 (100)** | **205 (100)** | **1028 (100)** |

Note: Amongst the 1098 participants with information about asbestos exposure, 70 (6.4%) (44 men and 26 women) were assessed as having neither occupational nor non-occupational exposure. Although it was not possible to identify asbestos exposure among these participants, this should not be taken to mean that these participants have never been exposed to asbestos; rather it means that no evidence of above background exposure was obtained by the exposure methods used.

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