Original Article

The epidemic of malignant mesothelioma in China: a prediction of incidence during 2016–2030

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Background: Malignant mesothelioma is an invasive cancer with a poor prognosis. The crude incidence rate of malignant mesothelioma in China increased throughout 2000 to 2013, which attracted attention. In order to predict the incidence trend of malignant mesothelioma in China, a Bayesian age-period-cohort (APC) prediction model was constructed using publicly available data from the National Cancer Registration Network.

Methods: Based on the annual reports of the national cancer registration from 2005 to 2015, the incidence trend of malignant mesothelioma from 2016 to 2030 in China was forecast using the APC Modeling and Prediction package from the Institute of Biomedical Engineering, London.

Results: The crude incidence rates of malignant mesothelioma decreased from 2.2 per one million person-years in 2005 to 1.6 per one million person-years in 2015. The incidence rates remained stable over the 11-year time period after age standardization. Aging was found to have a dominant effect on the trends. The Bayesian APC model showed that the crude incidence rates would increase from 1.4 per one million person-years in 2016 to 1.9 per one million person-years in 2030, and the estimated number of new incident cases would increase to 2,775 in 2030. The age-standardized incidence rate (ASR) remained steady.

Conclusions: In the future decade, the incidence of malignant mesothelioma may increase, but the ASR will remain stable. Considering its high degree of malignancy, malignant mesothelioma still needs to be taken seriously.

Keywords: Malignant mesothelioma; incidence; trend; prediction model

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Introduction

Malignant mesothelioma is an invasive cancer with a poor prognosis. Depending on the tumor location, two categories comprise most of the classifications: malignant pleural mesothelioma and malignant peritoneal mesothelioma, between which the former accounts for the majority of cases. The crude incidence rate of malignant mesothelioma in China increased gradually during 2000 to 2013, and it was reported to be 1.5 per one million person-years in 2013, with 1.67 and 1.4 per one million person-years in males and females diagnosed, respectively (1). However, there have been no other recent reports on the incidence rate of this malignancy in China (2-4).

Reports have shown that the incidence of malignant mesothelioma may be correlated with exposure to asbestos or other carcinogenic mineral fibers (5,6). Brazil, Russia, India, and China cumulatively consumed about 1.37 million tons of asbestos in 2016, accounting for nearly 80% of the global total; after India, China is the world's second-largest consumer and producer of asbestos (7,8). The above data raised public health concerns about whether the incidence of malignant mesothelioma in China would increase (1). Thus, predicting the incidence trend of malignant mesothelioma in China will serve as an early warning and attract more attention to this disease.

The past few decades have witnessed advances in analyzing and predicting a disease trend. Many models, such as age models, age-period (AP) models, age-period-cohort (APC) models, and power models, have been widely used in the literature to describe disease trends in populations. Of these models, Bayesian APC modeling was used in some studies to analyze and predict the occurrence of lung cancer in China (9,10). Therefore, to help control malignant mesothelioma, this study used Bayesian APC modeling and publicly available data to predict its incidence trend from 2016 to 2030. We present the following article in accordance with the STROBE reporting checklist (available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-22-233/rc).

Methods

Study subjects

The National Cancer Registration Network served as the source of cases meeting the requirements of completeness and quality for data collection (see Table S1). By the end of 2015, China had 501 cancer registries, and 368 registries' data qualified for the final analysis, covering a population of about 300 million people (11). Data cleansing and quality control continued after collection from the cancer registrations. Invasive cases of malignant mesothelioma (ICD10: C45) were extracted and analyzed from the overall annual report (12). Given that malignant mesothelioma is rarer than other tumors, all cancer registries' incidence case and rate data from 2005 to 2015 were extracted. Detailed variables were collected for each case, including the particular year and patient age at diagnosis and gender. Population census data for estimating the future incidence rates during 2016 to 2030 were based on China's projected population from World Population Prospects 2019 (https://population.un.org/). The cases were divided into 5 age groups: 40 years or younger, 40 to 49 years, 50 to 59 years, 60 to 69 years, and 70 years or older. The calculation of age-standardized incidence rates (ASR) was based on China's population structure in 2000 and 2015 and Segi's population expressed per 100,000 persons (see Table S2). The study was conducted in accordance with the Declaration of helsinki (as revised in 2013).

Statistical analysis

The crude incidence rate of malignant mesothelioma in 2030 was projected for each age group by using the Bayesian APC method. The traditional APC model can be formulated as:

$$\begin{aligned} y_{ij} &\sim B\left(n_{ij}, p_{ij}\right) \\ n_{ij} &= \log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \mu + \theta_i + \Phi_j + \Psi_k \end{aligned} \quad [1]$$

The logit of the incidence probability consists of an intercept μ, age effect θ*i*, period effect Φ*j*, and cohort effect ψ*k*. The Bayesian hierarchical approach uses Gaussian random walk (RW) priors of different orders for the APC parameters of θ, ϕ, and ψ (9). It combines prior knowledge with observed data to derive a posterior distribution. The RW1 prior was used to predict the malignant mesothelioma incidence rate. This model was conducted in the software package Bayesian APC Modeling and Prediction package (BAMP v.1.3.0; Institute of Biomedical Engineering, Imperial College, London, UK) (9). Markov chain Monte Carlo simulations were run for 1,010,000 iterations, with the initial 10,000 iterations used as burn-in to minimize the effects of initial values. The projected rates and 95% confidence intervals (CIs; using 2.5% and 97.5% quantile

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of the 1,000,000 iterated results) were obtained through 1,000,000 iterations of model simulations. The posterior and predictive deviance information criterion (DIC value) of the model were used as a measure of goodness of fit (13).

Results

As shown in *Table 1*, the crude incidence rates of all cancer registries in China were 2.2, 1.9, and 1.6 per one million person-years in 2005, 2010, and 2015, respectively. Both males and females had fluctuating trends ranging from 2.6 to 1.8 per one million person-years for males and from 1.8 to 1.5 per one million person-years for females during 2005–2015. The ASR China and ASR World remained relatively stable values.

Bayesian APC model

The full three-factor APC model was superior to either of the two-factor models (AP or AC). The DIC of the APC model was 74.01, indicating a better fit than the other sub-models (79.13 for AC and 75.61 for AP). Therefore, the APC model was adopted to predict the incidence rate of malignant mesothelioma.

The observed crude incidence rates of malignant mesothelioma, aggregated into each 1-year period and 10-year age group, are plotted in *Figure 1*. The group 40 years or younger was excluded because it lacked a sufficient number of cases. The effects of age, period, and cohort were within a comparable range, allowing direct comparison of the slopes of the effects. This may be due to malignant mesothelioma is a rare cancer, so the sample size was not enough to distinguish the influencing factors of the age, period, and cohort. However, the APC model was retained to predict incidence because the Bayesian paradigm has provided useful measures of the uncertainty associated with malignant mesothelioma in the past (14). Furthermore, considering the difference of gender distribution of malignancy, the crude incidence and the numbers of cases stratified by gender were predicted using the Bayesian APC model.

Predicted incidence and numbers of cases of malignant mesothelioma

The predicted versus actual incidence cases and rate of malignant mesothelioma from 2005 to 2015 in China were showed in Table S3. The predicted crude incidence rates of malignant mesothelioma by gender and age groups from 2016 to 2030 are shown in *Table 2*. The crude incidence rate of the age group of people younger than 40 years will be less than 1.0 per one million person-years. With the increase of age (by 10-year age groups), the incidence rate will increase gradually from 0.1 to 7.0 per one million person-years. *Figure 2* shows the actual and predicted crude incidence rates by gender and age groups from 2005 to 2015 and from 2016 to 2030. The crude incidence rates and ASR will remain stable in all subgroups from 2016 to 2030. On the basis of the predicted ASR, the numbers of new malignant mesothelioma cases by gender were predicted for the period 2016 to 2030. As demonstrated in *Table 3*, by the year 2030, the number of cases in China will reach 2,775, including 1,554 male patients.

Discussion

Based on the national cancer registry annual reports of China, the trend in the incidence of malignant mesothelioma was analyzed over an 11-year period from 2005 to 2015. The results showed a wavelike decrease of change in the incidence rate during this period. Although China was still one of the countries with the largest asbestos consumption in the world at that time (7,8), the decreasing trend of the incidence rate of malignant mesothelioma may be due to the improvements in the working and living environment in China, which drastically diminished people's exposure to asbestos. The results support this conclusion that different age groups had a similar downward trend in the incidence rate, which indicates that the incidence rate had little correlation with asbestos exposure and its incubation period. In recent years, some studies had found that other mineral fibers, such as erionite, present in the environment can cause mesothelioma (15,16). Even if these natural exposures are not heavy exposures, they may play a role in the interaction between genes and the environment in causing mesothelioma (17). It is now accepted that about 10–12% of mesotheliomas are caused by germline mutations of *BAP1* and other genes (18). Patients with germline BAP1 mutations have a better prognosis, these mesotheliomas is less aggressive, as found by the low-grade histology of most of them (19). Genetic testing for mesothelioma has been gradually recommended in China, especially for patients without asbestos exposure and younger age individuals (20). Mesothelioma also occurs in patients with no evidence of asbestos exposure in China, and there are some areas in China where there is a local

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Table 1 Incidence cases and rate of malignant mesothelioma from 2005 to 2015 in China

Category	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Male											
Number of cases, n	72	83	66	77	111	137	128	215	199	268	285
Crude rate, /10^6	2.6	2.8	2.2	2.3	2.6	2.2	1.7	2.1	1.7	1.8	1.8
ASR[a] China 2000[b], /10^6	1.4	1.5	1.2	1.2	1.3	1.5	1.2	1.5	1.2	1.2	1.1
ASR China 2015[c], /10^6	2.7	2.6	2.4	2.3	2.3	2.2	1.8	2.0	1.7	1.7	1.6
ASR World[d], /10^6	1.9	2.0	1.5	1.5	1.7	1.5	1.2	1.5	1.2	1.2	1.1
Female											
Number of cases, n	50	57	51	70	81	98	104	178	152	188	231
Crude rate, /10^6	1.8	1.9	1.7	2.1	1.9	1.6	1.4	1.8	1.4	1.3	1.5
ASR China 2000, /10^6	0.9	0.9	0.9	1.1	1.0	1.1	1.0	1.2	0.9	0.8	0.9
ASR China 2015, /10^6	1.7	1.8	1.7	1.7	1.7	1.5	1.4	1.5	1.3	1.2	1.3
ASR World, /10^6	1.3	1.2	1.1	1.3	1.2	1.0	0.9	1.2	0.9	0.8	0.9
Both sexes											
Number of cases, n	122	140	117	147	192	235	232	393	351	456	516
Crude rate, /10^6	2.2	2.4	2.0	2.2	2.2	1.9	1.6	2.0	1.5	1.6	1.6
ASR China 2000, /10^6	1.2	1.2	1.0	1.1	1.2	1.3	1.1	1.3	1.0	1.0	1.0
ASR China 2015, /10^6	2.2	2.2	2.0	2.0	2.0	1.8	1.6	1.8	1.5	1.5	1.4
ASR World, /10^6	1.6	1.6	1.3	1.4	1.5	1.2	1.0	1.3	1.0	1.0	1.0

[a], ASR (units: person-years); [b], age standardized incidence rates was based on the China population structure in 2000; [c], age standardized incidence rates was based on the China population structure in 2015; [d], age standardized incidence rates was based on Segi's population expressed per 100,000 persons. ASR, age-standardized rate.

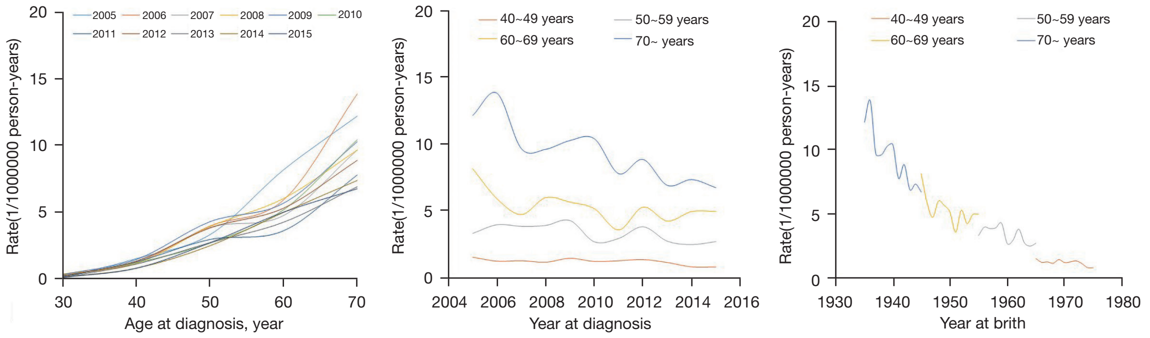

Figure 1 Incidence of malignant mesothelioma per 100,000 person-years by age, year and birth cohort.

epidemic of peritoneal mesothelioma not linked to asbestos exposure (21,22). Therefore, estimates of the incidence of mesothelioma cannot be based only on asbestos exposure.

In addition, in the past few years, there has been no complete and accurate data available on the production and import of asbestos and other mineral fibers by year in China. Insufficient data may lead to incorrect prediction results. On account of the above-mentioned considerations, this study only used the previous trend changes in the incidence of malignant mesothelioma to predict its future

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Table 2 Predicted incidence rates of malignant mesothelioma in China (/10^6 person-years)

Category	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Male															
<40 (95% CI)	0.1 (0.1–0.2)	0.1 (0.1–0.2)	0.1 (0.1–0.2)	0.1 (0.1–0.3)	0.1 (0–0.3)	0.1 (0–0.3)	0.1 (0–0.3)	0.1 (0–0.3)	0.1 (0–0.3)	0.1 (0–0.3)	0.1 (0–0.4)	0.1 (0–0.4)	0.1 (0–0.4)	0.1 (0–0.4)	0.1 (0–0.4)
40~ (95% CI)	0.9 (0.5–1.4)	0.9 (0.5–1.5)	0.9 (0.5–1.6)	0.9 (0.5–1.7)	0.9 (0.4–1.7)	0.9 (0.4–1.8)	0.9 (0.4–1.8)	0.9 (0.4–1.9)	0.8 (0.3–2.0)	0.8 (0.3–2.0)	0.8 (0.3–2.1)	0.8 (0.3–2.1)	0.9 (0.3–2.3)	0.8 (0.3–2.2)	0.9 (0.3–2.3)
50~ (95% CI)	2.9 (1.9–4.3)	2.9 (1.7–4.7)	2.9 (1.6–4.7)	2.9 (1.6–5.2)	2.9 (1.5–5.3)	2.9 (1.4–5.4)	2.9 (1.4–5.8)	2.8 (1.3–5.9)	2.7 (1.2–5.8)	2.7 (1.1–6.1)	2.7 (1.1–6.5)	2.7 (1.1–6.3)	2.7 (1.0–7.0)	2.7 (1.0–6.8)	2.6 (0.9–7.0)
60~ (95% CI)	5.0 (3.3–7.7)	5.1 (3.1–8.2)	5.1 (3.0–8.6)	5.1 (2.8–9.4)	5.1 (2.7–9.1)	5.1 (2.7–9.6)	5.1 (2.6–9.7)	5.0 (2.5–10.4)	4.9 (2.3–10.7)	4.9 (2.2–11.7)	4.9 (2.3–12.0)	4.8 (2.1–12.1)	4.9 (2.0–12.2)	4.9 (1.9–12.9)	4.8 (1.9–13.1)
70~ (95% CI)	8.9 (5.8–13.4)	8.9 (5.4–13.9)	8.8 (5.0–14.1)	8.7 (5.0–15.1)	8.7 (4.4–15.9)	8.6 (4.4–16.6)	8.6 (4.3–17.3)	8.8 (4.2–18.1)	8.9 (4.1–19.2)	8.8 (4.1–21.3)	8.8 (4.0–22.3)	8.9 (3.8–22.4)	9.0 (3.8–23.7)	9.0 (3.7–23.5)	9.0 (3.7–24.3)
Sub-total (95% CI)	1.5 (1.0–2.4)	1.6 (0.9–2.5)	1.6 (0.9–2.7)	1.7 (0.9–3.0)	1.7 (0.8–3.1)	1.7 (0.9–3.3)	1.8 (0.8–3.5)	1.8 (0.8–3.8)	1.8 (0.8–4.0)	1.9 (0.8–4.4)	1.9 (0.8–4.7)	2.0 (0.8–4.9)	2.0 (0.8–5.2)	2.1 (0.8–5.4)	2.1 (0.8–5.6)
ASR[a] China 2000[b]	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
ASR China 2015[c]	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
ASR World[d]	1.1	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Female															
<40 (95% CI)	0.2 (0.1–0.3)	0.2 (0.1–0.3)	0.2 (0.1–0.3)	0.2 (0–0.3)	0.2 (0–0.3)	0.2 (0–0.3)	0.2 (0–0.3)	0.2 (0–0.3)	0.2 (0–0.3)	0.2 (0–0.4)	0.2 (0–0.4)	0.2 (0–0.4)	0.2 (0–0.4)	0.2 (0–0.4)	0.2 (0–0.4)
40~ (95% CI)	0.9 (0.5–1.5)	0.9 (0.5–1.6)	0.9 (0.5–1.7)	0.9 (0.5–1.7)	0.9 (0.4–1.8)	0.9 (0.4–1.9)	0.9 (0.4–1.8)	0.9 (0.3–1.8)	0.9 (0.3–1.9)	0.8 (0.3–2.0)	0.8 (0.3–1.9)	0.8 (0.3–2.0)	0.8 (0.3–2.0)	0.8 (0.2–2.2)	0.8 (0.2–2.2)
50~ (95% CI)	2.3 (1.4–3.6)	2.3 (1.3–3.8)	2.3 (1.4–4.1)	2.3 (1.3–4.1)	2.3 (1.2–4.4)	2.3 (1.2–4.7)	2.3 (1.1–4.7)	2.3 (1.1–5.0)	2.2 (1.0–4.9)	2.2 (0.9–5.2)	2.2 (0.9–5.3)	2.2 (0.9–5.2)	2.2 (0.8–5.7)	2.2 (0.8–5.8)	2.2 (0.7–5.9)
60~ (95% CI)	4.0 (2.5–6.3)	4.0 (2.3–6.5)	4.0 (2.2–6.7)	3.9 (2.2–7.0)	3.8 (2.0–7.2)	3.8 (2.0–7.5)	3.8 (1.9–7.9)	3.8 (1.9–8.3)	3.7 (1.8–8.0)	3.7 (1.7–8.2)	3.7 (1.6–8.5)	3.7 (1.6–8.7)	3.6 (1.5–9.5)	3.6 (1.5–9.7)	3.7 (1.4–10.0)
70~ (95% CI)	5.3 (3.2–8.3)	5.3 (3.1–8.4)	5.3 (2.9–9.3)	5.2 (2.8–9.2)	5.2 (2.6–9.6)	5.3 (2.5–10.4)	5.3 (2.5–10.9)	5.3 (2.5–11.4)	5.4 (2.5–12.0)	5.5 (2.4–13.1)	5.6 (2.6–12.7)	5.7 (2.5–13.4)	5.5 (2.3–13.9)	5.4 (2.3–13.8)	5.4 (2.1–14.4)
Sub-total (95% CI)	1.3 (0.8–2.0)	1.3 (0.8–2.2)	1.4 (0.7–2.4)	1.4 (0.7–2.5)	1.4 (0.7–2.6)	1.4 (0.7–2.9)	1.5 (0.7–3.0)	1.5 (0.7–3.2)	1.5 (0.7–3.3)	1.6 (0.7–3.6)	1.6 (0.7–3.7)	1.6 (0.7–3.9)	1.7 (0.6–4.2)	1.7 (0.6–4.4)	1.7 (0.6–4.6)
ASR China 2000[a]	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
ASR China 2015[b]	1.3	1.3	1.3	1.2	1.2	1.2.	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
ASR World[c]	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Both sexes															
<40 (95% CI)	0.1 (0.1–0.2)	0.1 (0.1–0.3)	0.1 (0.1–0.3)	0.1 (0–0.3)	0.1 (0–0.3)	0.1 (0–0.3)	0.1 (0–0.3)	0.1 (0–0.3)	0.1 (0–0.3)	0.1 (0–0.3)	0.1 (0–0.4)	0.1 (0–0.4)	0.1 (0–0.4)	0.1 (0–0.4)	0.1 (0–0.4)
40~ (95% CI)	0.9 (0.5–1.5)	0.9 (0.5–1.5)	0.9 (0.5–1.6)	0.9 (0.5–1.7)	0.9 (0.4–1.7)	0.9 (0.4–1.8)	0.9 (0.4–1.8)	0.8 (0.3–1.9)	0.8 (0.3–1.9)	0.8 (0.3–2.0)	0.8 (0.3–2.0)	0.8 (0.3–2.1)	0.8 (0.3–2.2)	0.8 (0.3–2.2)	0.8 (0.3–2.3)
50~ (95% CI)	2.6 (1.7–4.0)	2.6 (1.5–4.2)	2.6 (1.5–4.4)	2.6 (1.4–4.7)	2.6 (1.4–4.9)	2.6 (1.3–5.1)	2.6 (1.2–5.2)	2.5 (1.2–5.5)	2.5 (1.1–5.3)	2.4 (1.0–5.6)	2.4 (1.0–5.9)	2.5 (1.0–5.8)	2.5 (0.9–6.3)	2.5 (0.9–6.3)	2.4 (0.8–6.5)
60~ (95% CI)	4.5 (2.9–7.0)	4.5 (2.7–7.3)	4.5 (2.6–7.7)	4.5 (2.5–8.2)	4.5 (2.3–8.2)	4.4 (2.3–8.5)	4.5 (2.2–8.8)	4.4 (2.2–9.3)	4.4 (2.1–9.4)	4.3 (2.0–9.9)	4.4 (1.9–10.2)	4.3 (1.8–10.4)	4.3 (1.8–10.9)	4.2 (1.7–11.3)	4.3 (1.6–11.6)
70~ (95% CI)	7.0 (4.4–10.6)	6.8 (4.1–10.9)	6.9 (3.9–11.5)	6.8 (3.8–11.9)	6.9 (3.4–12.5)	6.7 (3.3–13.2)	6.9 (3.3–1.38)	6.9 (3.3–14.4)	7.1 (3.2–15.2)	7.1 (3.2–16.8)	7.2 (3.2–17.0)	7.1 (3.1–17.4)	7.2 (3.0–18.3)	7.1 (2.9–18.2)	7.0 (2.8–18.8)
Total (95% CI)	1.4 (0.9–2.2)	1.5 (0.9–2.4)	1.5 (0.8–2.5)	1.5 (0.8–2.7)	1.6 (0.8–2.9)	1.6 (0.8–3.1)	1.6 (0.8–3.3)	1.7 (0.8–3.5)	1.7 (0.8–3.7)	1.7 (0.7–4.0)	1.8 (0.7–4.2)	1.8 (0.7–4.4)	1.8 (0.7–4.7)	1.9 (0.7–4.9)	1.9 (0.7–5.1)
ASR China 2000[a]	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
ASR China 2015[b]	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.3
ASR World[c]	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

[a], ASR (units: person-years); [b], age standardized incidence rates was based on the China population structure in 2000; [c], age standardized incidence rates was based on the China population structure in 2015; [d], age standardized incidence rates was based on Segi's population expressed per 100,000 persons. ASR, age-standardized rate; CI, confidence interval.

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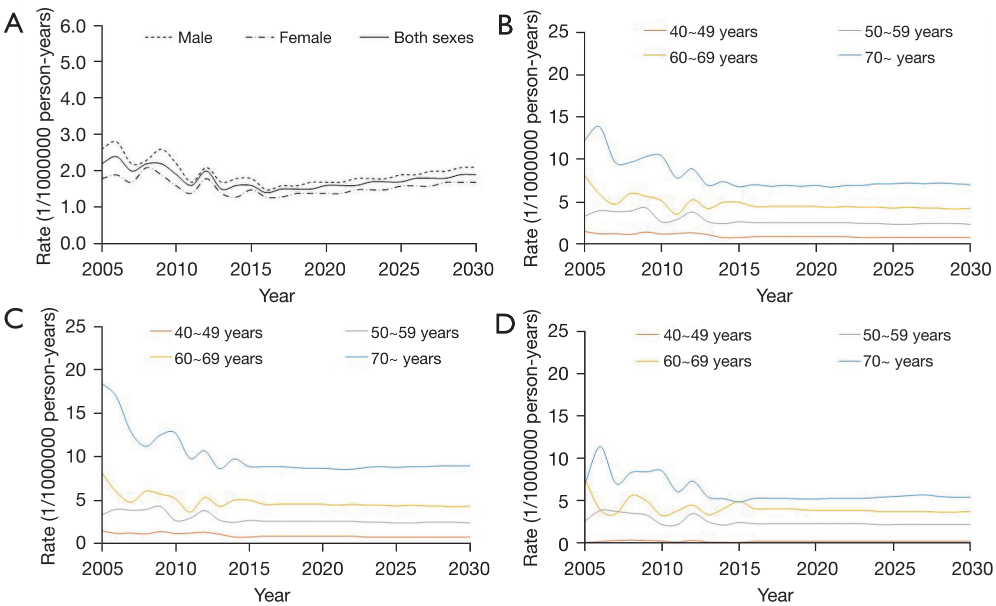

Figure 2 Modelled and predicted malignant mesothelioma crude incidence from 2005 to 2030. [The incidence from 2005 to 2015 was observed, and that from 2016 to 2030 was predicted, where (A) for total population; (B) for both sexes (the color of the segment increases with age group); (C) for male (the color of the segment increases with age group); (D) for female (the color of the segment increases with age group)].

development trend, abandoning the incomplete and inaccurate data related to asbestos and other mineral fibers in the model. Similar studies were also carried out in other countries (20-22).

Although APC models have been used successfully in many different settings in South Korea and Italy (23,24), other models such as JoinPoint regression (25) and Poisson log-linear model (26) have also been employed. It has been reported that the incidence rates of malignant mesothelioma were higher in some European countries (UK, the Netherlands, Malta, Belgium), but that it was very low in East Asia (27-29). The reasons for the discrepancy might be complicated, such as under-diagnosis or under-registration of malignant mesothelioma, and the long latency periods of the disease. In addition, genetic susceptibility, environmental exposures, and occupational exposures might also contribute to the development of this malignancy (30,31).

In a Bayesian APC analysis, age is often the most important variable as it implies consistent extrinsic factors, such as exposure accumulation. Period implies all factors affecting a person at a particular time, such as pollution or medical interventions. Cohort implies events affecting generations, such as malnutrition of children owing to war or changes in habits. Our results demonstrated a strong relationship between age and the incidence of malignant mesothelioma, possibly due to age-related causes such as accumulative exposures to carcinogens over time and mutation accretion that are necessary for the unregulated carcinogenic cell proliferation (32).

The World Health Organization predicted that, between 2018 and 2040, there would be a gradually increasing trend of the disease—the number of new malignant mesothelioma cases would shift from 3,060 to 4,699 (male: from 1,730 to 2,780; female: from 1,330 to 1,919) (33). We also used Bayesian APC models to predict the incidence rates and cases and found that the rates would remain stable and slowly increase in the next ten years. The predicted crude incidence of malignant mesothelioma showed that the incidence increased with the increase of age, and also with the increase of year. However, the age standardization rates showed no difference between years, indicating that the incidence was affected by age. According to our results, although the incidence and new cases of malignant mesothelioma in China will remain stable in the next ten years, the cancer still needs to be taken seriously due to its high malignancy and poor survival.

This study might have some limitations. Firstly, we

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Table 3 Predicted incidence cases of malignant mesothelioma in China (number)

Category	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Male															
<40 (95% CI)	55 (30–91)	55 (27–94)	54 (24–96)	55 (20–105)	54 (17–112)	55 (16–114)	54 (16–114)	54 (15–122)	53 (15–122)	53 (14–121)	53 (14–137)	51 (13–138)	50 (12–128)	49 (12–130)	48 (11–127)
40~ (95% CI)	115 (68–179)	112 (60–180)	109 (60–187)	104 (54–191)	98 (45–188)	94 (42–190)	90 (38–182)	86 (36–193)	84 (32–195)	84 (31–201)	85 (32–215)	88 (31–223)	93 (31–249)	96 (31–251)	99 (31–272)
50~ (95% CI)	276 (181–415)	290 (171–469)	299 (166–489)	313 (171–562)	322 (166–600)	332 (166–626)	337 (161–684)	337 (158–711)	330 (146–702)	323 (136–732)	322 (130–771)	311 (126–734)	307 (116–790)	294 (110–748)	278 (100–749)
60~ (95% CI)	342 (228–523)	359 (220–574)	369 (215–618)	380 (209–694)	383 (202–687)	392 (205–731)	394 (198–755)	390 (193–816)	395 (189–862)	412 (187–973)	424 (195–1,036)	434 (188–1,088)	458 (188–1,150)	484 (189–1,267)	492 (189–1,341)
70~ (95% CI)	334 (218–505)	347 (210–542)	356 (203–570)	367 (209–635)	385 (195–705)	405 (208–783)	436 (215–872)	475 (228–973)	505 (234–1,092)	527 (243–1,273)	554 (248–1,390)	576 (244–1,446)	602 (252–1,574)	619 (254–1,611)	637 (261–1,725)
Sub–total (95% CI)	1,122 (725–1,713)	1,163 (688–1,859)	1,187 (668–1,960)	1,219 (663–2,187)	1,242 (625–2,292)	1,278 (637–2,444)	1,310 (628–2,607)	1,341 (630–2,815)	1,367 (616–2,973)	1,400 (611–3,300)	1,437 (619–3,549)	1,460 (602–3,629)	1,511 (599–3,891)	1,542 (596–4,007)	1,554 (592–4,214)
Female															
<40 (95% CI)	56 (29–97)	56 (24–96)	55 (19–102)	56 (13–108)	55 (13–109)	55 (13–117)	55 (13–118)	54 (12–114)	53 (12–121)	53 (11–129)	52 (11–126)	51 (11–133)	51 (10–133)	49 (10–133)	49 (10–137)
40~ (95% CI)	112 (64–178)	110 (61–183)	107 (56–189)	103 (51–187)	97 (46–185)	92 (41–190)	88 (39–181)	83 (33–178)	81 (28–176)	79 (27–190)	80 (26–186)	83 (28–201)	87 (27–211)	89 (26–235)	92 (26–246)
50~ (95% CI)	217 (132–330)	226 (130–366)	237 (140–413)	248 (135–438)	255 (134–482)	264 (131–536)	264 (128–541)	266 (127–589)	263 (120–576)	261 (112–613)	256 (104–614)	255 (99–595)	248 (90–625)	237 (86–624)	226 (76–613)
60~ (95% CI)	273 (172–431)	282 (166–462)	288 (163–492)	289 (161–519)	290 (153–551)	295 (154–581)	296 (151–619)	299 (148–659)	303 (145–653)	312 (144–684)	319 (140–739)	335 (142–791)	348 (145–910)	364 (148–966)	385 (148–1,034)
70~ (95% CI)	240 (145–371)	246 (145–390)	258 (143–450)	267 (142–471)	281 (138–518)	302 (141–595)	323 (153–668)	345 (163–744)	373 (172–832)	399 (178–954)	421 (194–965)	445 (195–1,052)	451 (188–1,128)	456 (194–1,161)	469 (179–1,252)
Sub–total (95% CI)	898 (542–1,407)	919 (526–1,497)	945 (521–1,646)	963 (502–1,723)	978 (484–1,845)	1,008 (480–2,019)	1,027 (484–2,127)	1,047 (483–2,284)	1,074 (477–2,358)	1,105 (472–2,570)	1,129 (475–2,630)	1,169 (475–2,772)	1,183 (460–3,007)	1,195 (464–3,119)	1,221 (439–3,282)
Both sexes															
<40 (95% CI)	111 (59–188)	110 (51–190)	110 (43–198)	111 (33–213)	109 (30–221)	110 (29–231)	109 (29–232)	108 (27–236)	107 (27–243)	106 (25–250)	105 (25–263)	102 (24–271)	101 (22–261)	99 (22–263)	97 (21–264)
40~ (95% CI)	226 (132–357)	222 (121–363)	216 (116–376)	207 (105–378)	195 (91–373)	187 (83–380)	178 (77–363)	170 (69–371)	165 (60–371)	163 (58–391)	166 (58–401)	170 (59–424)	180 (58–460)	185 (57–486)	191 (57–518)
50~ (95% CI)	493 (313–745)	516 (301–835)	536 (306–902)	561 (306–1,000)	577 (300–1,082)	596 (297–1,162)	601 (289–1,225)	603 (285–1,300)	593 (266–1,278)	585 (248–1,345)	578 (234–1,385)	566 (225–1329)	555 (206–1,415)	531 (196–1,372)	504 (176–1,362)
60~ (95% CI)	614 (400–954)	641 (386–1,036)	657 (378–1,110)	669 (370–1,213)	672 (355–1,238)	687 (359–1,312)	690 (349–1,374)	689 (341–1,475)	698 (334–1,515)	724 (331–1,657)	743 (335–1,775)	769 (330–1,879)	806 (333–2,060)	848 (337–2,233)	877 (337–2,375)
70~ (95% CI)	575 (363–876)	593 (355–932)	613 (346–1,020)	634 (351–1,106)	666 (333–1,223)	706 (349–1,378)	759 (368–1,540)	820 (391–1,717)	878 (406–1,924)	926 (421–2,227)	975 (442–2,355)	1,021 (439–2,498)	1,052 (440–2,702)	1,075 (448–2,772)	1,105 (440–2,977)
Total (95% CI)	2,019 (1,267–3,120)	2,082 (1,214–3,356)	2,132 (1,189–3,606)	2,182 (1,165–3,910)	2,220 (1,109–4,137)	2,287 (1,117–4,463)	2,337 (1,112–4,734)	2,389 (1,113–5,099)	2,441 (1,093–5,331)	2,505 (1,083–5,870)	2,567 (1,094–6,179)	2,628 (1,077–6,401)	2,694 (1,059–6,898)	2,737 (1,060–7,126)	2,775 (1,031–7,496)

CI, confidence interval.

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directly extracted the data after statistical analysis instead of raw data for further analysis. Completed demographics data and environmental factors, such as asbestos and other mineral fibers exposure for enrolled and non-enrolled population is not evaluable, which limited the accuracy of prediction. Furthermore, there may be a high rate of misdiagnosis (close to 50%) varying from region to region and hospital to hospital in China largely because of a limited application of immunohistochemistry for mesothelioma. Additionally, the calculation after 2016 was based on China's projected population from World Population Prospects 2019, which comprises the total population of China based on an estimate. However, we used the population covered by cancer registries to calculate the incidence rate during the period of 2005 to 2015, which may lead to underestimating the number of incidences after 2016. Therefore, a more comprehensive registry network to cover the entire area is needed to make the prediction more accurate and representative in the future.

In conclusion, the incidence of malignant mesothelioma in China may increase over the next decades, while the ASR will remain stable. Our findings enrich the epidemiological data on malignant mesothelioma in China.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

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