Original Article

Survival analysis of 15,402 pneumoconiosis cases in Jiangsu Province of China from 1961 to 2019

Xianping Song[1#], Huanxi Shen[1#], Lang Zhou[2#], Guohua Qian[1], Jian Shi[1], Sheng Xu[1], Xiaojin Fei[1], Baoli Zhu[2], Lei Han[2]

[1]Kunshan Center for Disease Prevention and Control, Suzhou, China; [2]Institute of Occupational Disease Prevention, Jiangsu Provincial Center for Disease Control and Prevention, Nanjing, China

Contributions: (I) Conception and design: All authors; (II) Administrative support: None; (III) Provision of study materials or patients: None; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

[#]These authors contributed equally to this work.

Correspondence to: Baoli Zhu; Lei Han, PhD. Institute of Occupational Disease Prevention, Jiangsu Provincial Center for Disease Control and Prevention, Nanjing 210009, China. Email: zhubl@jscdc.cn; hanlei@jscdc.cn.

Background: Pneumoconiosis has been reported as one of the major global burdens of occupational health-related diseases. The global prevalence had increased since 1990. Prevention and treatment of pneumoconiosis in the project of occupational health have been a priority of the action plan of Healthy China 2030.

Methods: A life table was used to explore the survival and fatality rate of pneumoconiosis. Using Cox proportional hazards regression model, the factors of survival time were investigated.

Results: A total of 15,402 cases had several species of pneumoconiosis, including silicosis, coal worker pneumoconiosis and welder pneumoconiosis that accounted for 68.49%, 19.41% and 3.84% of total pneumoconiosis, respectively. Eighty percent of cases were initially diagnosed at stage I, 15.5% at stage II, and 4.5% at stage III. The overall average survival time was determined as 14.74±9.57 years, the life expectancy reached 34.324 years in total, and the total mortality of patients suffering from pneumoconiosis was 19.89%. The average dust exposure period, average survival time and life expectancy progressively decreased with the stage upgrade, whereas the age of onset and mortality rate tended to increase. Dust exposure years, initially diagnosed at stage II or stage III, stage I upgrade to stage II, stage I upgrade to stage III and low economic level were found as important risk factors for the survival of patients suffering from pneumoconiosis.

Conclusions: Stage II and stage III of pneumoconiosis may have a direct effect on the survival time of patients suffering from pneumoconiosis. The prevention and delay of the progression of pneumoconiosis are critical to prolonging the survival time of cases.

Keywords: Pneumoconiosis; stage of pneumoconiosis; mortality rate; survival analysis; cox regression analysis

Submitted Sep 30, 2021. Accepted for publication Mar 25, 2022.
doi: 10.21037/apm-21-2824
View this article at: https://dx.doi.org/10.21037/apm-21-2824

Introduction

Pneumoconiosis refers to a chronic disease attributed to long-term inhalation and deposition of productive dusts in lungs during professional activities. The main pathological manifestations of pneumoconiosis include ongoing pulmonary fibrosis and other parenchymal irreversible variations that can occur after exposure ceases (1). Known pneumoconiosis consists of silicosis, coal worker pneumoconiosis (CWP), graphitosis and carbon black pneumoconiosis (2). Thus far, there has been no effective treatment available for pneumoconiosis, and prevention has been used as the main means to reduce the morbidity and mortality of pneumoconiosis. Pneumoconiosis continues to be one of the major global burdens of occupational health-related disease.

From the global perspective, in 2017, pneumoconiosis had the prevalent cases of 527,500 (3), and its prevalence had increased since 1990 from 0.0054% to 0.007% (4). As reported by Shi *et al.*, the number of patients suffering from pneumoconiosis increased by 66.0%. However, the age-standardized incidence rates decreased by 0.6% per year on average from 1990 to 2017, as revealed by the data of the Global Burden of Disease Study 2017 (5). National Institute for Occupational Safety and Health (NIOSH) data indicated that the prevalence of progressive massive fibrosis (PMF), the most severe form of pneumoconiosis, significantly increased (6). According to 2018 study, the prevalence of pneumoconiosis in long-tenured working miners was 10% higher than that of the United States (7). According to Cynthia Lu *et al.*, the estimated prevalence of coal workers pneumoconiosis in the United States in the 2000s exceeded that in the 1990s (8). A total of 21,488 patients suffering from pneumoconiosis died globally in 2016, and the rate of pneumoconiosis mortality decreased by 41% from 1990 to 2016 (9). Pneumoconiosis remains the critical occupational disease in China. According to the estimation of the National Health Commission of China, nearly 200 million workers were exposed to occupational hazards (10). On the whole, 17,064 new patients with occupational diseases were reported in 2020, which included 14,367 patients of pneumoconiosis that accounted for approximately 84.19% of the total reported cases (11). The Chinese central government has allocated 809 million yuan to occupational disease prevention and treatment projects in 2019. Furthermore, occupational health has been prioritized in the action plan of Healthy China 2030.

The classification of pneumoconiosis is considered an indicator to measure the severity of pneumoconiosis, as well as a main basis for cases to be compensated for occupational diseases. Pneumoconiosis is assigned as the simple (mild) or complicated (severe) level in accordance with the international classification of pneumoconiosis published by the International Labor Office (ILO, 2011). The above two types further fall to categories 1, 2 and 3 for the simple disease, as well as to categories A, B and C for the complicated disease based on radiographs, respectively (12). However, pneumoconiosis is separated into three stages (stage I, stage II and stage III) in accordance with the professional history and radiographs in China (13). There is hierarchical correlation between the three stages and the ILO radiological categories. Stage I represented ILO simple pneumoconiosis, and stage III represented complicated pneumoconiosis of ILO categories B and C; besides, stage II was between the above two stages (14). The classification of pneumoconiosis can be used as a vital factor for the survival time of cases. As reported by Ortmeyer *et al.*, the life expectancy of miners as a whole is consistent with that of the general population (15). According to a specific 20-year follow-up study on miners and ex-miners in South Wales, the subjects with simple and category A pneumoconiosis survived, as well as those without any evidence of pneumoconiosis (16). An elevated mortality was reported only in miners with category B and C pneumoconiosis (17).

Though the government has done considerable work, pneumoconiosis remains one of the major social burdens. Since the goal of economic development is ultimately to expedite the progress of people, the survival time and quality of patients suffering from pneumoconiosis have aroused huge attention. We collected the data of cases first diagnosed with pneumoconiosis from 1961 to 2019 in Jiangsu province, to investigate the survival time and relevant factors of pneumoconiosis at different stages. We present the following article in accordance with the STROBE reporting checklist (available at https://apm.amegroups.com/article/view/10.21037/apm-21-2824/rc).

Methods

Study subjects

A total of nearly 20,000 cases were collected in the follow-up and retrospective investigation of pneumoconiosis in Jiangsu Province in 2019. Excluding cases lacking the time of onset, survival status cannot be investigated, and no exact death date of death cases, etc., 15,402 pieces of relatively complete data were screened out. The study population consisted of 15,402 workers who were first diagnosed with pneumoconiosis from 1961 to 2019 in Jiangsu province. The patients were diagnosed by an institution qualified for pneumoconiosis diagnosis in Jiangsu Province that was performed by at least three radiologists in accordance with the Diagnostic Criteria of Pneumoconiosis. Since the diagnostic criteria were constantly revised, "silica dust workers medical preventive measures", "GB 5906-

Table 1 Cox regression variable assignment table

Variable name	Assignment description
Dust exposure years (X1)	Continuous variable
Age of onset (X2)	Continuous variable
First diagnostic stage (X3)	Stage I =0, stage II =1, stage III =2
Types (X4)	Silicosis =0, Coal worker's pneumoconiosis =1, Welder's pneumoconiosis =2, others =3
Industry category (X5)	Mining =0, manufacturing =1, public management and social security =2, others =3
Upgrade of stages of pneumoconiosis (X6)	Stable stages =0, upgrade I to II =1, upgrade II to III =2, upgrade I to III =3
Economic level (X7)	High level =1, medium level =2, low level =3

1986 pneumoconiosis X-ray diagnostic criteria and principles of treatment", "GB 5906-1997 X-ray diagnosis of pneumoconiosis", "GBZ 70-2002 diagnostic criteria for pneumoconiosis", "GBZ 70-2009 diagnostic criteria and GBZ 70-2015 diagnostic criteria for pneumoconiosis" have been successively employed for pneumoconiosis diagnosis from 1961 to 2019. Pneumoconiosis was significantly separated into three stages. The study was conducted based on the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of the Jiangsu Province Center for Disease Control and Prevention (No. 2012025) and individual consent for this retrospective analysis was waived.

Data source

The information of patients suffering from pneumoconiosis was acquired and submitted by diagnosis institutions via Network Direct Report System of Occupational Diseases. In addition, the follow-up of pneumoconiosis cases was conducted by the occupational disease prevention and control department of CDC each year to ensure that their information was updated timely. The data acquired involved basic demographic information, types of work, industry categories, economic levels of companies, initial dates of dust exposure, end dates of dust exposure, dates of the first diagnosis of pneumoconiosis, types of pneumoconiosis, diagnosis of the stages, dates of diagnosis of each stage outcome variable, date of death, etc. The missing data were checked to ensure the data to be integral and reliable. The data of pneumoconiosis cases were collected from 1961 to 2019 in accordance with the summary of the most recent follow-up information in Jiangsu province.

Definition

Death cases: died of pneumoconiosis or its complications (e.g., tuberculosis and pulmonary heart disease) were defined as death cases.

Censored cases: death from other causes (e.g., accidents, liver failure, renal and autoimmune disease), or still alive at the end of observation were classified as censored data.

Statistical analysis

Descriptive and survival analyses were conducted with the R Programming Language. Categorical variables were analyzed by performing the χ^2 tests. For survival analysis, Kaplan-Meier method and Cox proportional hazards regression model were used in accordance with the partial maximum likelihood estimation of the forward method [forward: likelihood ratio (LR)]. *Table 1* lists the regression variable assignment.

Results

Demographic and occupational characteristics

Silicosis (10,549 cases, 68.49%), CWP (2,990 cases, 19.41%) and welder pneumoconiosis (591 cases, 3.84%) were the top three of the total reported pneumoconiosis. The data of demographic and occupational characteristics fell into three groups based on the pneumoconiosis stage. There were 12,322 (80.00%) patients first diagnosed at stage I, 2,386 (15.49%) at stage II, and 694 (4.51%) at stage III among all the 15,402 subjects. Most of the patients (13,847, 89.90%) remain the first diagnosed stages and keep stable, 1,107 (7.19%) upgrade from stage I to stage II, 232 (1.51%)

Table 2 Demographic and occupational characteristics involved in this study

Variables	Stage I (n=12,322)		Stage II (n=2,386)		Stage III (n=694)		F	P
	N	%	N	%	N	%		
Gender							9.245	<0.001
Male	11,628	94.4	2,199	92.2	645	92.9		
Female	694	5.6	187	7.8	49	7.1		
Age (years), mean ± SD	69.42±10.73		70.59±12.11		68.46±13.01		14.832	<0.001
25–40	98	0.8	19	0.8	10	1.4		
40–60	1,911	15.5	403	16.9	161	23.2		
≥60	10,313	83.7	1,964	82.3	523	75.4		
Age of onset (years), mean ± SD	54.14±11.18		54.96±11.47		56.82±11.53		22.376	<0.001
Dust exposure time (years), mean ± SD	16.24±9.89		17.05±9.88		15.02±9.48		12.986	<0.001
<10	4,214	34.2	723	30.3	274	39.5		
10–20	4,063	33.0	842	35.3	230	33.1		
20–30	2,989	24.3	587	24.6	148	21.3		
≥30	1,056	8.6	234	9.8	42	6.1		
Types							35.788	<0.001
Silicosis	8,178	66.4	1,800	75.4	567	81.7		
CWP	2,557	20.8	359	15	74	10.7		
Welder's pneumoconiosis	551	4.5	38	1.6	2	0.3		
Others	1,036	8.4	189	7.9	51	7.3		
Survival time (years), mean ± SD	14.92±9.60		14.90±9.34		10.91±9.12		58.512	<0.001
Outcome variables							114.400	<0.001
Dead	2,157	17.5	679	28.5	227	32.7		
Survival	10,165	82.5	1,707	71.5	467	67.3		

SD, standard deviation.

upgrade from stage II to stage III and 216 (1.40%) upgrade from stage I to stage III. The average age of the three stages was 69.42±10.73, 70.59±12.11, and 68.46±13.01 years, respectively. The age of onset at stage III was higher than that at stage I and stage II. In contrast to the above result, the average dust exposure period at stage III was less than that at stage I and stage II, and the dust exposure period generally ranged from 1 to 58 years. The overall average survival time of all the subjects was 14.74±9.57 years, and the survival time at stage III was 10.91±9.12 years, significantly less than that at stage I (14.92±9.60 years) and stage II (14.90±9.34 years). The total mortality of patients suffering from pneumoconiosis at stage I, stage II and stage III was 19.89%, and 17.5%, 28.5% and 32.7%, respectively, and the mortality rate tended to increase with the upgrade of the stage. All the variables of the three stages were statistically significant (P<0.001, *Table 2*).

Mean survival time of patients suffering from pneumoconiosis in different age groups

Table 3 lists the cumulative survival rate and the mean survival time of different age groups. Ten age groups were classified with an interval of 5 years old in the respective group. According to the corrected observed patients, the death probability of pneumoconiosis cases in different age

Table 3 Cumulative survival rate and its standard error of 15,402 patients suffering from pneumoconiosis

Age groups	Observed patients	Surviving patients	Died patients	Cumulatively observed patients	Corrected observed patients	Mortality rate	Survival rate	Cumulatively survival rate	Cumulatively mortality rate	Hazard rate	Median survival time (years)
<30	4	2	2	15,402	15,401	0.0001	0.9999	0.9999	0.0001	0.0001	1.83
30–	41	33	8	15,398	15,381.5	0.0005	0.9995	0.9994	0.0006	0.0005	11.33
35–	82	69	13	15,357	15,322.5	0.0008	0.9992	0.9985	0.0015	0.0008	18.00
40–	213	176	37	15,275	15,187	0.0024	0.9976	0.9961	0.0039	0.0024	34.00
45–	475	395	80	15,062	14,864.5	0.0054	0.9946	0.9907	0.0093	0.0054	24.64
50–	824	648	176	14,587	14,263	0.0123	0.9877	0.9785	0.0215	0.0124	26.36
55–	993	751	242	13,763	13,387.5	0.0181	0.9819	0.9608	0.0392	0.0182	24.09
60–	1,831	1,454	377	12,770	12,043	0.0313	0.9687	0.9307	0.0693	0.0318	30.59
65–	3,466	2,991	475	10,939	9,443.5	0.0503	0.9497	0.8839	0.1161	0.0516	36.27
≥70	7,473	5,820	1,653	7,473	4,563	0.3623	0.6377	0.5637	0.4363	0.0000	36.61

groups was calculated. The cumulative survival rate tended to decrease with age. The mean survival time of patients suffering from pneumoconiosis in 40–45 and over 65 years of age was longer than that of others. The deceased cases are listed in *Table 3*.

Age-specific mortalities for pneumoconiosis cases at the respective stage

Age-specific mortalities and mean survival time at the respective stage are listed in *Table 4*. There were considerable observed cases and dead patients in the older age group of the three stages. The high mortality rate and decreasing mean survival time were found at stage II and stage III compared with those at stage I. However, all the variables had no obvious trend variations from the perspective of age groups.

Comparison of survival curves between the three-stage groups

Figure 1 illustrates that the survival curve of patients suffering from pneumoconiosis at stage I was higher than those at the other two stages, and the survival curve of pneumoconiosis cases at stage II was higher than that at stage III. Moreover, a significant difference was identified in the survival time of the three stages (P<0.001). The cumulative survival rate at the three stages tended to decrease as the survival time was prolonged. The whole life expectancy of all the subjects reached 34.324 years. The life expectancy regardless of age at stage I stage II and stage III reached 35.354, 31.045 and 24.926 years, respectively, and the chi-square value of Kaplan-Meier was 289.383. A statistically significant difference was identified between the above three groups (P<0.001).

Multivariate Cox regression analysis of pneumoconiosis cases

As demonstrated by the results of the Cox regression analysis in *Table 5*, dust exposure years, first diagnostic stage (stage II and stage III), upgrade stages of pneumoconiosis (upgrade I to II, upgrade I to III), economic level (low level) were correlated with the death of pneumoconiosis. First diagnosed to stage III [relative risk (RR) =2.371, 95% confidence interval (CI): 2.056–2.733], upgrade I to III (RR =1.673, 95% CI: 1.346–2.079), first diagnosed to stage II of pneumoconiosis (RR =1.612, 95% CI: 1.461–1.779) were reported as the top three risk factors, followed by upgrade I to II (RR =1.232, 95% CI: 1.099–1.379), low economic level (RR =1.103, 95% CI: 1.004–1.212) and dust exposure years (RR =1.081, 95% CI: 1.077–1.085).

Discussion

Pneumoconiosis is one of the most common occupational diseases worldwide. In the proposed study, a survival analysis was conducted with 15,402 patients suffering from

Table 4 Age-specific mortalities for patients with pneumoconiosis in each stage

Age	Stage I				Stage II				Stage III			
	Observed patients	Died patients	Mortality rate (%)	Median survival time (years)	Observed patients	Died patients	Mortality rate (%)	Median survival time (years)	Observed patients	Died patients	Mortality rate (%)	Median survival time (years)
<30	2	0	0	2.00	1	1	100.0	1.46	1	1	100.0	1.50
30–	33	2	6.1	8.00	4	3	75.0	11.00	4	3	75.0	4.00
35–	63	6	9.5	18.00	14	7	50.0	5.86	5	0	0	17.00
40–	167	23	13.8	34.00	34	9	26.5	15.47	12	5	41.7	7.64
45–	363	50	13.8	26.63	71	18	25.4	17.06	41	12	29.3	20.03
50–	623	117	18.8	26.76	152	45	29.6	15.76	49	14	28.6	12.31
55–	780	174	22.3	24.72	152	46	30.3	31.12	61	22	36.1	19.04
60–	1,451	262	18.1	30.70	282	73	25.9	33.26	98	42	42.9	12.61
65–	2,925	349	11.9	36.82	420	89	21.2	34.52	121	37	30.6	22.88
≥70	5,915	1,174	19.8	37.03	1,256	388	30.9	34.49	302	91	30.1	35.88

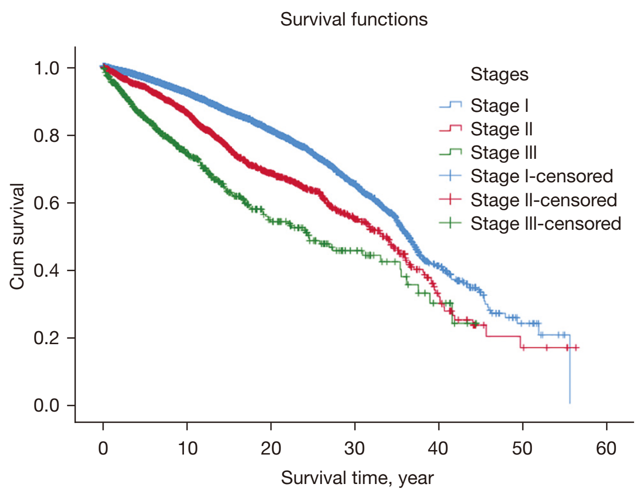

Figure 1 Survival curves of 15,402 pneumoconiosis patients in three stages.

pneumoconiosis diagnosed in one of the major industrial provinces in China. The types of pneumoconiosis here mainly covered silicosis, CWP, welder pneumoconiosis and other types (e.g., asbestosis, cement pneumoconiosis, founder pneumoconiosis, potter's pneumoconiosis). The survival time and life expectancy at stage III were significantly shorter than those at stage I and stage II. Dust exposure years, first diagnosed at stage II or stage III, stage I upgrade to stage II, stage I upgrade to stage III and low economic level had correlations with the death of pneumoconiosis cases.

The three most common types of pneumoconiosis included asbestosis, silicosis and CWP. To be specific, silicosis is more frequent than asbestosis in developing nations, whereas this trend is reversed in developed nations (2,18). CWP and silicosis were listed as the top two reported new cases of pneumoconiosis as indicated from the national occupational disease report from 2015 to 2016 in China (19). Silicosis, CWP, welder pneumoconiosis and asbestosis were listed as the top four of pneumoconiosis types in this study due to the developmental non-ferrous metals, metallurgy and coal mining industries in Jiangsu province. Stage I (80%) still accounted for the majority of the total patients suffering from pneumoconiosis, followed by stage II and stage III, which was consistent with the reports of characteristics of pneumoconiosis in Shanghai, Hubei and Tianjin (20,21). Stage of pneumoconiosis would upgrade with the progression of lung pathological variations since the occurrence of pneumoconiosis is considered a gradual process. Pneumoconiosis stages were correlated with the first diagnosis time. Most cases were diagnosed at stage I, thereby indicating that the occupational health monitoring policy (e.g., regular physical examinations) may exert a certain effect. There were statistically significant differences in the average age of onset and dust exposure period at different stages, which were correlated with the

Table 5 Multivariate Cox regression analysis of 15,402 patients suffering from pneumoconiosis

Variables	β	Standard error	Wald χ^2	P	RR	95% CI
Dust exposure years	0.078	0.002	1,592.840	<0.001	1.081	1.077–1.085
Age of onset	–0.014	0.002	43.878	<0.001	0.986	0.981–0.990
First diagnostic stage			190.108	<0.001		
Stage I					1.000	
Stage II	0.478	0.050	90.509	<0.001	1.612	1.461–1.779
Stage III	0.863	0.073	141.311	<0.001	2.371	2.056–2.733
Types (X4)			24.096	<0.001		
Silicosis	–0.076	0.078	0.938	0.333	0.927	0.795–1.081
Coal worker's pneumoconiosis	–0.273	0.088	9.628	0.002	0.761	0.640–0.904
Welder's pneumoconiosis	–0.833	0.340	5.989	0.014	0.435	0.223–0.847
Others					1.000	
Industries			139.708	<0.001		
Mining	–0.078	0.076	1.039	0.308	0.925	0.797–1.074
Manufacturing	–0.444	0.088	25.419	<0.001	0.642	0.540–0.762
Public management and social security	–0.825	0.093	78.178	<0.001	0.438	0.365–0.526
Others					1.000	
Upgrade of stages of pneumoconiosis			31.008	<0.001		
Stable stages					1.000	
Upgrade I to II	0.208	0.058	12.945	<0.001	1.232	1.099–1.379
Upgrade II to III	0.077	0.116	0.440	0.507	1.080	0.860–1.355
Upgrade I to III	0.514	0.111	21.522	<0.001	1.673	1.346–2.079
Economic level			212.356	<0.001		
High level					1.000	
Medium level	–0.584	0.053	120.895	<0.001	0.558	0.503–0.619
Low level	0.098	0.048	4.165	0.041	1.103	1.004–1.212

CI, confidence interval; RR, relative risk.

time, concentration, free silica content and individual sensitivity of pneumoconiosis cases, and whether they were checked and diagnosed timely (22).

The mortality rate in 15,402 patients suffering from pneumoconiosis was 19.89%, higher than 13.4% (366 of 2,738) in a survival analysis conducted in a cohort of 2,738 cases with simple CWP in the Huai-Bei coal mine (17). The difference above might further confirm that the death rate of silicosis is higher than that of CWP. Silicosis is generally known as the most common, fastest- progressing and most harmful type of pneumoconiosis (23). Silicosis (68.49%) was confirmed as the most part of pneumoconiosis in this study. First diagnosed in stage III was correlated with shorter dust exposure time. The proportion of silicosis in each stage may be the important reason for this difference. There were 66.37% (8,178/12,322) silicosis patients in stage I, 75.44% (1,800/2,386) in stage II, 81.70% (567/694) in stage III. Silicosis progresses to stage III was short than other types. Although their dust exposure time was not long, a proportion of silicon dust exposed workers were directly classified as stage III pneumoconiosis in the first diagnosis. There were a highest proportion of silicosis in stage III in this study, the dust exposure time of stage III may short than other two stages. The overall average survival time of all the subjects, correlated with the first diagnosed age, reached 14.74±9.57 years. As reported by Han *et al.*, 459 CWP patients diagnosed from 1963 to 2014 in a state-owned coal mine in China had an average life span of 12.1 years (24). Short survival time could reveal the great harm of dust to people and correspond to the high first diagnosed age of pneumoconiosis. The age of onset of novel patients suffering from pneumoconiosis in China showed an overall upward trend. The first diagnosed age of 2,738 CWP patients from 1963 to 1989 in Huai-Bei coal mine reached 47.6±7.0 years (17), and the average age of onset of 838 CWP cases from 1970 to 2011 in the Kailuan Colliery Group was 52.0±4.3 years (25). The median age of onset of novel cases of pneumoconiosis from 1997 to 2009 in China reached 51.00 years. Furthermore, age of onset of silicosis was elevated from 51.0 years in 1997 to 54.5 years in 2009 (26).

As revealed from the life table, overall mortality probability and mean survival time increased with the age of 15,402 patients suffering from pneumoconiosis. The mortality probability ascending trend with age existed in considerable survival analysis reports. As illustrated by a study on global occupational-attributable deaths and disability-adjusted life years (DALYs) from pneumoconiosis, the age-standardized death rates were the highest in the older age groups, and the highest rate of DALYs was identified in 75–84-year age group (9). The increase in mean survival time may be determined by the majority of observed cases in older age groups. As indicated from existing research, the survival time of stage I pneumoconiosis cases can reach the level of normal people since programmatic treatment was arranged for free under the diagnosis of pneumoconiosis (15,27). Given the higher age of onset and 80% of cases first diagnosed at stage I, numerous subjects were involved in the older age groups here.

Pneumoconiosis was classified into three stages in China. Stage I represented simple pneumoconiosis, and stage III represented categories B and C of complicated pneumoconiosis; stage II was between the above two stages (14). The mortality rate tended to increase at the three stages of pneumoconiosis, followed a declining life expectancy. Stage III with the most severe lung function damage had a notable ascent in death risk over cases at stage II or I (28). As indicated by the cumulative survival curve, the cumulative survival rate of patients suffering from pneumoconiosis decreased with the upgrade of pneumoconiosis. The prevention and delay of the progression of pneumoconiosis were found to significantly prolong the survival time of patients.

As indicated by the Cox model, dust exposure years, first diagnosed at stage II or stage III, stage I upgrade to stage II, stage I upgrade to stage III and low economic level were found as the vital risk factors of the survival of patients suffering from pneumoconiosis. Han *et al.* reported that the RR of death was 0.902, 0.943, 1.897 for the initial dust exposure year, age of onset and first diagnostic stage, respectively (24). Moreover, the RR of progression from stage I to III was 2.360 in another survival analysis of 2,738 cases with simple pneumoconiosis (17). Economic level will affect the preventive measures against dust in the region, the regulations and policies adopted for dust enterprises, the medical expenses of pneumoconiosis patients, nursing expenses, nutrition expenses, and wages for lost work. etc., which will indirectly affect the diagnosis and treatment of patients with pneumoconiosis. As demonstrated by the multivariate analysis results above, the prognosis of pneumoconiosis could be a complex process dependent of multiple factors. Lung tissue was more severely damaged as the patients were more exposed to occupational dust, which indirectly caused a shortened survival time of patients (29). Furthermore, as confirmed by the three survival analyses of pneumoconiosis whether the patients were first diagnosed at stage II or stage III or subsequently upgraded to stage II or stage III, the case's survival time would be directly affected. Delaying the progression of pneumoconiosis and staying at stage I could significantly impact the survival of patients suffering from pneumoconiosis.

This study might have the following shortcomings. The analysis of factors affecting the survival time of patients suffering from pneumoconiosis may be insufficient. The survival and progression of pneumoconiosis is indeed affected by many factors. Due to the limitation of the collected data, we have included all influencing factors which can be analyzed. Dust exposure years, age of onset, first diagnostic stage, types of pneumoconiosis, industry category, upgrade of stages of pneumoconiosis, and economic level were included in the Cox proportional hazards regression model.

There might be misclassification bias since the study used medical diagnostic records preserved over the past few decades though the medical records for every case were checked during the annual regular follow-up. In addition, information bias (e.g., retrospective bias or investigator bias) were inevitable in this long-term retrospective study. A series of measures were employed to control the above bias. In the follow-up phase, questions were designed as objective indicators to reduce the survey bias (e.g., dust-exposure age and diagnosis time). Newly diagnosed patients suffering from pneumoconiosis have been preferentially selected during the screening stage. Cox proportional hazards regression model has used to analyze multiple and complex factors that affect the survival time of patients suffering from pneumoconiosis. Meantime, as impacted by the limited data, there was still a lack of many factors from the onset to death of pneumoconiosis cases, further accumulation and improvement of epidemiological data are needed in the future.

Conclusions

Existing studies showed that the data of occupational disease reported less than 7% of the actual incidence of occupational diseases (1,30). The pneumoconiosis cases investigated in this study were just the tip of the iceberg. The incidence of pneumoconiosis might still increase subsequently with the development of industry and the improvement of diagnostic technology (7). Elimination of dust and personal protection of pneumoconiosis workers are of high significance. A considerable number of measures have been employed to protect workers against dust inhalation. However, dust concentration in the workplace seriously exceeds the standard, and insufficient occupational health supervision, limited dust prevention technology and low coverage rate of occupational health examination and others still reduce the incidence of pneumoconiosis. Pneumoconiosis refers to an incurable chronic disease. Social support and care significantly impact the quality of life for cases. Much effort is required to reduce the incidence of pneumoconiosis and prolong the survival time of patients suffering from pneumoconiosis.

Acknowledgments

We would like to express our gratitude to all participants for their contributions to the study.

Funding: This study was supported by the General Project of Jiangsu Natural Science Foundation (No. BK20201485) and Key Medical Research Project of Jiangsu Provincial Health Commission (No. K2019026).

Footnote

Reporting Checklist: The authors have completed the reporting STROBE reporting checklist. Available at https://apm.amegroups.com/article/view/10.21037/apm-21-2824/rc

Data Sharing Statement: Available at https://apm.amegroups.com/article/view/10.21037/apm-21-2824/dss

Peer Review File: Available at https://apm.amegroups.com/article/view/10.21037/apm-21-2824/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://apm.amegroups.com/article/view/10.21037/apm-21-2824/coif). The authors have no conflicts of interest to declare.

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 based on the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of the Jiangsu Province Center for Disease Control and Prevention (No. 2012025) and individual consent for this retrospective analysis was waived.

References

1. Qi XM, Luo Y, Song MY, et al. Pneumoconiosis: current status and future prospects. Chin Med J (Engl) 2021;134:898-907.
2. Cullinan P, Reid P. Pneumoconiosis. Prim Care Respir J 2013;22:249-52.
3. Benziger CP, Roth GA, Moran AE. The Global Burden of Disease Study and the Preventable Burden of NCD. Glob Heart 2016;11:393-7.

4. GBD Chronic Respiratory Disease Collaborators. Prevalence and attributable health burden of chronic respiratory diseases, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet Respir Med 2020;8:585-96.
5. Shi P, Xing X, Xi S, et al. Trends in global, regional and national incidence of pneumoconiosis caused by different aetiologies: an analysis from the Global Burden of Disease Study 2017. Occup Environ Med 2020;77:407-14.
6. Hall NB, Blackley DJ, Halldin CN, et al. Current Review of Pneumoconiosis Among US Coal Miners. Curr Environ Health Rep 2019;6:137-47.
7. Blackley DJ, Halldin CN, Laney AS. Continued Increase in Prevalence of Coal Workers' Pneumoconiosis in the United States, 1970-2017. Am J Public Health 2018;108:1220-2.
8. Lu C, Dasgupta P, Cameron J, et al. A systematic review and meta-analysis on international studies of prevalence, mortality and survival due to coal mine dust lung disease. PLoS One 2021;16:e0255617.
9. GBD 2016 Occupational Chronic Respiratory Risk Factors Collaborators; GBD 2016 occupational chronic respiratory risk factors collaborators. Global and regional burden of chronic respiratory disease in 2016 arising from non-infectious airborne occupational exposures: a systematic analysis for the Global Burden of Disease Study 2016. Occup Environ Med 2020;77:142-50.
10. The Lancet. Improving occupational health in China. Lancet 2019;394:443.
11. National HC. 2020 Statistical Communique on the Development of Health Services in China. 2021. Available online: http://www.nhc.gov.cn/guihuaxxs/s10743/202107/af8a9c98453c4d9593e07895ae0493c8.shtml
12. Guidelines for the Use of the ILO International Classification of Radiographs of Pneumoconioses (Revised Print, 2011). 2018. Available online: https://www.ilo.org/global/publications/books/WCMS_168337/lang--en/index.htm
13. National Occupational Health Standard of the People's Republic of China: Diagnosis of occupational pneumoconiosis. GBZ 70-2015. 2015. Available online: http://www.nhc.gov.cn/cms-search/xxgk/getManuscriptXxgk.htm?id=2eb89b2e218e40a1ae563b3a887aa107
14. Muszyńska-Graca M, Dąbkowska B, Brewczyński PZ. Guidelines for the use of the International Classification of Radiographs of Pneumoconioses of the International Labour Office (ILO): Substantial changes in the currrent edition. Med Pr 2016;67:833-7.
15. Ortmeyer CE, Baier EJ, Crawford GM Jr. Life expectancy of Pennsylvania coal miners compensated for disability as affected by pneumoconiosis and ventilatory impairment. Arch Environ Health 1973;27:227-30.
16. Atuhaire LK, Campbell MJ, Cochrane AL, et al. Mortality of men in the Rhondda Fach 1950-80. Br J Ind Med 1985;42:741-5.
17. Li X, Liu CF, Guan L, et al. Deep Learning in Chest Radiography: Detection of Pneumoconiosis. Biomed Environ Sci 2021;34:842-5.
18. Cheng BW, Su M. International incidence trend of coal workers' pneumoconiosis and silicosis. Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi 2019;37:75-8.
19. Zou XX, Zhang B, Wang HJ. Study on the current situation of social security for pneumoconiosis in China. Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 2021;39:954-6.
20. Mo J, Wang L, Au W, et al. Prevalence of coal workers' pneumoconiosis in China: a systematic analysis of 2001-2011 studies. Int J Hyg Environ Health 2014;217:46-51.
21. Li ML, Liu J, Qin XL, et al. Analysis of silicosis surveillance data in Tianjin in 2017. Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi 2019;37:842-5.
22. Go LHT, Cohen RA. Coal Workers' Pneumoconiosis and Other Mining-Related Lung Disease: New Manifestations of Illness in an Age-Old Occupation. Clin Chest Med 2020;41:687-96.
23. The Lancet Respiratory Medicine. The world is failing on silicosis. Lancet Respir Med 2019;7:283.
24. Han L, Gao Q, Yang J, et al. Survival Analysis of Coal Workers' Pneumoconiosis (CWP) Patients in a State-Owned Mine in the East of China from 1963 to 2014. Int J Environ Res Public Health 2017;14:489.
25. Shen F, Yuan J, Sun Z, et al. Risk identification and prediction of coal workers' pneumoconiosis in Kailuan Colliery Group in China: a historical cohort study. PLoS One 2013;8:e82181.
26. Long Z, Liu W, Qi JL, et al. Mortality trend of chronic respiratory diseases in China, 1990-2019. Zhonghua Liu Xing Bing Xue Za Zhi 2022;43:14-21
27. Li Y, Liu GQ, Yan W, et al. Analysis of the diagnostic results and complications of pneumoconiosis patients with different insurance types. Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi 2020;38:736-38.
28. Okumura E, Kawashita I, Ishida T. Computerized

Classification of Pneumoconiosis on Digital Chest Radiography Artificial Neural Network with Three Stages. J Digit Imaging 2017;30:413-26.
29. Peng Y, Li X, Cai S, et al. Prevalence and characteristics of COPD among pneumoconiosis patients at an occupational disease prevention institute: a cross-sectional study. BMC Pulm Med 2018;18:22.
30. Li Y, Xian W, Xu H, et al. Time trends and future prediction of coal worker's pneumoconiosis in opencast coal mine in China based on the APC model. BMC Public Health 2018;18:1010.

Cite this article as: Song X, Shen H, Zhou L, Qian G, Shi J, Xu S, Fei X, Zhu B, Han L. Survival analysis of 15,402 pneumoconiosis cases in Jiangsu Province of China from 1961 to 2019. Ann Palliat Med 2022;11(7):2291-2301. doi: 10.21037/apm-21-2824