Research

Respiratory mortality and life expectancy of Yokkaichi Asthma patients, Japan: late health effects of air pollution in 1960-70s

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Abstract

Background: Since around 1960, chronic obstructive pulmonary disease (COPD) and asthma began to occur frequently among people in Yokkaichi city (Mie Prefecture, Japan), due to sulfur oxides air pollution, known as Yokkaichi Asthma. The pollution had improved markedly by the end of 1970s; no new cases had been reported after 1988. The study is aimed at examining the late health effects of air pollution among Yokkaichi Asthma patients.

Methods: Mortality rates and life expectancy of patients, registered in 1965–88, were investigated for 1975 – 2000.

Results: Mortality rates from COPD and asthma were significantly higher in patients than in the population of Mie Prefecture. For all age classes (except for males of 80–84 years in 1985), life expectancies of both males and females were significantly reduced in patients as compared with the population of Mie Prefecture. The potential gains in life expectancy by elimination of the mortality from respiratory diseases including COPD and asthma were larger for all age classes in the patients.

Conclusions: Mortality and life expectancies were adversely affected in the patients due to increase in death from respiratory diseases, although the air pollution had been solved.

Background

YOKKAICHI is a city with the largest population among the cities and towns of Mie Prefecture, located in the center of Japan. This is an industrial city and faces Ise Bay on the Pacific Ocean side of the Japanese archipelago. During World War Ⅱ, naval fuel factories were constructed in the southern part of Yokkaichi Harbor, but were destroyed by bombing before operations were started. In 1957, a petroleum complex was built on and began operations around the remains of this facility. The complex included the largest heavy oil-fired power station and refinery in Japan at that time. As this complex used crude oil with a high sulfur content (more than 3%) and did not employ suitable measures for desulphurization, the annual sulfur dioxide (SO_2) emission level exceeded 100,000 tons, which resulted in air pollution with a increased concentration of sulfur oxides, as high as 1 ppm in polluted areas.

Since around 1960, respiratory diseases, including bronchial asthma, began to occur frequently among people in the vicinity of the complex, and this subsequently became a major health problem in Japan, known as Yokkaichi Asthma(Yokkaichi Zensoku, in Japanese). A series of countermeasures based on an area-wide total emission control system were introduced since 1972, as a result of a successful lawsuit brought by nine inhabitants of the area against six companies in the Yokkaichi Trial, for reparations for health damage due to air pollution. Sulfur oxides air pollution in this region had improved markedly and the pollution reached the level same as that in un-polluted area by the end of 1970s; atmospheric sulfur oxides levels are now below 0.01 ppm in Yokkaichi area (http://www.yokkaichicity.org/index.htm). Recently, a historical review of Yokkaichi pollution problem has been published by Yoshida et al [1].

A group of researchers of Mie University [1–10] published a bulk of reports regarding health problems among residents in Yokkaichi area up to 1990. These studies revealed that in response to worsening air pollution, the mortality from bronchial asthma and chronic bronchitis began to increase, and that the mortality due to bronchial asthma decreased immediately after improvement of pollution whereas the mortality due to chronic bronchitis decreased to the level in the control area 4 to 5 years after the concentration of SO_2 began to satisfy the ambient air quality standard. Similar trends were also observed in medical consultation rates, incidence and prevalence for respiratory diseases.

To offer financial support to the patients, a Public Relief–System for air pollution was established in 1965 by Yokkaichi–city for the first time in the world. The system was disbursed from the city; and next year, the Japanese government decided that the national treasury, Mie Prefecture and industries related to the pollution also had to pay for the public relief. In 1969, this program was expanded to the national one, resulting in "Pollution–Related Health Damage Special Measures Law" by the Japanese government. Four years after, the "Pollution–Related Health Damage Compensation Law " was enacted and enforced.

The laws established that financial support to victims of environmental pollution in Japan, including Yokkaichi Asthma patients, is based on the imposition from industries responsible for the pollution. Thus, medical expenses of patients who met the three criterions below had been paid by the program for Yokkaichi cases.

1) With Specified Disease: Diseases (bronchial asthma, chronic bronchitis, pulmonary emphysema, and their complication), of which excessive occurrence in the polluted area had been confirmed epidemiologically.
2) In Specified Area: Areas where prevalence of the specified diseases had been increased.
3) During Specified Period: Three years of residence in the specified area.

Registration and compensation were carried out since 1965; no new cases had been reported after 1988 in Yokkaichi.

It has been frequently documented that, as a traditional pollutants, both SO_2 and suspended particulate (SP) usually occur together, representing a complex mixture of produced by fossil fuel (especially coal) consumption [11-18]. Also, evidence has been given that SP may exert adverse effects on health without high level of SO_2 [14,16,18]. However, residual health effects after the improvement of pollution have not been well investigated.

The present study is aimed at examining the late health effects of air pollution that occurred several decades ago in Yokkaichi. First, recent trends in mortality from respiratory diseases (i.e. chronic bronchitis, pulmonary emphysema and asthma) among registered patients are investigated. Also, life expectancy of the patients is assessed, because this is one approach to assess health effects of pollution as studies by Tamashiro et al [19] who examined the effects on life expectancy from elevated methylmercury exposure in five coastal towns of southern Japan but failed to demonstrate marked changes, and by Kan and Chen [20] who showed that the long-term air particulate matter exposure caused reduction of life expectancy in residents of Shanghai, China.

Methods

Subjects

Records of 1,354 patients registered for Yokkaichi city during 1965-1988 by "Public Relief-System by Yokkaichi city (1965), " "Pollution-Related Health Damage Special Measures Law (1969)," and "Pollution-Related Health Damage Compensation Law (1973)" were used with the authorization by Yokkaichi-city. Data obtained were sex, year of birth, the dates of registration and death, cause of death, and diagnosis at registration (Tables 1 and 2). Records of 1,232 patients [survival 518 (243 males and 275 females), death 714 (410 males and 304 females, on December 30, 2002)]

registered after 1973 were used for the analysis, to compare the results with those for whole population of Mie Prefecture, of which mortality data had been published since 1973 [21,22].

Age-adjusted mortality rate (indirect method)

Age-adjusted mortality rates of patients for all and specific causes were calculated by the indirect method [23] using age-specific mortality rates of the whole population of Mie prefecture (standard population) for each of the census years of 1975-2000 (every 5th year). In this calculation, number of patients of each age-class was an average over $\pm$ 2 years of the census year. As after 1995, chronic bronchitis and pulmonary emphysema were togethered into chronic obstructive pulmonary disease (COPD) by ICD10 [24], the comparison between patients and Mie Prefecture was made for COPD and asthma, respectively.

Calculation of life expectancy by life-table method

The abridged life table method [25-28] was used to calculate life expectancies of patients for ages of 0-84 years (5-year intervals). The fraction of the last age interval of life [25] was used to construct an abridged life table. Those fractions were calculated from a complete life table for the census years of 1975-2000 (every 5th year) respectively, in Japan [29]. The number of patients was those on October 1 for each year; the number of death was an average over $\pm$2 years of the census year. Standard error (SE) for life expectancy was estimated by Chiang method [25-28, 30,31]. By the same method, life expectancies for whole population of Mie prefecture were calculated from data of Mie Prefecture [22] for the same period as patients.

Potential gains in life expectancy

Techniques for partial multiple decremental life tables [26,32] were

used to find the corresponding life expectancies for patients and for the population of Mie Prefecture by elimination of death due to respiratory diseases, viz, chronic bronchitis, pulmonary emphysema, asthma, pneumonia and acute bronchitis but cancer. The potential gains in life expectancy were the differences between the life expectancies when these causes were removed and when they were presented.

Results

For all causes, mortality rates were significantly higher in patients than in the population of Mie Prefecture, excepting males in 1975 and females in 1980 (Fig 1). Mortality rates from COPD and asthma were also higher in patients. By contrast, mortality from all other causes was not significantly different between the two groups.

Life expectancies for patients and Mie Prefecture are shown in Table 3. For all ages (except for males of 80–84 years in 1985), life expectancies of both males and females were significantly reduced in patients as compared with Mie Prefecture, for 1975–2000. As shown in Table 4, the reduction in life expectancy was larger in younger patients; and differences among age-classes became smaller during the observation period.

The potential gains in life expectancy for patients and Mie Prefecture by elimination of the mortality from respiratory diseases (see above) are shown in Table 5. Patients showed larger gains in life expectancy for all age classes.

Discussion

Mortality rates of COPD and asthma of patients were significantly higher than those of the whole Mie Prefecture for 1975–2000. By contrast, the differences were not significant for other illness. Patients also showed

shorter life expectancy as compared with whole Mie Prefecture. As life expectancy was calculated based on the death rate, it seems that the shortening of the expectation of life reflected high mortality rates of patients.

Potential gain in life expectancies for 1975–2000 was more greatly prolonged in patients when death from respiratory diseases was eliminated for both males and females. The excess in the potential gain in life expectancy in the patients seems almost as same as the differences in life expectancy between patients and Mie Prefecture (Table 4), suggesting that the reduction in life expectancy could have been attributed to the respiratory mortality. As this was prominent for males in particular, it is suggested that such influence had been great in males.

The studies on Yokkaichi Asthma had focused mainly on the effects of SO_2 and/or sulfuric acid mists [1,7,33] whereas those in other countries have shown that SO_2 + SP or SP alone lead to adverse health effects [11–18]. However, monthly prevalence of respiratory disease during the period from 1962–65 was significantly correlated with corresponding values of SO_2 as well as the amount of dust fall in Yokkaichi area, although the level of total SP and dust fall in this area were reported not to be high [2,7]. It had been suspected that low pH value of dust contributed to Yokkaichi Asthma problems [7,33].

No increased cardiovascular mortality had been observed in residents of Yokkaichi area [10] whereas the elevated mortality from COPD and asthma were reported [1–10]. Increase in cardiovascular mortality has not been demonstrated in the registered patients of Yokkaichi Asthma, either [3,8,9]. By contrast, it has been demonstrated that SO_2 causes increase in cardiovascular mortality [15,17,34] and hospital admission rate [17,35,36]. The reason for this discrepancy remains to be elucidated.

Thus, the present study revealed the adverse health effects of the victims after the improvement of air pollution and no new excess incidence of COPD and asthma due to pollution since 1988, although it is suggested that there may be an error in the estimates of life expectancies by Chiang method when

the population size is smaller than 1000 [37]. As asthmatics are sensitive to air pollutants such as SO_2, SP, ozone and nitrogen dioxide [38], the increased respiratory mortality observed here may suggest that the patients are sensitive to such air pollutants. Adequate measures for protecting their health are still important.

Conclusions

Mortality and life expectancies were adversely affected in the Yokkaichi Asthma patients due to increase in death from respiratory diseases, although the air pollution had been solved.

Authors' contributions

PG carried out statistical analyses including life-table methods and prepared the first draft. KY conceived the study, participated in its design and coordination, and helped to draft the manuscript. MS wrote a program for the life-table analysis. HK participated in data collection and coordination of the study.

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Figure legend

Figure 1. Age-adjusted mortality rates in Yokkaichi Asthma patients() and whole population of Mie Prefecture () (per 100,000 population). COPD = chronic bronchitis and pulmonary emphysema.

* $p < 0.05$

Table 1. Numbers of survival[a] and death[b] for Yokkaichi Asthma patients

Sex		1975	1980	1985	1990	1995	2000
Males							
	Survival	396	439	420	389	327	281
	Death	63	91	78	82	50	46
Females							
	Survival	369	417	421	422	372	317
	Death	41	41	60	58	49	55

[a]On October 1.

[b]Sum over 5 years (± 2 years of each year).

Table 2.Number of death[a] by causes

Causes	Sex	1975	1980	1985	1990	1995	2000
Respiratory Diseases							
Chronic bronchitis	Males	4	10	6	5	2	5
	Females	1	4	8	2	8	2
Pulmonary emphysema	Males	4	2	0	3	1	2
	Females	0	0	1	3	0	0
Asthma	Males	6	15	10	20	6	6
	Females	7	9	8	10	5	7
Respiratory cancer	Males	0	3	5	3	3	4
	Females	0	1	0	2	0	1
Others[b]	Males	5	9	18	12	11	6
	Females	7	1	11	5	4	7
Other than respiratory diseases							
	Males	44	52	39	39	27	23
	Females	26	26	32	36	32	38

[a] Sum over 5 years (± 2 years of each year)
[b] Respiratory diseases other than above.

Table 4 Reduction in life expectancy (years) in patiens as compared with Mie Prefecture[a]

Ages(years)	1975	1980	1985	1990	1995	2000
Males						
0–4	4.52	13.59	11.50	8.54	–	–
5–9	4.68	14.43	12.10	9.06	2.57	–
10–14	4.77	14.56	12.21	9.15	2.63	1.51
15–19	2.49	14.64	12.29	9.20	2.68	1.55
20–24	2.82	14.91	12.57	9.44	2.84	1.74
25–29	3.20	15.20	12.86	9.74	0.76	1.96
30–34	3.43	15.43	13.09	9.93	0.95	2.15
35–39	3.80	7.18	13.32	10.10	1.11	2.35
40–44	4.36	5.14	6.06	10.35	1.30	2.59
45–49	3.97	5.52	6.43	6.80	1.59	2.89
50–54	3.36	6.07	6.10	5.89	1.99	3.31
55–59	1.81	5.59	5.42	5.19	2.59	3.87
60–64	0.43	3.66	3.27	4.89	1.99	4.64
65–69	0.63	3.76	3.15	4.02	2.72	5.14
70–74	0.94	3.33	2.32	3.05	2.41	4.85
75–79	0.76	1.01	1.34	1.58	2.05	2.88
80–84	0.32	0.43	0.01	1.29	0.57	0.58
Females						
0–4	5.27	10.44	13.88	–	–	–
5–9	6.10	11.09	14.44	8.79	7.49	–
10–14	6.19	11.15	14.51	8.85	7.53	–
15–19	6.25	11.19	14.56	8.88	7.56	5.46
20–24	6.36	11.29	14.64	5.40	7.61	5.54
25–29	6.52	11.42	14.74	5.49	7.69	5.64
30–34	6.67	1.94	14.85	5.60	7.78	5.73
35–39	6.86	2.06	7.02	5.70	7.88	5.84
40–44	7.09	2.26	7.19	5.86	8.02	5.98
45–49	7.40	2.54	6.07	6.04	8.22	6.19
50–54	4.33	2.86	5.32	4.38	8.50	6.47
55–59	3.29	2.65	4.47	4.76	7.52	6.82
60–64	1.93	3.22	4.02	4.77	6.61	7.26
65–69	1.10	2.40	3.59	4.35	6.84	5.95
70–74	1.21	1.83	2.59	3.07	4.86	4.80
75–79	0.23	1.25	2.37	2.41	3.97	1.89
80–84	0.07	0.00	0.98	0.62	0.87	0.04

[a]Caculaded from Table 3.

Table 5 Potential gains in life expectancy(years) by elimination of mortality from respiratory diseases[a]

	1975		1980		1985		1990		1995		2000	
Ages(years)	Patients	Mie	Patients	Mie	Patients	Mie	Patients	Mie	Patients	Mie	Patients	Mie
Males												
0-4	-	0.50	-	0.50	-	0.52	-	0.59	-	0.64	-	0.62
5-9	-	0.49	-	0.45	-	0.51	-	0.57	-	0.63	-	0.60
10-14	-	0.48	-	0.45	-	0.51	-	0.57	-	0.63	-	0.60
15-19	-	0.46	-	0.44	-	0.50	-	0.57	-	0.63	-	0.60
20-24	-	0.46	-	0.44	-	0.50	-	0.57	3.54	0.62	-	0.60
25-29	-	0.46	-	0.44	-	0.49	-	0.56	-	0.62	-	0.60
30-34	-	0.46	2.89	0.44	-	0.49	-	0.55	-	0.61	-	0.60
35-39	-	0.45	3.77	0.44	-	0.48	-	0.55	-	0.60	-	0.59
40-44	3.18	0.45	-	0.44	-	0.48	-	0.55	-	0.60	-	0.59
45-49	3.30	0.45	-	0.43	4.30	0.48	-	0.55	-	0.60	-	0.59
50-54	3.47	0.45	4.05	0.43	4.46	0.48	5.19	0.55	-	0.59	-	0.60
55-59	3.94	0.45	4.31	0.43	4.78	0.48	4.68	0.55	3.70	0.59	-	0.59
60-64	1.94	0.44	3.85	0.43	4.50	0.47	4.50	0.54	3.13	0.59	-	0.59
65-69	2.17	0.41	3.23	0.41	3.82	0.47	3.38	0.53	3.21	0.57	2.99	0.57
70-74	1.45	0.36	2.83	0.37	2.67	0.43	3.23	0.49	3.22	0.52	2.73	0.54
75-79	1.08	0.25	1.72	0.29	1.46	0.34	1.39	0.41	2.53	0.42	2.84	0.44
80-84	0.46	0.11	0.77	0.13	0.60	0.16	0.89	0.19	0.93	0.21	0.91	0.23
Females												
0-4	-	0.36	-	0.33	-	0.32	-	0.34	-	0.34	-	0.32
5-9	-	0.32	-	0.30	-	0.31	-	0.32	-	0.34	-	0.31
10-14	-	0.31	-	0.30	-	0.30	-	0.32	-	0.34	-	0.31
15-19	-	0.31	-	0.30	-	0.30	-	0.32	-	0.34	-	0.31
20-24	-	0.31	-	0.30	-	0.30	-	0.31	-	0.34	-	0.31
25-29	-	0.30	2.20	0.29	-	0.29	-	0.30	-	0.34	-	0.31
30-34	-	0.30	-	0.29	13.52	0.29	-	0.30	-	0.33	-	0.31
35-39	-	0.30	-	0.29	-	0.29	-	0.30	-	0.33	-	0.30
40-44	-	0.30	-	0.28	5.53	0.29	-	0.29	-	0.33	-	0.30
45-49	4.57	0.29	-	0.28	-	0.28	2.92	0.29	-	0.32	-	0.30
50-54	4.14	0.28	2.72	0.28	3.14	0.28	-	0.28	3.25	0.32	-	0.30
55-59	3.48	0.27	-	0.28	3.30	0.28	2.03	0.28	1.94	0.31	-	0.29
60-64	3.85	0.26	2.79	0.27	3.45	0.27	2.08	0.27	2.07	0.31	2.22	0.28
65-69	2.67	0.25	2.12	0.25	3.22	0.25	2.21	0.26	2.12	0.30	2.46	0.27
70-74	2.45	0.22	1.74	0.23	2.29	0.23	1.82	0.23	2.18	0.27	1.43	0.25
75-79	1.97	0.17	1.74	0.17	2.09	0.18	1.86	0.19	2.12	0.22	1.12	0.20
80-84	0.97	0.09	0.70	0.09	1.16	0.09	0.94	0.09	1.03	0.11	0.30	0.11

[a] See Methods section.
- = Unable to be calculated because of no deaths.

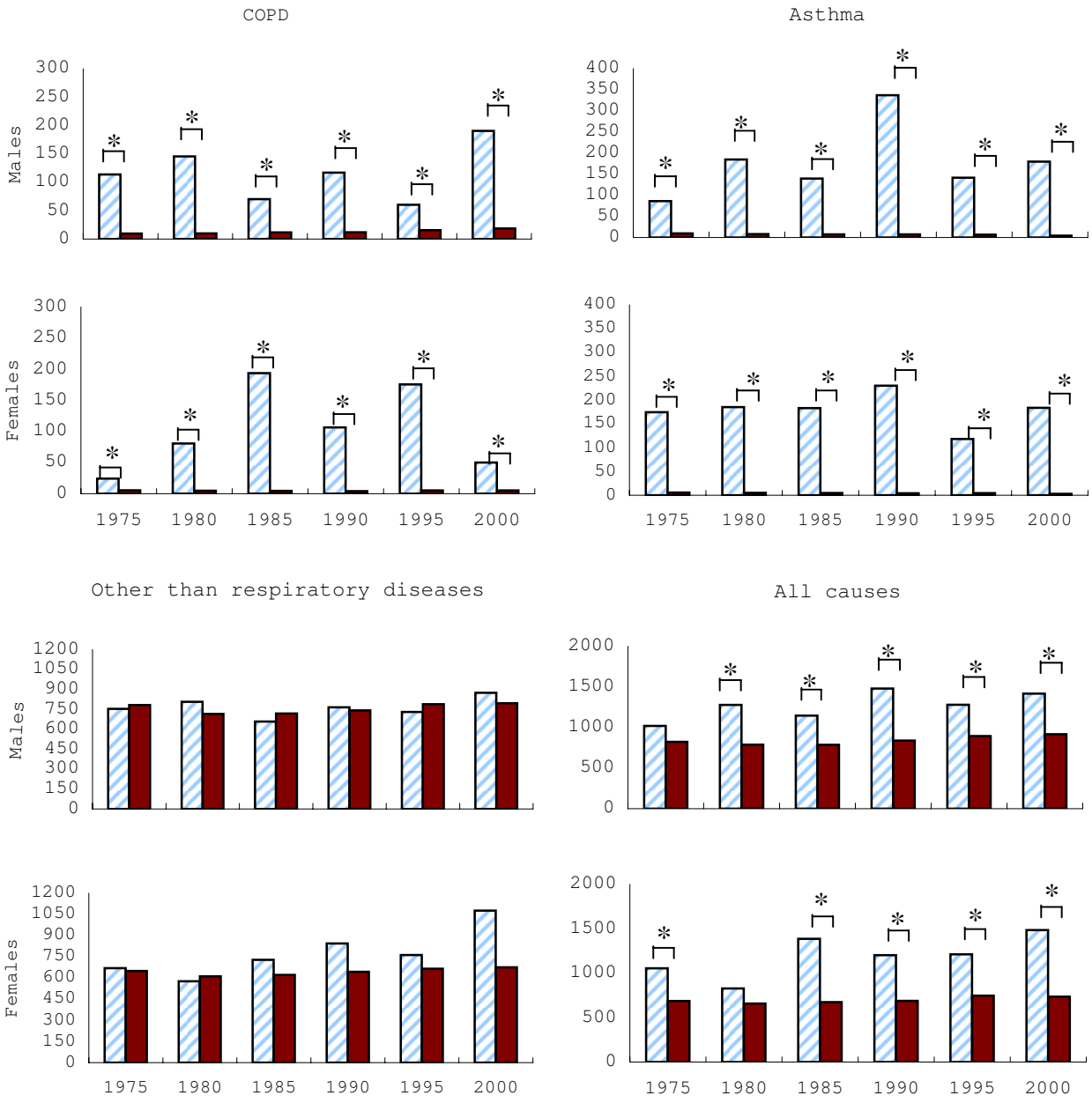
COPD
Asthma
Other than respiratory diseases
All causes
Males
Females
1975
1980
1985
1990
1995
2000

Figure 1

Additional files provided with this submission:

Additional file 1: table 3.doc, 35K
http://www.ehjournal.net/imedia/2120502800153530/supp1.doc