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Original Article

Occupational Lung Cancer Surveillance in South Korea, 2006-2009

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Objectives: The lung cancer mortality in Korea has increased remarkably during the last 20 years, and has been the first leading cause of cancer-related deaths since 2000. The aim of the current study was to examine the time trends of occupational lung cancer and carcinogens exposure during the period 2006-2009 in South Korea, by assessing the proportion of occupational burden.
Methods: We defined occupational lung cancer for surveillance, and developed a reporting protocol and reporting website for the surveillance of occupational lung cancer. The study patients were chosen from 9 participating university hospitals in the following 7 areas: Seoul, Incheon, Wonju, Daejeon, Daegu, Busan, and Gwangju.
Results: The combined proportion of definite and probable occupational lung cancer among all lung cancers investigated in this study was 10.0%, 8.6%, 10.7%, and 15.8% in the years 2006 to 2009, respectively, with an average of 11.7% over the four-year study period. The main carcinogens were asbestos, crystalline silica, radon, polyaromatic hydrocarbons (PAHs), diesel exhaust particles, chromium, and nickel.
Conclusion: We estimated that about 11.7% of the incident lung cancer was preventable. This reveals the potential to considerably reduce lung cancer by intervention in occupational fields.

Key Words: Occupational cancer, Lung cancer, Surveillance, Occupational disease burden, Asbestos

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Introduction

South Korea has experienced rapid industrialization and urbanization during the last 50 years. Marked socio-economic development has been taking place in South Korea during these years, along with the westernization of eating habits and increased driving rates. These changes have affected the pattern of cancer incidence and mortality in South Korea. Cancer has been the most common cause of death in Korea since 1983 and is a major public health concern [1]. The incidence rate for all cancer combined increased by 2.6% annually from 1999 to 2005 [2]. The lung cancer mortality in Korea has increased remarkably during the last 20 years [3], and has been the first leading cause of cancer-related deaths since 2000 [4].

The discussion of the scientific evidence linking cancer to environmental and occupational exposures has been an area of contention for the past three decades, since the assertion in 1977 by Higginson and Muir that 80% of all cancers were due to environmental exposures [5]. Doll and Peto [6] reviewed the largely avoidable factors of cancer such as life-style and other environmental factors [6]. Doll and Peto provisionally estimated that the proportion of current U.S. cancer deaths attributed to occupational factors is 2-8% (lung cancer being the major contributor to this).

If the proportion of lung cancer deaths attributed to occupational factors in South Korea is provisionally estimated as 10% [5,6], the lung cancer deaths due to occupational origin would have been 1,427 in South Korea in 2007. But this kind of estimate of the contribution of cancer deaths due to occupation can be underestimated because it fails to account for the limitations in the data on which the estimate is based. Most exposure data can be available only at large scaled industries. So it is important to find hidden cases by surveillance activities to overcome these kinds of limitation. Once reports of work-related conditions are received by a health agency, they must be analyzed, interpreted, acted upon, and summarized for dissemination. Surveillance activities facilitate reporting of new cases, a necessary first step in controlling occupational cancer.

The aim of the current study is to report the results for the time trends of occupational lung cancer and carcinogens exposure during the period 2006-2009 in South Korea.

Materials and Methods

We developed reporting protocol and reporting website for surveillance of occupational lung cancer [7]. Nine university hospitals in 7 areas, such as Seoul, Incheon, Wonju, Daejeon, Daegu, Busan, and Kwangju, participated in this occupational lung cancer surveillance during the period from 1st march 2006 to 31st November 2009, with 3,353 patients being interviewed.

We collected data about the population characteristics (age, sex, residential address, name and address of working factory), clinical information about lung cancer (diagnostic name of disease, date at diagnosis, diagnostic methods, pathological diagnosis), and exposure information about occupational carcinogens (kinds of carcinogen, occupation, industry classification of working factory, exposure periods, latent periods). Occupations were classified according to the Korean Standardized Classification of Occupations (KSCO) which is modified from the International Standardized Classification of Occupations (ISCO) [8].

The surveillance case definition of occupational lung cancer includes the criteria A, B, and C below.

A. Primary lung cancer is diagnosed by the following methods

1) Radiological diagnosis: symptoms, objective findings, diagnosed by computerized tomography (CT) or magnetic resonance imaging (MRI).
2) Pathological diagnosis: biopsy, cytology, bronchoscopic biopsy or washing, diagnosed by transthoracic biopsy or diagnostic thoracostomy.

B. Exposure to carcinogens and carcinogenic process

1) Exposure to confirmed carcinogens and carcinogenic processes which are classified as the International Agency for Research on Cancer (IARC) group 1 .
   Based largely on the evaluations published by IARC, lists of occupational carcinogens are augmented with additional information [9,10].
2) Exposure to carcinogens IARC group 2A, excluding B1.

C. Latent periods

1) Ten years or more after exposure to carcinogens, or taking a cancer-related job
2) Less than 10 years after exposure to carcinogens, or taking a cancer-related job
   Definite cases were defined as ones satisfying criteria A plus B1 plus C1.
   Probable cases were defined as ones satisfying criteria A plus B1 plus C2, or A plus B2 plus C1.
   Possible cases were defined as ones satisfying criteria A plus B2 plus C2.

We assume that occupational exposure to carcinogen means working more than 6 months at carcinogenic process at least. A "latent period" is the lag time between exposure to a disease-causing agent and the onset of the disease the agent causes. We collected data for occupational lung cancer for 2006-2009 and analyzed using SAS software (SAS Institute Inc., Cary, NC).

Table1. Portion of definite and probable occupational lung cancer during 2006-2009

Period	Number (%)				
	Definite	Probable	Possible	Suspicious	Total
2006	10 (1.8)	47 (8.2)	35 (6.1)	478 (83.9)	570 (100.0)
2007	24 (3.0)	45 (5.6)	120 (14.9)	615 (76.5)	804 (100.0)
2008	17 (1.9)	80 (8.8)	61 (6.7)	747 (82.5)	905 (100.0)
2009	26 (2.4)	144 (13.4)	98 (9.1)	806 (75.0)	1,074 (100.0)
Total	77 (2.3)	316 (9.4)	314 (9.4)	2,646 (78.9)	3,353 (100.0)

Results

We considered the following as important occupational confirmed carcinogens in South Korea: asbestos, crystalline silica, polyaromatic hydrocarbons (PAHs), diesel engine exhaust (DEE), coal tar, pitch, hexavalent chromium, nickel and nickel compounds, cadmium and cadmium compounds, arsenic, bis (chloromethyl) ether (BCME), and radon.

We also considered the following as confirmed carcinogenic processes: construction, asbestos-related, ceramic mines, welding, iron and steel founding, metal plating (chromium, nickel, cadmium), aluminium production, painter (occupational exposure), chemical manufacture including PVC (polyvinyl chloride), boot and shoe manufacture and repair, professional driving, strong-inorganic-acid mists containing sulfuric acid furniture and cabinet making.

We interviewed all 3,353 cases during 4 years from 2006 to 2009. Overall, there were 77 (2.3% of all cases), 316 (9.4%), and 314 (9.4 %) cases of definite, probable and possible occupational lung cancer, respectively. The other 2,646 cases (78.9 %) were suspicious and not related with occupation (Table 1). The kinds of occupational carcinogen detected in the lung cancer patients were as follows: asbestos, DEE, crystal silica, PAHs, hexavalent chromium, radon, nickel, pesticide (carnogenic), wood dust, dioxin, welding fume, painting, cadmium, formaldehyde, steel industry, aluminum smelting, rubber industry, plastic manufacture, and arsenic (Table 2). The most important occupational carcinogen in our study was asbestos, which accounted for 29% of all cases exposed to definite and probable carcinogens.

Table 2. Exposure to definite and probable carcinogens

	2006	2007	2008	2009	Total
Total	57	69	97	170	393
Asbestos	26	17	24	47	114
DEE	12	15	33	39	99
Crystalline silica	5	26	15	37	83
PAHs	5	9	39	6	59
Hexavalent chromium	10	16	12	9	47
Radon	2	5	13	17	37
Nickel	7	14	6	8	35
Pesticide (carnogenic)	0	0	1	23	24
Wood dust	7	2	1	10	20
Dioxin	3	3	4	5	15
Welding fume	1	3	1	7	12
Painting	0	0	4	6	10
Cadmium	1	2	3	2	8
Formaldehyde	7	1	0	0	8
Steel industry	1	0	4	0	5
Aluminum smelting	0	0	2	0	2
Rubber industry	0	0	1	0	1
Plastic manufacture	0	0	1	0	1
Arsenic	0	1	0	0	1

DEE: diesel engine exhaust, PAHs: polyaromatic hydrocarbons.

The risk groups for occupational lung cancer due to asbestos were as follows: elementary workers in construction, ship engineers, building boiler fitters and mechanics, ship mechanics, building demolition workers, automobile mechanics, welders, cement and lime production-related machine operators, railroad train mechanics, building facilities, electrical fitters and mechanics, plumbers, interior carpenters, construction managers, cleaners, water treatment plumbers, ship assemblers, electric train drivers, bricklayers, and metal casting machine op-

Table 3. Risk groups for occupational lung cancer due to asbestos

KSCO	No.	%
Elementary workers in construction (91001)	16	14.0
Ship engineers (23723)	14	12.3
Building boiler fitters and mechanics (75351)	10	8.8
Ship mechanics (75220)	10	8.8
Building demolition workers (77293)	7	6.1
Automobile mechanics (75109)	7	6.1
Welders (74309)	6	5.3
Cement and lime production-related machine operators (84331)	4	3.5
Railroad train mechanics (75232)	4	3.5
Building facilities, electrical fitters and mechanics (76221)	3	2.6
Plumbers (79290)	3	2.6
Interior carpenters (77244)	3	2.6
Construction managers (14111)	2	1.8
Cleaner (94119)	2	1.8
Water treatment plumbers (79211)	2	1.8
Ship assemblers (85432)	2	1.8
Electric train drivers (87103)	2	1.8
Bricklayers (77251)	2	1.8
Metal casting machine operators (84110)	2	1.8
Steel structure builders (77112)	1	0.9
Building painters (77361)	1	0.9
Building repairers (77391)	1	0.9
Ore and metal furnace operators (84141)	1	0.9
Armed forces (A1)	1	0.9
Construction finishing-related technical workers (77399)	1	0.9
Textile processing machine operators (82119)	1	0.9
Die and mold makers (74110)	1	0.9
Agricultural machinery fitters and mechanics (75391)	1	0.9
Plasters (77310)	1	0.9
Automobile engineers and researchers (23536)	1	0.9
Ship engineers and researchers (23537)	1	0.9
Sheet metal makers (74220)	1	0.9
Total	114	100.0

KSCO: Korean Standardized Classification of Occupations.

erators (Table 3).

Discussion

The definite and probable carcinogens in this study were asbestos, PAHs, DEE, crystalline silica, radon, hexa-valent chromium, and nickel. Crystalline silica, cadmium, nickel, arsenic, chromium, diesel fumes, beryllium, and asbestos have been well established as lung cancer carcinogens in previous studies such as job-exposure matrix studies [11] and CAREX [12,13].

Asbestos is a carcinogen causing diseases such as mesothelioma and lung cancer in humans. Its use sharply increased in Korea in the 1970s as Korea's economy developed rapidly. As its use was only recently banned, previously applied asbestos still causes many problems [14].

DEE is an important carcinogen to occupational lung cancer [15,16]. A French study [17] did not consider DEE as an occupational carcinogen. Our study showed that occupational groups exposed to DEE in South Korea are taxi, truck, and bus drivers, automobile engine mechanics, and traffic controllers.

Crystalline silica is a definite carcinogen which affects several sectors of industry such as quarry workers, granite polishing, construction workers, tunneling workers, concrete casting and sandblasting activity [18,19]. In this study, cement dust and wood dust are recognized as important contributors to occupational lung cancer in South Korea. Lung cancer incidence may be increased in groups exposed to cement dust occupationally, because cement dusts contain the potent carcinogens crystalline silica and hexa-valent chromium. Recent studies have claimed wood dust to be an occupational carcinogen in lung as well as head and neck cancers [20-23].

Surveillance case definitions for occupational illnesses are intended for specific applications such as the use of state health departments to facilitate standardized counting of cases and to help set priorities for follow-up of reported cases; consequently they may differ from the case definitions used in clinical medicine [24]. The criteria applied to epidemiologic surveillance for prevention efforts may not be as "strict" as those used in clinical medicine or in epidemiologic studies of disease etiology. Likewise, our proposed epidemiologic case definitions may differ from the criteria used to determine compensability and disability. We tried to make less tight our surveillance case definition, because we wanted many clinicians to participate in reporting cases.

The percentage of definite and probable occupational lung cancers was 11.7% among all lung cancers investigated in this study. This result is comparable with a previous French study18 in which 11.3% of male cancers were associated with occupation, but only 4.3% of female cases. The cases associated with occupation may have been as high as 24.9% if the possible cases were also involved. In 1995, Landrigan and Baker maintained that Doll and Peto's estimate of the contribution of cancer deaths due to occupation was too low and that it failed to take into account the limitations on the data on which the estimate was based [25]. In Great British, the proportion of cancers attributable to occupational exposures was 4.9% (men, 8%; women, 1.5%) [26]. The proportion of cancers attributable to occupational exposures in France in 2000 was 2.7% of all male cancers and 0.3% of all female cancers [18]. The fraction identified as work-related lung cancer is often underestimated, even in countries with advanced reporting systems for work-related cancers. After applying the CAREX [12,13] exposure estimate to each industry sector, Mosavi-Jarrahi et al estimated that the fraction of lung cancer attributed to carcinogens in the workplace was 1.5% (95% CI of 1.2-1.9) for females and 12% (95% CI of 10-15) for males in Iran [27].

Lung cancer is the fastest growing cancer in South Korea. Over the last 15 years, mortality from lung cancer has more than tripled. The Korea Labor Welfare Corporation approved compensation for 41 cases of lung cancer and 19 cases of mesothelioma from 1993 to 2007. Males accounted for 91.7% (55 cases) of the approved cases. The most common age group was 50-59 yr (45.0%). The statistics pertaining to asbestos-related occupational cancers in Korea differ from those in other developed countries in that more cases of mesothelioma were compensated than lung cancer cases. Also, the mean latency period for disease onset was shorter than reported by existing epidemiologic studies; this discrepancy may be related to the short history of occupational asbestos use in Korea [28]. Our study revealed the possibility of severe under-estimation in recognizing occupational lung cancer and a consequent under-compensation in South Korea.

Our study had some limitations, including recall bias, because exposure assessment depended only on the patients' memories. We did not collect the information about smoking habits. In addition, exposure to environmental tobacco smoke (ETS), which is an important source of occupational exposure to carcinogens in South Korea, was not included. This suggests that the percentage of lung cancer attributable to occupational origin may have been more than 11.7%. We assume that occupational exposure to carcinogen means working more than 6 months at carcinogenic process at least. This assumption is so strong that we may not detect the carcinogenic effects of new carcinogens sensitively.

Occupational exposure to carcinogens is widespread and can result in tragic consequences for exposed workers. Clinicians are in a unique position of being able to identify associations between workplace exposure and human malignancy, and virtually all occupational carcinogens have first been recognized by astute clinicians [29]. Further, occupational cancers are usually preventable, and clinicians can be very effective in triggering preventive activities by industry, unions, and public authorities.

Conclusions

The percentage of definite and probable occupational lung cancers was 11.7% among all lung cancers investigated in this study. As underreporting of occupational cancer is a major challenge, identification of new cases in clinical settings such as in this study can be very valuable.

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