Original Article

Screening of Workers with Presumed Occupational Methanol Poisoning: The Applicablility of a National Active Occupational Disease Surveillance System

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A B S T R A C T

Background: Methyl alcohol poisoning in mobile phone–manufacturing factories during 2015–2016 was caused by methyl alcohol use for cleaning in computerized numerical control (CNC) processes. To determine whether there were health complications in other workers involved in similar processes, the Occupational Safety and Health Research Institute conducted a survey.
Methods: We established a national active surveillance system by collaborating with the Ministry of Employment and Labor and National Health Insurance Service. Employment and national health insurance data were used. Overall, 12,048 employees of major domestic mobile phone companies and CNC process dispatch workers were surveyed from 2016 to 2017. We investigated methyl alcohol poisoning by using the national health insurance data. Questionnaires were used to investigate diseases due to methyl alcohol poisoning.
Results: Overall, 24.9% of dispatched workers were employed in at least five companies, and 23.9% of dispatched workers had missing employment insurance history data. The prevalence of blindness including visual impairment, optic neuritis, visual disturbances, and alcohol toxicity in the study participants was higher than that reported in the national health insurance database (0.02%, 0.07%, 0.23%, and 0.03% versus 0.01%, 0.07%, 0.13%, and 0.01%, respectively, in 2015). Moreover, 430 suspicious workers were identified; 415 of these provided an address and phone number, of whom 48 responded (response rate, 11.6%). Among the 48 workers, 10 had diseases at the time of the survey, of whom 3 workers were believed to have diseases related to methyl alcohol exposure.
Conclusion: This study revealed that active surveillance data can be used to assess health problems related to methyl alcohol poisoning in CNC processes and dispatch workers.

1. Introduction

Methanol is a class of hydrocarbons composed of carbon, hydrogen, and oxygen. From mid-2015 to 2016, acute visual impairment caused by methanol poisoning occurred consecutively in 7 workers at 3 mobile phone part manufacturers in Korea. Workers who had symptoms of poisoning were mainly working on aluminum cutting for mobile phones in computerized numerical control (CNC) processes. The Ministry of Employment and Labor surveyed the workplaces where the incidents occurred and confirmed that low-priced methanol was used instead of ethanol, which is less toxic as an aluminum cutting solution. In addition, workers with visual impairment were exposed to high concentrations of methanol during product cleaning [1].

Workers with symptoms of methanol poisoning can experience severe health effects such as acute visual impairment, optic neuritis, and respiratory failure. In previous studies, it was found that workers were commonly young (in their 20s and 30s) and were frequently dispatched as employees for subcontractors [2–4]. In addition, the majority of individuals with methanol poisoning are dispatch workers.

In June 2016, the Ministry of Employment and Labor recognized the seriousness of methanol poisoning and therefore requested that the Occupational Safety and Health Research Institute (OSHRI) conduct an epidemiological study to identify any additional cases of methanol poisoning. The OSHRI thus attempted to establish a national active surveillance system for the first time, and we identified the workers with presumed occupational methanol poisoning. This system could potentially overcome the limitations of the existing regional surveillance system, which is confined to specific regions (i.e., Gumi, Incheon, and Busan) [5], allowing for a national survey.

The aim of this study was to construct the first-ever national active surveillance system in Korea and to prevent disease aggravation from workers with presumed occupational methanol poisoning. In addition, we aimed to identify the health status and workplace characteristics of smartphone CNC process workers with methanol poisoning.

2. Materials and methods

In this study, three steps were followed to establish the national active surveillance system. First, the labor inspector of the Ministry of Employment and Labor surveyed the workplace to identify workers who were at high risk of methanol exposure. Second, the data regarding employment insurance and national health insurance were linked to identify methanol poisoning−related diseases. Third, the work history was confirmed and the work-relatedness between methanol poisoning and work was assessed via phone interviews and mail questionnaires that were sent to workers with methanol poisoning−related diseases (Fig. 1).

2.1. Study participants

To identify the workers involved in similar processes, workers' specific health examination data and employment insurance data were examined. However, there is no information on CNC processes or dispatching companies. To obtain information about the CNC process workers, the Ministry of Employment and Labor requested the cooperation of mobile phone manufacturers, especially dispatch companies, to share the company's employee lists and employees' personal information. A labor inspector directly visited 269 workplaces to identify workers who were subcontracted in major domestic mobile phone−manufacturing companies or who were CNC process owners. The mobile phone manufacturers provided information on both original workers and dispatched workers. When labor inspectors identified CNC process workers, they also determined whether they were dispatch workers. The initial list of workers was compiled from June to July 2016, followed by a total of four additional field examinations conducted from July 2016 to July 2017. Overall, 12,048 workers identified via the field surveys were selected for inclusion in the study (Fig. 1). Among the study participants, 1,607 workers had experience as dispatch workers. The information for the selected workers was linked with employment insurance data to collate the final database. The period of inquiry for the employment insurance was from 2012 to July 2017. We verified each worker's working period, past workplace name, and employment insurance status recorded in the employment insurance database. We used the 7th Korean Standard Classification of Disease and Cause of Death code for this study.

2.2. Linking national health insurance data

The OSHRI provided the National Health Insurance Service (NHIS) with identification numbers for the included study participants (12,048 workers). The NHIS searched for workers with diagnoses of blindness, optic neuritis, and visual impairment; in addition, they searched for workers with obvious toxic side effects of alcohol consumption. Visual impairment and optic neuritis are often complicated by endocrine diseases; therefore, diabetes and thyroid dysfunction were also included. These data were then provided to the OSHRI. The inclusion criterion in the NHIS is workers with ophthalmic impairment such as blindness, optic neuritis, visual disturbances, and alcohol toxicity. The 7th Korean Standard Classification of Disease and Cause of Death codes for blindness including visual impairment (H54), optic neuritis (H46−H47.7), visual disturbances (H53), and alcohol toxicity (T51) were searched. In total, we searched from the main diagnoses to the fourth subdiagnoses. When the NHIS provided information of four diseases from 2002 to 2015, the medical initiation date was also provided. A new case was defined when the start date of any of the four diseases was between 2002 and 2015. Overall, 430 workers were identified with ophthalmologic impairment and alcohol toxicity (Fig. 1). The original study population included cases of methanol poisoning from 2016. However, because the methanol poisoning incident occurred after the national health insurance data were collected (2002−2015), some of the cases might not be included in the linkage data set. It is known that methanol poisoning could occur before 2015 because methanol is a substance that had been used occupationally for a long time. Therefore, we included all the information available from the NHIS database since 2002.

The NHIS provided all data sets with unique identification numbers that did not contain any personal information.

The data linkage and analysis process was described in Fig. 2. In this study, when the Ministry of Employment and Labor selected the study participants, the OSHRI requested the NHIS data linkage of study participants to identify workers with ophthalmic impairment, retracking the information of workers with ophthalmic impairment. The data collection by the Ministry of Employment and Labor, the request for data linking through the NHIS, and requests for information were repeated.

2.3. Phone interview and mail questionnaire

Additional telephone and mail surveys were conducted to assess the causality between work and the methanol poisoning for the 430 suspected workers. We mailed the questionnaires twice to 415 workers whose postal codes were confirmed. At the same time, a telephone survey was conducted for 104 workers whose telephone numbers were confirmed. Fifteen people for whom we could not confirm both telephone numbers and addresses were not investigated (Fig. 1).

The questionnaire collected information on basic characteristics (sex, birth year), occupational history, and health effects of methanol poisoning. Occupational history included date of employment, occupation (white collar, blue collar), current job task/s, and the use of methanol. We also added a question regarding whether the workers were educated on methanol risks when they were working at mobile phone−manufacturing factories. We identified the past medical history associated with sight (blindness, optic neuritis, visual impairment) and others (diabetes, hypertension, tuberculosis) to assess health effects. We added questions regarding shift work, employment type (regular, temporary, or daily), and workplace type (contractor or subcontractor) to identify workplace characteristics.

The telephone interview was conducted by three trained research assistants. The assistants directly called workers to complete the questionnaire. Postal questionnaires were conducted at the same time as the telephone interviews; they were mailed twice to increase the response rate. The mailed questionnaire was
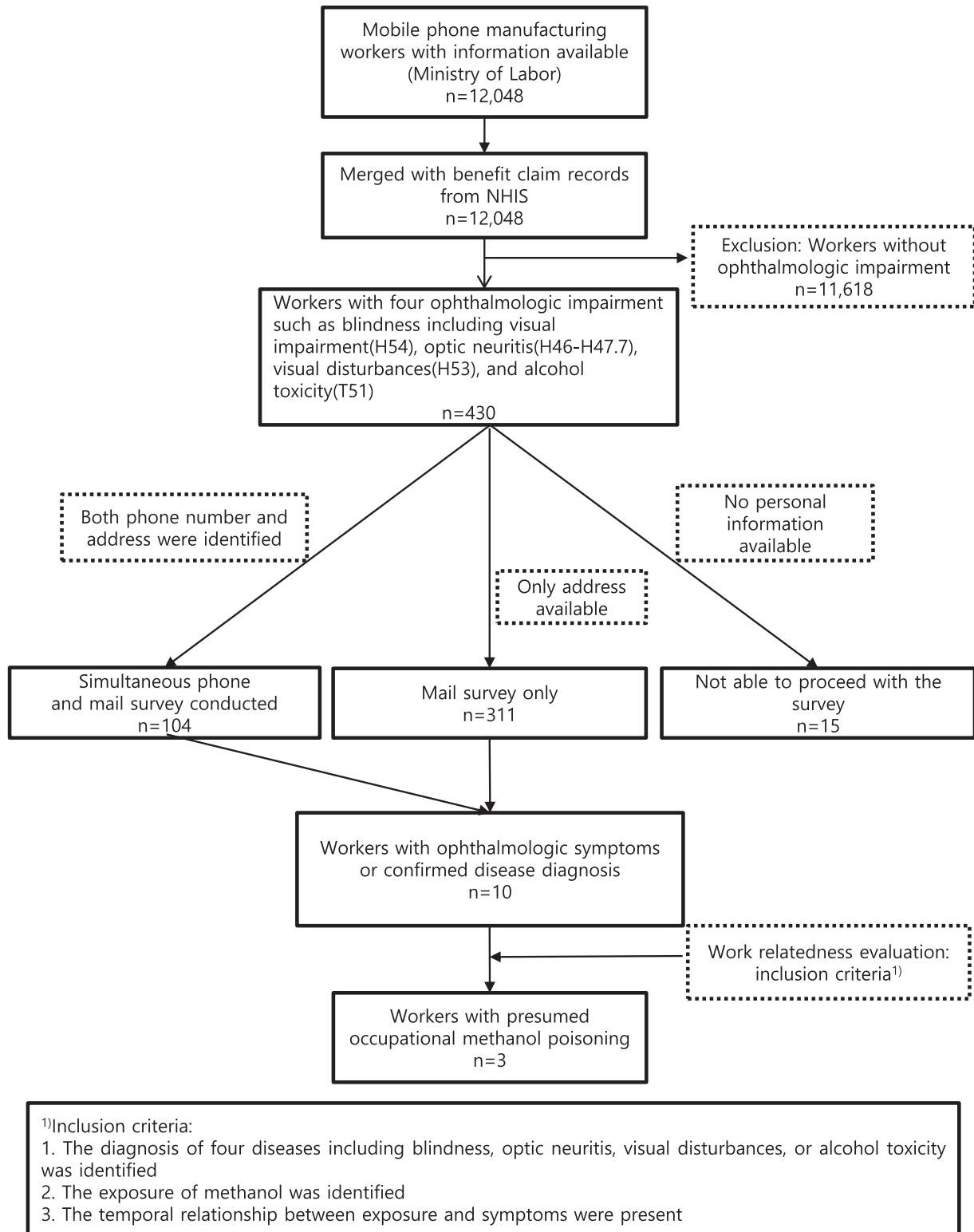
Fig. 1. Selection of workers with methanol poisoning. NHIS, National Health Insurance Service.

identical to the telephone questionnaire. A letter, questionnaire, and mailing envelope were inserted into each mailing envelope and were sent to 415 people whose addresses were confirmed. In the enclosed mailing envelope, a postage stamp was attached in advance so that the mail could be sent without any additional cost to participants.

2.4. Definition of methanol poisoning cases

Eye-related methanol poisoning symptoms were evaluated via the postal and telephone surveys. Overall, 10 workers were identified with symptoms related to methanol poisoning. To evaluate their work-relatedness, all the data, including employment

Fig. 2. Data linkage and analysis process. CNC, computerized numerical control.
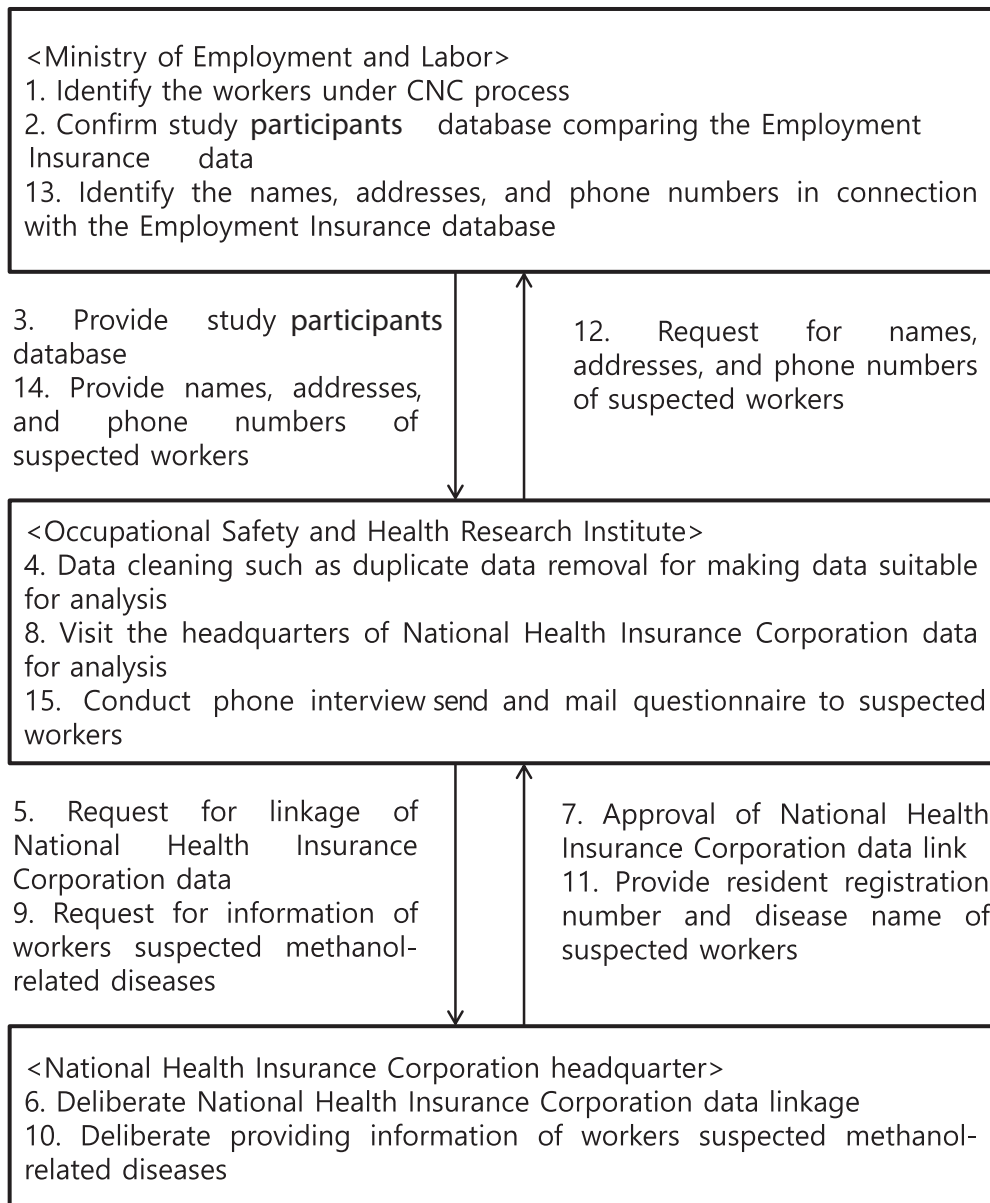
insurance, national health insurance, specific health examinations, and work environment assessments, were used. To identify methanol poisoning, the diagnosis of four diseases including blindness, optic neuritis, visual disturbances, and alcohol toxicity must be identified, the exposure of methanol must be identified, and the temporal relationship between exposure and symptoms should be present. The majority of the information was collected through the survey questionnaire. However, some respondents did not remember that they had been diagnosed with eye diseases and methanol poisoning, while others knew the disease name differently. To ensure validity, the data of the 10 respondents were linked with the NHIS data.

2.5. Ethical consideration and legal basis

This study was classified as a proactive epidemiological investigation by the Ministry of Employment and Labor and was conducted according to Article 43-2 of the Occupational Safety and Health Act. The Minister of Employment and Labor was able to request that the related organizations share necessary information for epidemiological investigation at any time. In addition, the NHIS committee deliberated to retracing the data of suspected patients. Later, the data were linked to employment insurance data.

3. Results

3.1. General characteristics of the study population (n = 12,048)

The age and gender distribution of the study participants is described in Table 1. Among the 12,048 participants, 7,295 (60.6%) were males and 2,442 (20.3%) were younger than 30 years. The majority of males aged 30−39 years (n = 2,884, 39.5%), while the majority of females aged 40−49 years (n = 1,319, 27.8%). Overall, 1,607 (13.3%) workers had been dispatched at some point (data not shown). Of the dispatched workers, 861 (53.6%) were dispatched to

Table 1
Distribution of study participants stratified by sex and age (n = 12,048)

Age (years)	Male		Female		Total	
	No.	%	No.	%	No.	%
<30	1,561	21.4	881	18.6	2,442	20.3
30 to 39	2,884	39.5	1,104	23.2	3,988	33.1
40 to 49	1,791	24.6	1,319	27.8	3,110	25.8
50 to 59	802	11	1,103	23.2	1,905	15.8
≥60	257	3.5	346	7.3	603	5
Total	7,295	60.6	4,753	39.5	12,048	100

work for subcontractors for the two Korean enterprises that manufacture smartphones.

3.2. Distribution of dispatched workers and their health effects (n = 12,048)

Table 2 shows the employment insurance data of 12,048 participants from 2012 to July 2017. Overall, 9,070 (75.3%) and 2,595 (21.6%) workers were employed in at least two and five companies, respectively. Among the dispatched workers, 401 (24.9%) worked for more than five companies, while 1,436 (89.4%) worked for one manpower company and were dispatched to various subcontractor places from there. In the study, 23.9% of dispatched workers had missing data on their employment insurance history (data not shown).

Table 3 shows the distribution of dispatched workers with ophthalmologic impairment (2002−2015). In total, 430 (3.6% of total participants and 2.8% of dispatched workers) workers were identified with any of the four diseases. When we limited the analysis to workers who were diagnosed with disease after they initiated employment at the mobile phone manufacturer, the prevalence of disease was 1.2% and 1.0% of all workers and dispatched workers, respectively. Each of the four diseases accounted for 0.1% of all workers. However, among dispatched workers, the prevalence of blindness (0.1%), optic neuritis (0.2%), visual impairment (0.7%), and alcohol poisoning (0.1%) was higher than that among all workers. The prevalence of blindness including visual impairment, optic neuritis, visual disturbances, and alcohol toxicity were 0.02%, 0.07%, 0.23%, and 0.03%, respectively, in 2015. However, the prevalence of blindness including visual impairment, optic neuritis, visual disturbances, and alcohol toxicity was 0.01%, 0.07%, 0.13%, and 0.01%, respectively, in the national health insurance database in 2015 (data not shown). The proportion of patients with

ophthalmologic impairment included in the study was higher than that reported in the national health insurance database.

Workers who developed eye-related diseases in 2002−2015 were identified form the data set (n = 12,048) provided by the NHIS. As a result, 430 workers [244 men (3.4%)] were identified with eye-related diseases (Table 4). Overall, 13 (0.2%) men and 9 (0.2%) women were identified with visual impairment or blindness, and 14 (0.2%) men and 10 (0.2%) women were identified with alcohol-related toxicities.

Among the 269 companies which were the study participants' current workplaces, 29 companies conducted working environment assessments, of which seven companies measured methyl alcohol. Compared with 200 ppm exposure limit in Korea, the measurement value was 10−40 ppm at one company in 2013. For the other companies, the values were low or nondetectable. Both acute and chronic methanol poisoning symptoms can manifest; therefore, we did not restrict our inclusion criteria based on the duration of exposure.

3.3. Phone interview and mail questionnaire results (n = 415)

Of the 415 questionnaires mailed to the participants, 48 responses (response rate, 11.6%) were obtained. In total, 27 of 104 (26.0%) workers responded to the telephone surveys conducted, and 21 of 311 (6.8%) workers responded to the mail survey only. None of the telephone survey respondents replied to the mail survey.

Table 5 also shows the participant employment history. The total [mean ± standard deviation (SD)] time spent working at manufacturing companies was 90.8 ± 80.4 months. The total (mean ± SD) working time was longer in males (114.2 ± 21.8 months) than in females (68.5 ± 11.5 months). Of the respondents, 78.7% replied that they had experience working in a mobile phone part−manufacturing company and that their average (mean ± SD) working time was 44.9 ± 54.9 months. The proportion of blue-collar workers (28, 73.7%) was higher than that of white-collar workers (10, 26.3%) at the time of employment in the cell phone−manufacturing company.

The most frequent work tasks preformed were CNC operation and product inspection (14, 35.9%), followed by inspection and packaging (9, 23.1%), development (2, 5.1%), and sales (2, 5.1%). Ten (26.3%) workers responded that they had mobile phone display−cleaning experience, while 28 (73.7%) workers did not. Fifteen (40.5%) workers answered that they had handled methanol while working at the mobile phone−manufacturing companies. Twenty-

Table 2
Number of workplaces and dispatched workers among the study participants according to employment insurance data (Jan 2012 to Jul 2017)

Number of workplaces (2012−2017)	Workers without dispatch experience		Workers with dispatch experience				Total	
	No	%	Number of outsourcing and subcontracting companies		Number of dispatched companies		No	%
			No	%	No	%		
1	2,544	24.4	434	27	1,436	89.4	2,978	24.7
2	2,359	22.6	302	18.8	120	7.5	2,661	22.1
3	1,923	18.4	267	16.6	40	2.5	2,190	18.2
4	1,421	13.6	203	12.6	9	0.6	1,624	13.5
5~10	2,101	20.1	388	24.1	2	0.1	2,489	20.7
≥11	93	0.9	13	0.8	—	0	106	0.9
Total	10,441	100	1,607	100	1,607	100	12,048	100

Table 3
Distribution of dispatched workers with ophthalmologic impairment from National Health Insurance Survey (NHIS) data

Diseases		Total cases			Cases after employment with the specified company		
		Nondispatch	Dispatch	Total	Nondispatch	Dispatch	Total
All diseases	No	385	45	430	133	16	149
	%	3.7	2.8	3.6	1.3	1	1.2
Blindness	No	19	3	22	10	1	11
	%	0.2	0.2	0.2	0.1	0.1	0.1
Optic neuritis	No	93	9	102	13	3	16
	%	0.9	0.6	0.8	0.1	0.2	0.1
Visual disturbances	No	260	29	289	5	11	16
	%	2.5	1.8	2.4	0	0.7	0.1
Alcohol toxicity	No	20	4	24	15	1	16
	%	0.2	0.2	0.2	0.1	0.1	0.1
Total workers		10,441	1,607	12,048	10,441	1,607	12,048

Table 4
Frequency of patients with visual impairment, including blindness, optic neuritis, visual disturbances, and alcohol-related toxicity, stratified by sex (2002—2015)

Disease	Men	%	Women	%	Total	%
Blindness (including visual impairment) (H54)	13 (7)*	0.2	9 (3)	0.2	22 (10)	0.2
Optic neuritis (H46—H47.7)	53 (26)	0.7	49 (38)	1	102 (64)	0.8
Visual disturbances (H53)	167 (84)	2.3	122 (76)	2.6	289 (160)	2.4
Alcohol toxicity (T51)	14 (6)	0.2	10 (8)	0.2	25 (15)	0.2
Total	244 (122)	3.4	186 (121)	3.9	430 (243)	3.6

* Indicates the number of patients who had endocrine diseases (such as diabetes and thyroid disease).

two (64.7%) workers replied that they did not receive any education on methanol hazards.

3.4. Screening of workers with presumed occupational methanol poisoning

The survey identified a total of 10 workers with eye-related symptoms such as visual impairment, optic neuritis, and glaucoma; other toxic effects of methanol, including alcoholic depression, were identified (Table 6). We conducted a work-relatedness evaluation of ten workers. The criteria were as follows: workers who worked at a mobile phone part—manufacturing factory and remembered exposure to methanol, workers who had a subjective symptom and were diagnosed with a visual impairment at the hospital, workers who were diagnosed with a disease after starting to work at the mobile phone manufacturer. Based on the work-relatedness evaluation criteria, three workers (Case 1, 4, and 10) were estimated to have a high possibility of occupational methanol poisoning.

Case 1 was diagnosed with toxic effects of methanol and visual impairment in 2013, which occurred while working at a mobile phone—manufacturing plant (2007—2014). In addition, Case 1 was a blue-collar worker and stated that she did not clean mobile phone displays but did handle methanol. She was involved in mobile phone assembly at work; however, she did not have education regarding methanol hazards. At the time of this study, she was working at another workplace and was still handling methanol. Case 4 replied in the questionnaire that he had amblyopia, but he was diagnosed with visual impairment in July 2015 as reported in the national health insurance database. The diagnosis was made approximately 6 months after he left the mobile phone—manufacturing plant (January 2015). Case 4 was a blue-collar worker, and he used methanol to clean the mobile phone displays. Case 10 stated that she was diagnosed with toxic effects of methanol and visual impairment in 2015. This was while she was

employed at a mobile phone part—manufacturing factory (2006—2015). Case 10 was a blue-collar worker, and she used methanol to clean mobile phone displays. For the remaining seven workers, it was determined that the work-relatedness of methanol poisoning was low. Cases 2, 3, 6, 8, and 9 did not satisfy the temporal relationship because the period in which disease was diagnosed occurred before employment by the mobile phone—manufacturing factory. Cases 5 and 7 were not exposed to methanol in the workplace.

To prevent aggravation of disease, three workers who were presumed to have methanol poisoning (Cases 1, 4, and 10) were provided guidance on ophthalmology and claims were made for workers' insurance through individual contact.

4. Discussion

The aim of this study was to identify additional cases of methanol poisoning on a national scale. Most cases of methanol poisoning were a result of accidental ingestion. Exposure in chemical laboratories that have old ventilation facilities [6] and poisoning due to a leak accident in a refrigerant production plant have been reported [7]. However, the methanol poisoning incident that occurred in 2016 occurred in a group of workers who conducted CNC cleaning work in the smartphone-manufacturing processes. We conducted this study to identify and characterize additional patients involved in a similar process.

We found that 13.3% of the workers had experience working as dispatchers and that they were frequently excluded from benefits such as employment insurance. In addition, 24% of the dispatched workers had more than five workplaces, and their workplaces changed frequently; there were many short-term workers. Among the study participants, only those who experienced blindness, optic neuritis, visual impairment, and methyl alcohol toxicity were classified as those who were treated after they were employed by the related company. Among all workers, the prevalence of all diseases was 0.1%. However, among dispatched workers, blindness (0.1%), optic neuritis (0.2%), visual impairment (0.7%), and methyl alcohol toxicity (0.1%) were more frequent than among all workers. Because dispatched workers have more work-related health problems than regular workers, active management of these workers is necessary.

The main diagnoses to the fourth subdiagnoses were selected for study participants in the NHIS data. There might have been overestimation of study participants because inclusion criteria were from main diagnoses to fourth subdiagnoses. However, the purpose of this methanol active surveillance was to find out all suspected workers with methanol poisoning; thus, overestimation would be better than nondetection. Moreover, selection of workers

Table 5
General characteristics and employment history of survey respondents by age group and sex (n = 48)

Characteristics	Male (n = 24)	%	Female (n = 24)	%	Total (n = 48)	
Survey type						
Telephone	16	66.7	11	45.8	27	56.3
Mail	8	33.3	13	54.2	21	43.8
Age (years)						
20–29	5	20.8	3	12.5	8	16.7
30–39	8	33.3	3	12.5	11	22.9
40–49	6	25.0	4	16.7	10	20.8
50–59	5	20.8	13	54.2	18	37.5
≥60	0	0.0	1	4.2	1	2.1
Total working period at manufacturing company (months)	114.2	±21.8	68.5	±11.5	90.8	±80.4
Ever worked in a mobile phone part–manufacturing company						
Yes	19	79.2	18	78.3	37	78.7
No	5	20.8	5	21.7	10	21.3
Working period (months)	33	±10.6	54.7	±15.0	44.9	±54.9
Currently working						
Yes	3	15.0	0	0.0	3	7.9
No	17	85.0	18	100.0	35	92.1
Occupation						
White collar	7	35.0	3	16.7	10	26.3
Blue collar	13	65.0	15	83.3	28	73.7
Duty						
CNC machining and product inspection	7	38.9	7	33.3	14	35.9
Inspection and packaging	0	0.0	9	42.9	9	23.1
Development	2	11.1	0	0.0	2	5.1
Sales	1	5.6	1	4.8	2	5.1
Others	8	44.4	4	19.0	12	30.8
Mobile phone display cleaning						
Yes	4	20.0	6	33.3	10	26.3
No	16	80.0	12	66.7	28	73.7
Methyl alcohol use						
Yes	7	36.8	8	44.4	15	40.5
No	9	47.4	5	27.8	14	37.8
unknown	3	15.8	5	27.8	8	21.6
Education on methyl alcohol exposure hazards						
Yes	5	31.3	7	38.9	12	35.3
No	11	68.8	11	61.1	22	64.7

systems have disadvantages as they are limited to workers who can visit the hospital. This highlights the need for national monitoring systems [10]. The study by Kang et al. [10] reported that Korea would benefit from a national monitoring system because it would allow for the collation of specific health examination, work environment assessment, and industrial accident compensation data for central organizations. To our knowledge, our study is the first to use comprehensive national data on employment insurance, national health insurance, specific health examinations, and work environment assessments to monitor the entire workforce nationwide.

Active surveillance is required for disease monitoring. The existing hospital-based surveillance systems include data only on suspected patients with occupational diseases who visited the emergency room or hospital outpatient clinics. If workers do not visit the hospital, she/he will not be evaluated by a doctor; thus, the existing system entails passive monitoring. However, if national data are used, researchers could use statistical techniques to perform active surveillance [5]. For example, if methanol poisoning occurs, it would be possible to search the linked national surveillance system to determine if there was ophthalmic disease and if an employee had experience working in an environment in which methanol exposure might occur. This would allow for the early selection of workers with a temporal relationship, and thus, the active identification of cases with poisoning could be possible.

Active surveillance systems are also preferential as workers who have had previous illnesses and patients who are currently experiencing symptoms can be included. In regional surveillance systems, if a worker had symptoms in the past, but she/he is no longer present, the worker will not be included in the monitoring system if she/he did not visit the hospital. In contrast, the use of national data will allow us to investigate historical data; therefore, we have an understanding of past medical conditions. Thus, previous occupational diseases that might have been missed could be included in the active surveillance system.

The use of active surveillance systems can possibly reduce the frequency of recall bias regarding previous job history. The regional surveillance system confirms previous job performance by interviewing patients suspected of occupational diseases. However, as time goes on, workers are less likely to remember their work duties. Depending on the presence or absence of their symptoms, the exposure level may be inflated. When exposure to hazardous substances was measured in a self-reported manner, it was identified that the exposure of workers with current symptoms was higher than that of workers without symptoms [11]. If harmful factors handled in the workplace are verified via the results of the work environment assessment and duplicate verifications can be made by the specific health examinations, it might be possible to reconstruct the past work history with a reduction in recall bias. In addition, if employment data are used to identify businesses in which there is likely to be exposures to methyl alcohol (mobile phone–manufacturing subcontractors or CNC process owners), it could be helpful in confirming objective job history related to disease outbreaks.

Despite these advantages, several tasks need to be addressed to build a national monitoring system. The first is to collaborate with the multiagency that owns the data. Currently, the Ministry of Employment and Labor has the jurisdiction over employment insurance, specific health examination, and work environment assessment data. Hospital health records are managed by the NHIS. For acute poisoning diseases, such as methyl alcohol poisoning, to be included in the surveillance system network, the integrated data must exist in advance. In this study, it took more than 2 months to collaborate with the Ministry of Employment and Labor and the NHIS to gain access to and link the data. This is a long time for the

suspected to have methanol poisoning using three criteria was performed in the surveys, and this could be a complement of overestimation.

To identify additional cases of methanol poisoning on a national scale, the OSHRI attempted to build a national occupational disease–monitoring system by comprehensively using national data such as employment insurance, national health insurance, specific health examination, and work environment assessment data. This national system was believed to have various advantages in comparison with the existing regional monitoring system.

It is preferable to conduct national surveys rather than regional surveys. Existing studies have established surveillance systems for specific areas in Korea, such as Incheon, Daejeon, Gumi, and Yeocheon [8]. The aforementioned studies established central monitoring headquarters linked to local medical institutions. This allowed for the establishment of a health-care delivery system or an information-sharing network and for the sharing of information on newly identified occupational diseases among medical personnel [9]. However, these regional occupational surveillance

Table 6
Work-relatedness assessment of the influence of methyl alcohol on the occurrence of disease among 10 workers with ophthalmologic symptoms or confirmed disease diagnosis

Characteristic	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
Sex	Female	Female	Male	Male	Female	Male	Male	Female	Female	Female
Age (years)	54	57	49	23	52	53	59	50	44	39
Health effects (survey results)										
Symptom or diagnosis (year of diagnosis)	Decreased vision	Decreased vision	Decreased vision	Amblyopia	Decreased vision	Optic neuritis (2012)	Glaucoma	Decreased vision	Decreased vision	Visual disturbances (2015) Methanol-related toxicity
National health insurance (date of first diagnosis)	Methanol-related toxicity Visual disturbances (Jan 2013)	Visual disturbances (Jan 2012)	Optic neuritis (Dec 2010)	Visual disturbances (Jul 2015)	Optic neuritis (missing)	Optic neuritis (Aug 2009)	Optic neuritis (Dec 2009)	Optic neuritis (2002–2005)	Visual disturbances (Jun 2007)	Optic neuritis (Aug 2004)
Endocrine diseases	Diabetes	None	None	None	None	None	None	None	Diabetes	None
Total working period at manufacturing company (months)	60	24	No response	8	36	240	60	18	48	89
Employment history										
Blue- or white-collar workers	Blue collar	Blue collar	Blue collar	Blue collar	Blue collar	Blue collar	Blue collar	Blue collar	Blue collar	Blue collar
Joining to retirement (period)	2007.01.01 – 2014.01.01 (84 months)	2015.01.01 – 2016.01.01 (12 months)	2015.01 (Less than 1 month)	2014.12.30 – 2015.01.02 (1 month)	2015.01.01 –2015.12.31 (12 months)	2013-2016 (48 months)	No answer	2013.04 -2014.01 (10 months)	2015.09-2016.01 (5 months)	2006.03.13 -2015.10.26 (115 months)
Involved in mobile phone part manufacturing	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Duty	Assembly	CNC machining	CNC machining	CNC machining	CNC machining	Vinyl produce	No answer	Assembly and cleaning	Display cleaning	Display cleaning
Experience cleaning mobile phone displays	No	Yes	Yes	Yes	Yes	No	No answer	Yes	Yes	Yes
Methanol use	Yes	Do not know	Do not know	Yes	No	Yes	No answer	Do not know	Yes	Yes
Education regarding methanol exposure hazards	Yes	No	No	Yes	Yes	No	No answer	No	No	No
Experience as a dispatched worker	No	No	Yes	Yes	No	No	No	No	No	No
Specific health examination conducted					C2 (observation of general disease) (history taking; decreased vision) (2016)			Normal (2014)	Normal (2016)	Normal (2011, 2013)
Working environment assessed	Methanol (ND., 0 −0.9 ppm) (2012, 2015)	Methanol (ND.) (2015)						Methanol (0 −16.3 ppm) (2014, 2015)		
Claimed for workers' insurance	No	No	No	No	No	No	No	No	No	No
Work-relatedness evaluation	High	Low	Low	High	Low	Low	Low	Low	Low	High

CNC, computerized numerical control; ND, not detectable.

identification of workers with acute poisoning and thus impacts time to the implementation of any intervention. Since the Personal Information Protection Act was enacted in 2011, the process of linking national data with the resident registration number has become more difficult. After spending several months to get approval to export the data from multiple organizations, the occupational disease might have already occurred in large quantities and thus the response as a result of passive surveillance would be delayed. For proactive measurement, cooperation of related organizations is necessary, and for this, there is a need to revise relevant regulations.

The second task is to find ways to reinforce information on insufficient exposure factors in the available national data. Information on exposure hazards is essential for work-related assessments, but there are no national data sources detailing exposure hazards. In this study, it was important to know whether methyl alcohol was used in the workplace; however, there were no data on the use of methyl alcohol. Therefore, telephone and postal questionnaires were mailed to ascertain information regarding employment histories. However, the issue regarding the identification of harmful exposures could be complemented via the use of operational definitions of data. In the early 2000s, several researchers attempted to use the data from the NHIS, but the diagnoses were often inaccurate. It was found that the concordance between the infectious disease code and the actual medical record in the NHIS database was only 10.1% [12]. To address this problem, validation of the diagnosis using various operational definitions (or algorithms) was conducted. As a result, in the study conducted in 2013, the operational definition for the diagnosis of rheumatoid arthritis using the health insurance services data reached a positive predictive value and specificity of greater than 90% [13]. The same research methodology should be applied in occupational medicine. The only requirement would be to change the target variable for validation from diagnosis to the exposure to a harmful factor. For example, if you wanted to determine if you were exposed to methyl alcohol, you could compare the gold standard with the selected working population using various operational definitions [14]. To identify the harmful factors in the workplace assessment and the specific health examination data, the duplication of the businesses where the exposure is confirmed should be verified with the smartphone-manufacturing subcontractor and the CNC-owned company to increase the accuracy of the identified exposure. If there is a high positive predictive value and a high level of specificity, it might be possible that the survey conducted could be simplified. If only the workers who satisfied both the diagnosis and the workforce criteria for this study were selected, the analysis target would be much less than 430 people. This would enable us to skip the mail survey and conduct the additional job confirmation within a few days by means of a phone call.

The third task is establishing exclusion criteria; for this, the temporal relationship between exposure and disease and the workers' underlying diseases should be considered. In this study, diseases generated after CNC-related employment were also analyzed along with total disease. It was possible to conduct the analysis because the data were collected directly by the labor inspector. For other cases, workers' specific health examination data, employment insurance data, and working environment assessment data can be compared with the initiation date of the concerned medical treatment in NHIS data. However, it is difficult to identify the exact exposure starting point at present; thus, it is necessary to develop a new algorithm when integrating each data. With regard to the workers' underlying disease, it is possible to link the data with general health examination or workers' specific health examination data.

We believe that it is possible to identify and implement interventions for workers with suspected occupational diseases within a few days if there was an operational definition for data linkage in the design of the surveillance system and confirmation of the exposure hazards. In addition, if this were the case, no questionnaires would be required. We propose a follow-up study in which the surveillance system is used to identify simulated cases of actual occupational poisoning. By applying various algorithms and testing for operational definitions with the highest positive predictive value and specificity, we can maximize the benefits of this monitoring system. This will be a genuine active surveillance system and will allow for the quick and accurate detection of cases of methyl alcohol poisoning.

This study was subject to several limitations. First, there may have been some workers exposed to methyl alcohol who were not included in the study population because of the data collection by a labor inspector's field visit. With the raw data, there was no information on the type of employment insurance or specific health examinations. In addition, workers employed by dispatching companies had many short-term working contracts and thus were not able to obtain insurance. It was therefore difficult to determine exactly how many more dispatched workers were not included in the survey, based on the information that the Ministry of Employment and Labor acquired. However, the nationwide labor inspector investigated jurisdiction, and all available information nationwide was used for data collection for the included study participants. In addition, through linkage to the employment insurance data, workers' specific health examination data, NHIS data, and work environment assessment data, missing data could be supplemented. Second, only 11.6% of the included workers responded to the survey. The reason for the low response rate of this study was that mail questionnaires were 311, which was about three times than the phone interview. When separated by phone interview and mail questionnaire, the response rate for the phone interview was 26%, which was higher than that for the mail questionnaire which was 6.8% (data not shown). As a result of the privacy laws, there was no way to obtain the phone number of the mail questionnaire workers and workers with no personal information available who did not reply. Because the response rate was low, it was thought that the results were not generalizable to the entire population of workers. However, considering that 48 respondents were not chosen by the researchers, there was no difficultly in generalizing these results. Third, the evaluation of environmental exposures was insufficient. Methyl alcohol poisoning may be caused by occupational inhalation; however, most of the cases documented in the literature occurred as a result of suicide intoxication or drinking alcohol-contaminated methyl alcohol [15,16]. To evaluate the occupational impact on methyl alcohol poisoning, nonoccupational exposures must first be excluded. In this study, confirmation of nonoccupational exposures was not sufficient.

Despite these limitations, this was the first attempt to use an active national surveillance system, using the currently available national data. Through this surveillance system, we were able to identify 3 workers who were thought to be addicted to methanol and were being continuously managed to prevent worsening of disease. In future, a more complete active surveillance system should be constructed ensuring that there is multiagency collaboration and easier data linkage. In addition, operational study definitions for the identification of the harmful exposures should be used. In this study, the only harmful factor considered was methanol; however, if active surveillance systems are applied to other harmful factors, it will contribute greatly to identification and prevention of occupational diseases in Korea by complementing the existing hospital-based surveillance system. Before that,

various studies exploring active surveillance systems in various conditions are needed.

In this study, we attempted to devise an active surveillance system by using national data such as workers' specific health examination, employment insurance, NHIS, and working environment assessment data, for the first time in Korea. To do so, three steps to identify methanol poisoning among workers were used. In the future, it might be possible to construct a more complete active surveillance system if the multiagency collaboration is made early and the data linkage is made easier. In addition, it would be useful for there to be more operational definitions for the identification of hazardous exposures. Active surveillance systems using national data might play a key role in the identification and prevention of occupational diseases in Korea by complementing the hospital-based surveillance systems.

Declarations

Ethics approval and consent to participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This study protocol was approved by the Ethical Committee of the Institutional Review Board of Occupational Safety and Health Research Institute in 2016 (IRB No. OSHRI -2016-14).

Conflicts of interest

There are no conflicts of interest to declare.

Acknowledgments

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.shaw.2019.07.003.

References

[1] Kim EA, Lee J, Park G, Eom H, Shin MY. Investigation of health status of workers in similar workplace with methyl alcohol poisoning. Occup Saf Health Res Inst 2017.

[2] Ryu J, Lim KH, Ryu DR, Lee HW, Yun JY, Kim SW, Kim JH, Jung-Choi K, Kim H. Two cases of methyl alcohol intoxication by sub-chronic inhalation and dermal exposure during aluminum CNC cutting in a small-sized subcontracted factory. Ann Occup Environ Med 2016;28:65.

[3] Choi JH, Lee SK, Gil YE, Ryu J, Jung-Choi K, Kim H, Choi JY, Park SA, Lee HW, Yun JY. Neurological complications resulting from non-oral occupational methanol poisoning. J Korean Med Sci 2017;32:371—6.

[4] Kim H, Ryu J. Acute occupational poisoning in Korea. Ewha Med J 2016;39:99—103.

[5] Kim EA, Kang C, Choi H, Lee S. Korea's occupational disease surveillance system: 2012 surveillance result report. Occupational Safety and Health Research Institute; 2012.

[6] Finkelstein Y, Vardi J. Progressive parkinsonism in a young experimental physicist following long-term exposure to methanol. NeuroToxicology 2002;23:521—5.

[7] Downie A, Khattab T, Malik M, Samara I. A case of percutaneous industrial methanol toxicity. Occup Med(Lond) 1992;42:47—9.

[8] Lim J, Jang S, Kim S. Local occupational disease surveillance system in Korea: current status and issues. Ann Occup Environ Med 2001;13:101—15.

[9] Cho S, Hong Y, Lim J, Jang S, Chun B. Occupational disease surveillance system; planning and management. Ann Occup Environ Med 2001;13:10—7.

[10] Kang SK, Ji Y, An YS, Kim HO, Ha MN, Kwon HJ, Paik NJ, Kim SA, Hong JC, Kim JY, Kang DH, Jung SH, Ha EH. The present status and perspective of nationwide occupational diseases surveillance system. Ann Occup Environ Med 2001;13:116—26.

[11] Pearce N, Checkoway H, Kriebel D. Bias in occupational epidemiology studies. Occup Environ Med 2007;64:562—8.

[12] Shin EC, Park YM, Park YG, Kim BS, Park KD, Meng KH. Estimation of disease code accuracy of national medical insurance data and the related factors. Korean J Prev Med 1998;31:471—80.

[13] Cho SK, Sung YK, Choi CB, Kwon JM, Lee EK, Bae SC. Development of an algorithm for identifying rheumatoid arthritis in the Korean National Health Insurance claims database. Rheumatol Int 2013;33:2985—92.

[14] Cheng CL, Lee CH, Chen PS, Li YH, Lin SJ, Yang YH. Validation of acute myocardial infarction cases in the national health insurance research database in Taiwan. J Epidemiol 2014;24:500—7.

[15] Rostrup M, Edwards JK, Abukalish M, Ezzabi M, Some D, Ritter H, Menge T, Abdelrahman A, Rootwelt R, Janssens B, Lind K, Paasma R, Hovda KE. The methanol poisoning outbreaks in Libya 2013 and Kenya 2014. PLOS ONE 2016;11:e0152676.

[16] Paasma R, Hovda KE, Jacobsen D. Methanol poisoning and long term sequelae — a six years follow-up after a large methanol outbreak. BMC Clin Pharmacol 2009;9:5.