Ph.D. Dissertation of Jinyoung Moon

Misdiagnosis in Occupational and Environmental Medicine: A Scoping Review and the Estimation of Missed Nonfatal Occupational Injuries using the International Labor Organization Occupational Injury Datasets

- Misdiagnosis in Occupational and Environmental Medicine –

직업환경의학에서의 오진: 주제범위 문헌고찰 그리고 국제 노동 기구 (ILO) 직업성 손상 데이터를 이용한 비치명적 직업성 손상의 보고누락 규모 추정

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Jinyoung Moon

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- Misdiagnosis in Occupational and Environmental Medicine -

Advised by Professor Domyung Paek

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Public Health

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Jinyoung Moon

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Chungsik Yoon

Sung-il Cho

Seung-Muk Yi

Hyoung-Ryoul Kim

Domyung Paek

Abstract

Introduction: Even though the topic, misdiagnosis in general medicine, was dealt with in many previous studies, the topic, misdiagnosis in occupational and environmental medicine was not dealt with properly and completely in previous literature. This study aims 4 objectives: (ⅰ) The first objective is to build up a conceptual serial diagnostic framework for occupational diseases (ODs) and environmental diseases (EDs). (ⅱ) The second objective is to develop a classification framework for the causes of misdiagnoses in occupational and environmental medicine (OEM). (ⅲ) The third objective is to conduct a scoping review for delayed and wrong diagnoses in OEM. (ⅵ) The final objective is to estimate the magnitude of missed nonfatal occupational injury reporting using the International Labor Organization (ILO) occupational injury datasets.

Conceptual diagnostic framework and classification framework: With the 2 types of cognitive functions and the role of each sub-components of the social system considered, a conceptual serial diagnostic framework was devised. With reference to misdiagnosis articles in general medicine and the unique features of OEM considered, the causation model with 6 serial steps was devised.

Scoping review for wrong diagnosis (including delayed diagnosis): A total of 79 articles were included in the scoping review. For clinical specialty, pulmonology (30 articles) and dermatology or allergy (13 articles) specialty were most frequent. For each disease, occupational and environmental interstitial lung diseases (ILD), misdiagnosed as sarcoidosis (8 articles), and other lung diseases (8 articles) were most frequent. For the causation model, the first step, Knowledge base, was the most vulnerable step (42 articles). For reported articles, the frequency of false-negative (55 articles) outnumbered the frequency of false-positive (15 articles).

Original research for missed occupational injury reporting: The ratio of discovered nonfatal occupational injuries to total nonfatal occupational injuries was 0.33 (95% CI 0.28-0.40) for Convention 029, 0.13 (95% CI 0.12-0.15) for Convention 105, and 0.48 (95% CI 0.42-0.54) for Convention 087. In other words, about 52 to 87% of nonfatal occupational injuries are not being reported.

Overall discussion: Without the established criteria for the probability of causation, compensation disputes surrounding the OD or ED case would occur. The clarification of the concept between the probability of causation and relative risk is needed. According to the exposure assessment method and applied biological model, the dose-response relationship can be markedly different. Imperfect exposure assessment is another essential

problem. OEM education and training for treating physicians and understanding the intentional behaviors of stakeholders are important. Previous literature about the causes of missed nonfatal occupational injury reporting due to employers, employees, and the government, respectively, was discussed. The role of the occupational health and safety system of the society in reducing the missed nonfatal occupational injury reporting was discussed.

Keyword: Occupational and Environmental Medicine; Misdiagnosis; Causation Model; Scoping Review; International Labor Organization (ILO) statistics

Student Number: 2019-36160

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1. INTRODUCTION

1.1. Misdiagnosis in general medicine

The diagnostic processes in medicine are comprised of several steps, which involve information gathering and clinical reasoning. The final goal of diagnostic processes is to determine the health problem of a patient. In actual clinical settings, these processes occur in a rather repetitive and untidy way. Information gathering, integration, interpretation, the generation of plausible hypotheses, and the continuous updating of prior probabilities occur in serial order or sometimes in reverse order, as depicted in Figure 1 (1).

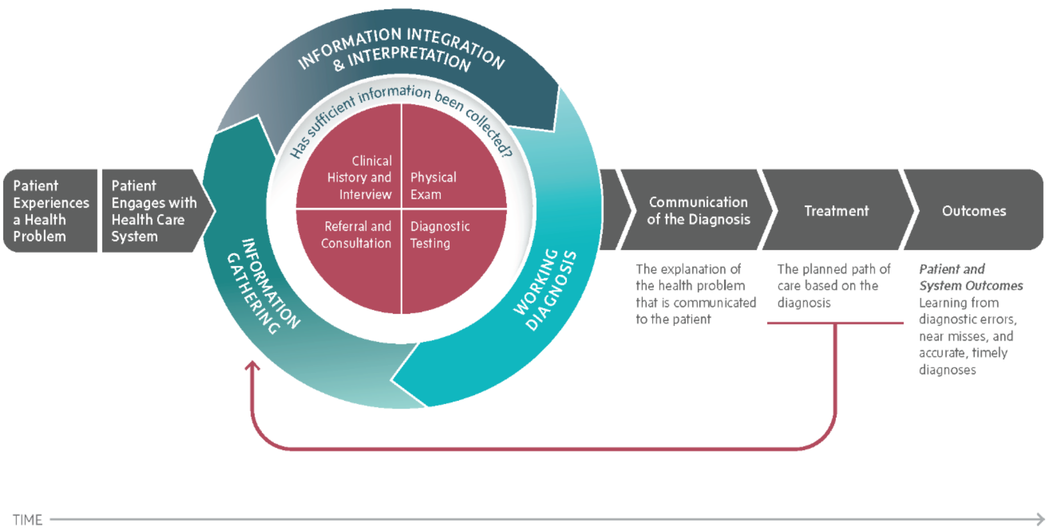


Figure 1. The conceptual model of the diagnostic process (1)

The diagnosis of a particular disease occurs in a particular work system. This work system is composed of various sub-components: diagnostic team members, tasks, medical technologies and tools, the organizational characteristics of a hospital, the physical environment in which the diagnosis is made, and the external environment covering all these sub-components (Figure 2) (2).

Diagnostic team members include patients, their families, and all health care professionals involved in their care. Tasks indicate goal-oriented actions for making a diagnosis. Technologies and tools indicate state-of-the-art and traditional medical technologies and tools, which are used during diagnostic processes. The organization includes the culture, rules, work procedures, leadership, and management considerations of the hospital in which a diagnosis is made. The physical environment indicates the physical conditions of the treatment space, such as the layout, distractions, lighting, and noise. The external environment includes all associated conditions such as the payment and care delivery system, the legal environment, and the medical-reporting environment of the society, which are covering all these sub-components (1).

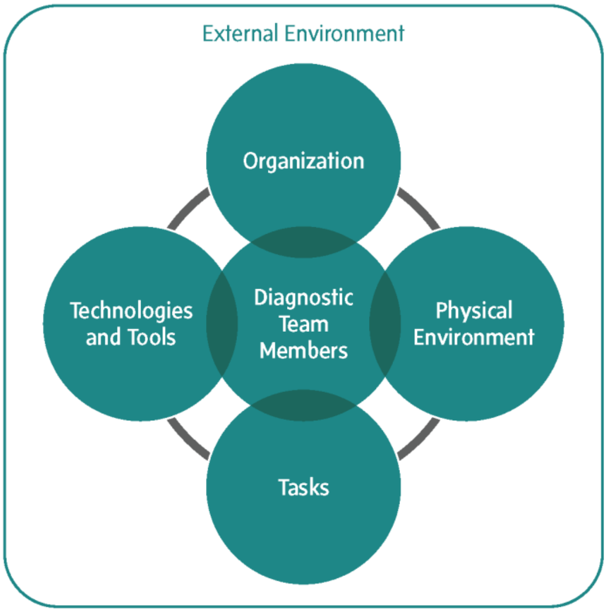


Figure 2. The sub-components of a particular work system (1)

From the general medical perspective, diagnostic errors (misdiagnoses) can be classified into 3 categories (3): (ⅰ) The first category is ‘delayed diagnosis.’ This indicates the situation when sufficient information for making a correct diagnosis had been available earlier. (ⅱ) The second category is ‘wrong diagnosis.’ This indicates the situation when another diagnosis was made before the correct diagnosis is made. (ⅲ) The third category is ‘missed diagnosis.’ This indicates the situation when no explicit diagnosis was made for a disease.

Misdiagnoses are encountered in everyday medical practice through overall medical specialties. Generally, it is believed that misdiagnoses are more common in clinical specialties (emergency medicine, internal medicine, general surgery, etc.) than in diagnostic specialties (radiology, pathology, laboratory medicine, etc.) (4). Neale et al. reported that 6% of the admitting diagnosis in British hospitals was incorrect (5). In particular, specialties requiring complex decision-making in settings with above-average uncertainty and stress (e.g., emergency medicine) reported up to 12% of diagnostic error rate (6, 7). Based on lifelong researches on diagnostic decision-making, Arthur Elstein concluded that the rate of diagnostic error would be about 10-15% in overall medical practices (8). This estimate proved reliable, according to another study (4).

1.2. Misdiagnosis in Occupational and Environmental Medicine

Diagnostic errors in OEM can also be classified into 3 categories as in general medicine (9). The first is the delayed diagnosis. This category indicates the situation when sufficient information had been available earlier. The second is the wrong diagnosis when another diagnosis can be made before the correct diagnosis was made. The third is the missed diagnosis when no diagnosis has been made.

When the misdiagnosis concept in OEM is dealt with, the definition of misdiagnosis must be classified into 2 classes. The first is (ⅰ) the misdiagnosis from the general medical perspective (‘medical misdiagnosis’): when the diagnostic criteria for other medical diseases are fulfilled. The second is (ⅱ) the misdiagnosis from the causal inference perspective (‘causal misdiagnosis’): when the occupational or environmental hazardous exposures contributed to the development of a disease. For this class of misdiagnosis, the probability of causation should have exceeded 50% (10). However, with the conservative and official characteristics of published articles considered, the reporting of this second class of misdiagnosis in OEM would be relatively scarce.

1.3. System perspective in OEM

The various social systems of society are an important environmental condition for persons living in the society (11, 12). If a person living in a country is forcibly located in another country with different social systems, including regulations, laws, conventional social rules, and background cultures, the person would be dealt with differently and would show a different performance. This concept can be applied to the diagnosis of ODs and EDs. According to the different characteristics of the social and health system and its sub-component, the diagnostic performance for ODs and EDs would be different from society to society. We will call this concept 'System Perspective in OEM" in this article.

Different sub-components in the OEM diagnostic system, including healthcare agencies and policies, research agencies and policies, OD and ED compensation system, adjudication system, administration agencies and policies, non-governmental organization, and even politics, can affect the diagnostic rate of ODs and EDs. This is because the characteristics and activities of these sub-components can affect the decision standpoint and knowledge base for the acknowledgment of an OD or ED.

1.4. Overall scope of this study

Table 1. The scope of misdiagnosis in OEM dealt with in this study

<table>
<tr><th colspan="4">Wrong diagnosis (including Delayed diagnosis)
Scoping review</th><th colspan="3">Missed diagnosis
The ILO data analysis</th></tr>
<tr><td></td><td>OD</td><td>OI</td><td>ED</td><td>OD</td><td>OI</td><td>ED</td></tr>
<tr><td>‘Medical’ misdiagnosis</td><td>○</td><td>○</td><td>○</td><td rowspan="2">X</td><td rowspan="2">○</td><td rowspan="2">X</td></tr>
<tr><td>‘Causal’ misdiagnosis</td><td>○</td><td>○</td><td>X</td></tr>
</table>

OD: Occupational Disease. OI: Occupational Injury. ED: Environmental Disease.
ILO: International Labor Organization

Before proceeding to the main body of this study, we should determine the scope of this study in dealing with misdiagnosis in OEM. The scope of misdiagnosis dealt with in this study is provided in Table 1. This study is composed of 2 main parts. The first part is a scoping review for the wrong diagnosis in OEM. This first part includes delayed diagnosis because when an occupational disease or environmental disease case is reported in the literature, a tentative initial diagnosis would be included as a wrong initial diagnosis. The second part is original research using the International Labor Organization (ILO) occupational injury datasets for missed diagnosis. The target topics are classified into ODs, Occupational Injuries (OIs), and EDs.

Another classification category is whether the misdiagnosis case is a medical misdiagnosis or a causal misdiagnosis. This causal misdiagnosis concept is a unique category solely existing in OEM, in which causal inference is essential. Except for causal misdiagnosis of ED, all other 5 categories of delayed and wrong diagnosis can be covered by the scoping review. However, the causal misdiagnosis of the ED category is so extensive to be covered in this study, and the cases in this category have not been dealt with sufficiently in published literature. Therefore, this category will not be dealt with in this study.

For missed diagnosis, original research using the ILO occupational injury datasets can not cover the ODs and EDs, only covering the OIs. However, with the various criteria for the acknowledgment of ODs and EDs among countries considered, a plausible estimation of the magnitude of missed ODs and EDs could be difficult in reality. Furthermore, no reliable, worldwide, and country-based dataset for ODs and EDs exists for the estimation of missed OD and ED magnitude. Only the ILO occupational injury datasets make the estimation of missed OIs possible using the ratification status of the ILO conventions. Therefore, we will deal with only OIs for missed diagnosis in OEM. The categories not dealt with in the result of this study will be discussed in detail in the Discussion section.

1.5. The rationale for the estimation of missed OIs using the ILO

OI datasets

The missed reporting (underreporting) of nonfatal occupational injuries is a long-discussed issue in occupational health and safety (13-15). For this missed reporting, 2 levels of cause exist; (ⅰ) individual-level causes and (ⅱ) organization-level causes (1). Using a picture of an iceberg of which only a small top portion is floating above sea level, Probst et al. (2019) are explaining that only a small fraction of total occupational injuries are being reported to the regulatory authority. Of the organizational-level causes, Rosenman et al. (2006) reported that a poor organizational safety climate and inconsistent supervisor safety enforcement are essential in inducing the missed reporting of occupational injuries (16).

However, most previous studies usually dealt with the missed reporting of nonfatal occupational injuries comparing a number of occupational injury reporting systems within the US (17-19) and did not deal with this missed reporting of nonfatal occupational injuries issue on the worldwide-scale. With the seriousness of this missed reporting of nonfatal occupational injuries issue considered, the approximate magnitude of this missed reporting should be calculated, and effective coping strategies should be devised.

The International Labor Organization (ILO) conventions are a good tool for the improvement of various organization-level causes of this missed reporting of nonfatal occupational injuries. If an ILO convention is ratified by the congress of a country, all private companies and public organizations should follow this rule that will be reflected on the country's national laws and regulations within a year. This compulsory nature of the ILO convention ratification makes all organizations in the country reduce the missed reporting of nonfatal occupational injuries. By using this phenomenon, we could estimate the magnitude of missed reporting in nonfatal occupational injury.

However, by ratifying an ILO convention, a preventive effect could be introduced on nonfatal occupational injuries. This preventive effect also should be considered when the 'revealing effect' is considered. Fortunately, we could estimate the magnitude of this preventive effect using the incidence rate of fatal occupational injuries. Fatal occupational injuries cannot be hidden because other statistic systems like the cause of death statistics collect information about the same incident (14). By using the magnitude of reduction in fatal occupational injury rate after convention ratification, we could capture the magnitude of the preventive effect, and by using this information, we could calculate the 'pure' magnitude of missed reporting in nonfatal occupational injuries.

1.6. The objective of this study

With the points dealt with until now considered, this study aims 4 objectives: (ⅰ) The first objective is to build up a conceptual serial diagnostic framework for ODs and EDs. (ⅱ) The second objective is to develop a classification framework for the causes of misdiagnoses in OEM. By this classification framework, we can understand the causes of misdiagnoses in OEM more deeply. The first and second discussion will co-constitute “the System perspective in OEM” concept. This concept could be used in future OEM researches. (iii) The third objective is to conduct a scoping review for misdiagnosis in OEM. To date, there has been no comprehensive review for misdiagnosis in OEM. However, with the potential wider implications of OD and ED considered, a comprehensive review for this topic is imperative. In this scoping review, the authors tried to organize stepwise frameworks for the diagnosis of an OD and ED. According to these frameworks, the authors tried to classify and analyze the collected articles. In addition, the distribution of misdiagnoses in OEM through each specialty of medicine and through false-negative to false-positive or both were also dealt with. By looking over the overall distribution patterns of misdiagnoses in OEM, the readers of this scoping review could understand the nature of misdiagnoses in OEM and devise possible preventive measures for reducing these misdiagnoses. (vi) Finally, the approximate magnitude of missed reporting in nonfatal occupational injury will be estimated using the ILO occupational injury data and the ratification of the ILO conventions data. Firstly, using the change of fatal occupational injury reporting rate, the preventive effect of an ILO convention will be calculated. And then, by applying the magnitude of this preventive effect on the nonfatal occupational injury reporting rate, the pure magnitude of missed reporting in nonfatal occupational injuries will be calculated. By revealing the magnitude of missed reporting in nonfatal occupational injuries, this study can give us valuable insight into the cause and coping strategies to reduce this missed reporting.

2-1. METHODS AND RESUTLS: THEORETICAL REVIEWS

2.1. A conceptual serial diagnostic framework in OEM

The diagnostic processes in OEM are divided into 2 steps. The first step is to find the most plausible explanation for the observed findings from a patient with an OD or ED. And then, the second step is the processes in which the various sub-components of the social system act as a mold for the diagnostic processes of an OD or ED.

2.1.1. To find the most plausible explanation for the observed findings

The diagnosis of an OD or ED involves identifying key features, applying comprehensive sound logics covering both explicit and implicit findings, synthesizing all these logics into a coherent story of an OD or ED development. These processes do not involve merely typical history taking and physical examination, but these processes also consider scantly observed findings from a patient importantly. These overall findings should be explained as a coherent story, based on the most appropriate disease development model, and to the best of the knowledge of an OEM physician. Considering this characteristic, the diagnostic processes in OEM require complicated mental processes involving cognition and decision-making for what story could best explain the gathered findings from a patient.

For this complex mental process, ‘Thinking, Fast and Slow’ by a Nobel Laureate, Daniel Kahneman, could provide valuable insight into the process of how the actual diagnosis is made (20). In this book, two separate cognitive processes for diagnostic reasoning are proposed. The first process is the ‘Heuristic approach’ (intuitive type 1 approach), and the second process is the ‘Analytical approach’ (systematic type 2 approach) (Table 2).

Table 2. The characteristics of type 1 and type 2 cognitive process (20)

Cognitive style	Type 1, heuristic, intuitive	Type 2, systematic, analytical
Computational principle	Associative	Rule-based
Responsiveness	Passive	Active
Capacity	High	Limited
Cognitive awareness/control	Low	High
Automaticity	High	Low
Rate	Fast	Slow
Reliability	Low	High
Errors	Relatively common	Rare
Effort	Low	High
Emotional attachment	High	Low
Scientific rigor	Low	High

Type 1 heuristic approach involves associative reasoning, passive responsiveness, high automaticity, and fast response. However, the reliability is somewhat low, accompanying errors and biases. In contrast with the type 1 approach, the type 2 analytical approach involves rule-based reasoning, active responsiveness, low automaticity, and slow response. The reliability of this approach is high, accompanying small errors and biases.

Recent findings from brain science further support this two-diagnostic-pathway theory and propose a much deeper understanding of human cognitive processes. They indicate that cognition is not just a passive perception but rather a series of predictions and error-checking by the brain. These whole processes are for making the best explanatory model of the current situation. When no errors are encountered in these processes, the brain constructs these neuronal layers into a hierarchical model set. This structure stores the perceived information as a pattern. At a later time when the brain encounters a similar situation, it uses the quick type1 heuristic processes to treat this situation.

2.1.2. The social system itself as a mold for the diagnostic processes of an OD or ED

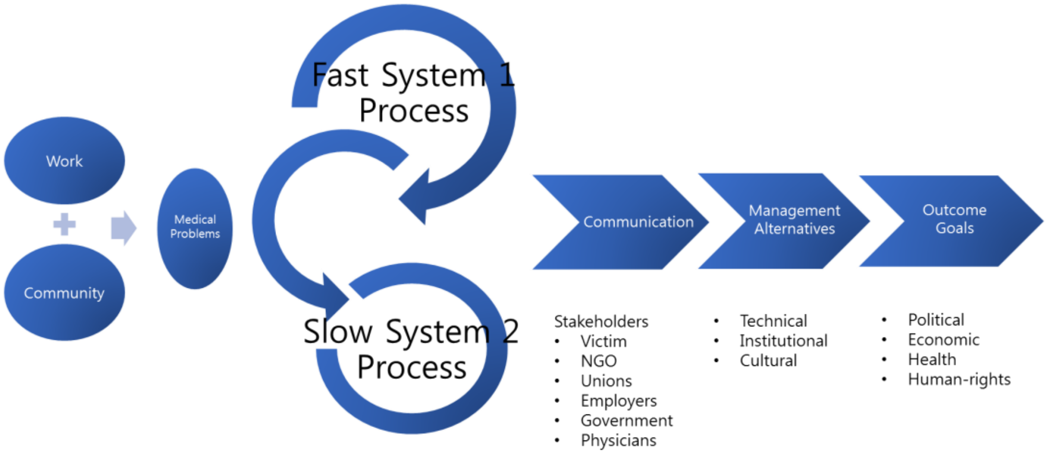


Figure 3. Diagnostic processes for an OD or ED: the role of the social system

For the presentation patterns of an OD or ED to be readily recognizable by the treating physicians, an adequate amount of knowledge for the OD or ED is a pre-requisite. This knowledge includes (ⅰ) the ideas on potential hazardous exposures, (ⅱ) various deviations from the normal health status, and (iii) a causal relationship between the hazardous potential exposures and the deviation from the normal health status. Among these sets of knowledge, in particular, the second 'various deviations from the normal health status' is composed of 3 constituents: (ⅰ) what is the baseline normal health status, (ⅱ) through what route do the persons were exposed to these hazardous exposures, (iii) if the persons had not been exposed to these hazardous exposures, how would the health status of exposed persons have changed.

To gather these types of knowledge, not only the processes for a conventional medical diagnosis but also other social context information (occupational and environmental conditions included) which might have contributed to the development or aggravation of an existing OD or ED is required. For gathering this information, the role of each sub-components of the social system is essential. These sub-components include healthcare agencies, research agencies, OD and ED compensation systems, adjudication systems, administration agencies, non-governmental organizations, all related policies, and political bodies. The activity of these sub-components and the network among these sub-components are essential for complete the overall diagnostic processes for an OD or ED. Figure 3 provides the role of these sub-components of the social system in the continuous diagnostic processes for an OD or ED.

Firstly, a suspected OD or ED patient from work or community enters into the healthcare system. In this healthcare system, the fast system 1 process and the slow system 2 process co-work to find out the possible explanation and the most plausible diagnosis for the patient. If the final OD or ED diagnosis is made, the knowledge about this OD or ED (epidemiology, risk factors, symptoms and signs, diagnosis, treatment, complications, treatment, and prognosis) is shared through various stakeholders. And then, technical, institutional, and cultural management alternatives are devised and applied to the persons subjected to the same occupational or environmental exposures. Through these processes, the final outcome goals to achieve are political, economic, health, and human-rights improvements.

For the communication among the sub-components of the social system in

Figure 3, these communications are essential for the broad sharing of related knowledge, findings, appropriate treatment options for the patient, and management alternatives for the hazardous occupational or environmental conditions. These communications constitute a network of feedbacks that contribute to the improvement of the overall processes of the diagnosis.

Finally, as for the management alternatives in Figure 3, an additional detailed explanation is needed. For an OD or ED, if available management alternatives or solutions do not exist, the identification of the OD or ED has no meaning in society. Therefore, usually, this OD or ED diagnosis is omitted. From this perspective, available technical, institutional, and cultural management options for an OD or ED themselves are encompassed into the diagnostic processes for the OD or ED. From this context, the pre-defined patterns between an OD or ED and the available management alternatives should be found in the society, for the society to diagnose the OD or ED.

2.2. A classification framework for the causes of misdiagnoses in OEM

2.2.1. Causation model for misdiagnosis of OD or ED

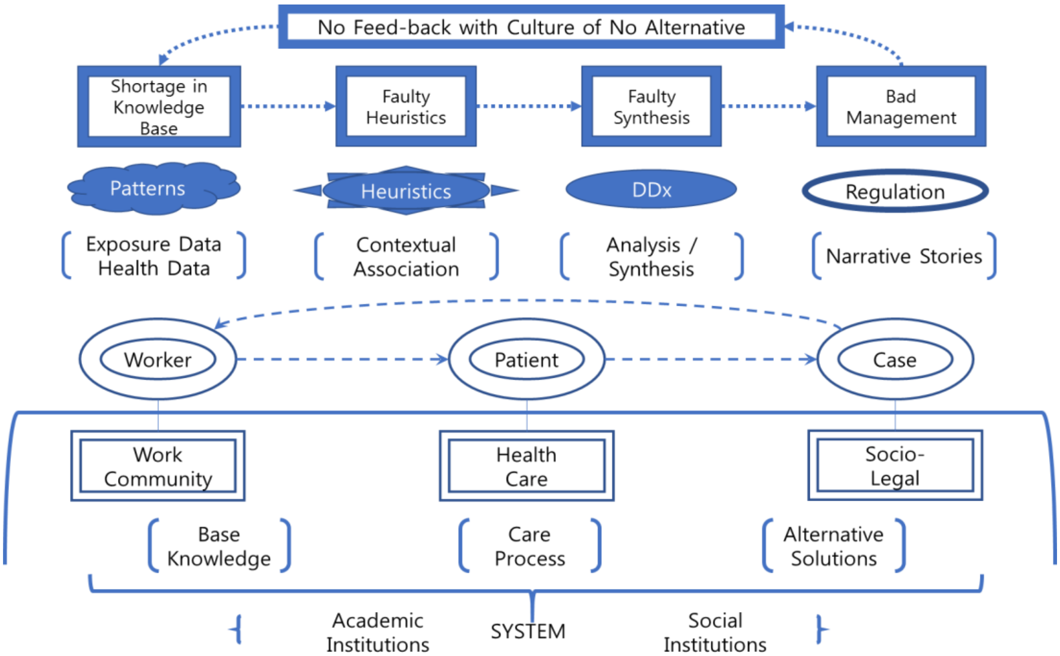
The ‘causation model’ for the classification of misdiagnoses in OEM according to the causes was devised using the concepts and definitions introduced in articles that deal with misdiagnosis in general medicine (21-24) (Table 3).

In Table 3, the causation model is composed of six serial steps: (i) In the first 'Knowledge base' step, if a physician has a deficient knowledge base for hazardous occupational and environmental exposures, the OD or ED diagnosis for a similar exposure group cannot be made. (ii) In the second 'Heuristics' step, if faulty heuristics is applied, an initial diagnosis will be incorrect. (iii) In the third 'Complete work-up' step, if complete work-ups are not conducted, a sufficient number of differential diagnoses cannot be included. (iv) In the fourth 'Diagnosis' step, if faulty synthesis is applied, the final tentative diagnosis will be incorrect. (v) In the fifth 'Management' step, if bad management is given, the treatment and preventive measures will fail. (vi) In the sixth 'Feedback' step, if the culture does not permit a diagnostic error or if there is a limited number of management alternatives, proper feedbacks to diagnostic processes and trial of other management options cannot be made. According to each step of this causation model, the selected articles were classified.

Table 3. Causation model for misdiagnoses in OEM

	Causation model					
	(ⅰ) Knowledge base	(ⅱ) Heuristics	(ⅲ) Complete work-ups	(ⅳ) Diagnosis	(ⅴ) Management	(ⅵ) Feedback
Proper work	The first case in a similar exposure group should be examined meticulously with the generation of the knowledge base.	The proper context should be generated based on recognized findings.	Complete work-ups should be done for the consideration of sufficient differential diagnoses.	A valid synthesis should be carried out.	Appropriate treatments and preventive measures should be given.	Appropriate feedback should be given to diagnosis and management.
Flaw	Shortage in knowledge Base	Faulty heuristics	Immature closure	Faulty synthesis	Bad management	No policy or social system for feedback
Consequences	The OD or ED diagnosis for a similar exposure group cannot be made.	An initial diagnosis will be incorrect	An important differential diagnosis cannot be included.	The final tentative diagnosis will be incorrect.	The treatment and preventive measures will fail	Proper feedbacks to diagnostic processes and a trial of other management options cannot be made.

2.3. System perspective model in OEM



The above part is the causation model provided in subsection 2.2.
The below part is the diagnostic process provided in subsection 2.1.

Figure 4. The system perspective model in OEM

With the conceptual serial diagnostic framework in OEM discussed in subsection 2.1 and the causation model for the classification of misdiagnoses in OEM discussed in subsection 2.2 co-considered, the system perspective model in OEM was devised (Figure 4). The upper part of this model is composed of the causation model, and the lower part of this model is composed of the main participatory agent in the serial diagnostic framework (workplace or community, healthcare agencies, and socio-legal agencies). The left part of this lower half is taken charge of by academic institutions, and the right part of this lower half is taken charge of by social institutions. In the left part, a worker or citizen becomes an OD or ED patient, and in the right part, this worker or citizen becomes a stereotyped-OD or ED case, with the spread of associated knowledge to the whole society.

2-2. METHODS: A SCOPING REVIEW

2.4. A scoping review for misdiagnosis in OEM

2.4.1. Literature search and inclusion criteria

A literature search was conducted by a medical librarian (information specialist, N.K. commented in the Acknowledgement section) in the library of one author’s affiliation (Department of Occupational and Environmental Medicine, Seoul Saint Mary’s Hospital). The medical librarian searched MEDLINE (PubMed), EMBASE, and the Cochrane Library (on 06 November 2020). Additionally, the authors searched the 3 databases on 08 January 2021 to complement the search results.

The inclusion and exclusion criteria were as follows: (ⅰ) The article deals with a misdiagnosis case or an issue related to misdiagnosis. (ⅱ) The misdiagnosis dealt with is an OD or an ED. (ⅲ) The misdiagnosis should have a meaning in the present time, considering changes in diagnostic criteria and technologies along the time. For example, before the development of Computed Tomography, there were many misdiagnoses for lung cancer. However, these cases do not have meaning because Computed Tomography became a standard imaging test for suspicious patients. (ⅳ) Both false-negative and false-positive misdiagnoses were included. (ⅴ) The publication year should be from 1990 to the present time.

(vi) If an author reported the same set of misdiagnosis series in a number of articles, only the most recent one was included. (vii) Literature in all languages was included.

Primary screening and selection of studies were conducted independently by the author.

2.4.2. Data items

Study type, subject population, initial misdiagnosis, correct final diagnosis, whether the article deals with a false-negative or false-positive case, the specialty of the doctor who made the initial and final diagnosis were summarized. For the classification between false-negative and false-positive, the OD or ED became the standpoint for classification. The content of each article was summarized in a supplementary table. Possible corrective strategies were also summarized in the table.

2.4.3. Data charting process

Finally, the distribution of misdiagnosis across each medical specialty, false-negative and –positive, and each diagnostic step of the typical framework and the causation model was summarized in a separate table, respectively.

2-3. METHODS: AN ORIGNAL RESEARCH

2.5. The estimation of the magnitude of missed nonfatal occupational injury reporting

2.5.1. The ILO occupational injury data

The ILO provides various labor data and statistics on their homepage (https://ilostat.ilo.org/). The 4 ILO data analyzed in this study are as follows: (ⅰ) Fatal occupational injuries per 100,000 workers by sex and migrant status, (ⅱ) Nonfatal occupational injuries per 100,000 workers by sex and migrant status, (ⅲ) Inspectors per 10,000 employed persons, and (ⅳ) Labor inspection visits per inspector.

2.5.2. The ratification status of ILO conventions

A total of 27 ILO conventions classified into 12 categories was used for the analyses. The conventions are classified according to the subject category in Table 4. Detailed explanation for each convention is provided in Supplementary material D.

The ratification status of each ILO convention by each country is provided on the ILO homepage (https://www.ilo.org/dyn/normlex/en/f?p=1000:11001:::NO:::).

The information was extracted and used for the analyses.

2.5.3. Descriptive analysis

All included countries were classified according to Gross Domestic Product (GDP) per person employed (constant 2011 Purchasing Power Parity $) in 2015. The GDP data were gained from the World Bank Open Data (https://data.worldbank.org/). The 9 categories for country classification are provided in Table 5.

In each GDP category, according to the ratification status of each ILO convention, the mean of reported values is provided. For all 27 ILO conventions, this descriptive analysis was conducted. For fatal injuries and labor inspectors, the figures are rounded to one decimal place. For nonfatal injuries and labor inspection visits, the figures are rounded to zero decimal places.

Table 4. The analyzed conventions classified according to the subject category

Freedom of association	Collective bargaining	Forced labor	Equality of opportunity and treatment	Tripartite consultation	Labor administration
C087	C098	C029	C100	C144	C150
C098	C151	C105	C111		C160
C135	C154		C156		
Labor inspection	Employment policy	Working time	Occupational safety and health	Social security (employment injury benefit)	Migrant workers
C081	C122	C001	C187	C102	C097
C129		C030	C155	C121	C143

Table 5. The classification of countries according to GDP per person employed in 2015

GDP per person employed (constant 2011 Purchasing Power Parity $)	Classification	Number of countries
100,000-210,000	1	16
80,000-100,000	2	19
60,000-80,000	3	20
40,000-60,000	4	34
30,000-40,000	5	25
20,000-30,000	6	25
10,000-20,000	7	35
5,000-10,000	8	30
1,500-5,000	9	25

2.5.4. Multilevel Poisson regression for the main analysis

For the calculation of risk ratios according to the ratification status of each ILO convention, a multilevel Poisson regression analysis was applied. The higherlevel unit of analysis was the classification of each country according to the GDP per person employed in 2015, and the lower-level unit of analysis was the ratification status of each ILO convention. Risk ratios are rounded to two decimal places.

2.5.5. The estimation of the magnitude of missed nonfatal occupational injury reporting

The effects of the ratification of a convention are divided into two parts. The first effect is a preventive effect reducing the incidence of occupational injuries. The second effect is a discovering effect revealing a concealed part of occupational injuries.

Through the RR for fatal injuries, the preventive effect of these ILO conventions can be inferred. From a general perspective, the occurrence of fatal injuries might be hard to be unreported because related persons would be killed from the injury. The possibility of non-reporting would be low. However, for nonfatal injuries, the occurrence of these injuries could be omitted from reporting because serious consequences might not follow this type of injury.

Precisely speaking, the RR for nonfatal injuries shows the combined effect of two origins: (ⅰ) The first part is the preventive effect of convention ratification on the already revealed nonfatal injuries. (ⅱ) The second part is the preventive effect of convention ratification on undiscovered nonfatal injuries plus the discovering effect of convention ratification on undiscovered nonfatal injuries.

Therefore, if we want to consider the two effects of convention ratification (a preventive effect and a discovering effect) in selecting the target conventions for estimating the missed nonfatal occupational injury reporting fraction, we should consider the RR for fatal injuries and RR for nonfatal injuries simultaneously. For the selection of conventions with the largest discovering effect, we selected the conventions with the least ratio value of RR for nonfatal injuries to RR for fatal injuries as the target conventions for the estimation.

For the estimation of the magnitude of missed nonfatal occupational injury reporting, the following steps were conducted in serial order: (ⅰ) As the first step, for a number of conventions with the least ratio value of RR for nonfatal injuries to RR for fatal injuries, the mean of fatal injuries and nonfatal injuries according to the ratification status of each convention was summarized in a separate table. (ⅱ) And then, by multiplying the reverse of the RR for fatal injuries by the mean of nonfatal injuries under the non-ratification of a convention, the anticipated reduced, already-discovered, nonfatal injuries can be calculated. (ⅲ) By subtracting this value from the mean of nonfatal injuries under the ratification of a convention, nonfatal injuries newly discovered can be calculated. (ⅳ) And then, by multiplying the RR for fatal injuries by the nonfatal injuries newly discovered, anticipated undiscovered nonfatal injuries before the ratification can be calculated.

(ⅴ) By calculating the ratio of the mean of nonfatal injuries under the non-ratification to the sum of the mean of nonfatal injuries under the non-ratification and anticipated undiscovered nonfatal injuries before the ratification, the ratio of already-discovered nonfatal injuries to total nonfatal injuries can be calculated. All ratios are rounded to two decimal points.

2.5.6. Statistical software

R software version 4.0.3 and package ‘dplyr’, ‘data.table’, and ‘lme4’ were used for the analyses.

3-1. RESULTS: A SCOPING REVIEW

3.1. A scoping review for misdiagnosis in OEM

3.1.1. Selection of evidence sources

Detailed search processes are in Supplementary material A-1 to A-4. By the medical librarian, a total of 1,168 articles were searched. By the authors, a total of 799 articles were searched. After excluding duplication, the authors conducted a primary selection process using the title and abstract. After this process, only 262 and 62 articles remained, respectively. A full-text review was conducted for these 262 and 62 articles. Finally, 76 articles remained. From the bibliographies of relevant articles, 3 articles were additionally searched. Finally, a total of 79 articles were included in this scoping review.

3.1.2. The characteristics and summary of individual evidence source

The characteristics of searched articles are summarized in Table 6. Of 79 articles, 25 articles were case reports, and the other 25 articles were case series. These study types were the most frequent type. Ten articles were narrative review, and 6 articles were discussion papers. Only 4 and 3 articles were cohort and case-control studies, respectively. The study period spread from 1967 to 2018. The study population was various, including a patient group in a hospital and workplace or community population.

For the specialty of the diagnosing doctor, the initial diagnosis category included OEM physicians only in 9 articles, but the final correct diagnosis category included OEM physicians in 17 articles.

The summary and possible corrective strategies for each article are provided in Supplementary material B.

Table 6. The characteristics of the final included articles

Article	Study type	Study period	Population	Initial misdiagnosis	Correct diagnosis	False (+) or (-)¶	The specialty of diagnosing doctor (the initial misdiagnosis)	The specialty of diagnosing doctor (the correct diagnosis)	Causation model€
Houle et al. (2012) (25)	Case series (retrospective)	2002-2011	St Michael's Hospital in Toronto, Ontario, Canada	Non-allergic irritant contact dermatitis	Allergic contact dermatitis (Occupational epoxy)	False (-)	Dermatology	Dermatology, OEM	[3] Complete work-ups
Griffin et al. (2018) (26)	Cohort study	2017-2018	A derivation and validation cohort in Guatemala	Acute kidney injury	Normal kidney function	False (+)	Nephrology, OEM	Nephrology	[3] Complete work-ups
Bruze et al. (2013) (27)	Case report	NA	Sweden	Allergic contact dermatitis (cobalt exposure)	Non-allergic contact dermatitis	False (+)	Dermatology	OEM	[3] Complete work-ups
Sastre et al. (2003) (28)	Case series (prospective)	NA	Spain	No asthmatic reaction	Occupational asthma (isocyanate)	False (-)	Allergy	Allergy	[3] Complete work-ups
Behrman et al. (2003) (29)	Case series (retrospective)	2000	Hospital workers in the same hospital in the US	Varicella-zoster virus infection	No infection	False (+)	OEM	OEM	[3] Complete work-ups
Stenton et al. (1994) (30)	Case report	NA	A nurse in a hospital in the UK	Occupational asthma	No asthmatic reaction	False (+)	OEM	OEM	[3] Complete work-ups
Inai et al. (2009) (31)	Discussion	2006-2007	Japan	Benign asbestos pleurisy	Mesothelioma	False (-)	Pathology	Pathology	[3] Complete work-ups
Ghio et al. (2014) (32)	Discussion	NA	US	Interstitial lung disease or other diseases	Interstitial lung disease or other diseases	False (+) and (-)	Pathology	Pathology	[3] Complete work-ups

Muller et al. (2006) (33)	Case-control study (prospective)	1997-2005	In a hospital in Germany	Sarcoidosis	Chronic beryllium disease	False (-)	Pulmonology and allergy	Pulmonology and allergy	[1] Knowledge base
Jacobs et al. (2005) (34)	Narrative review	NA	Published articles	Asthma or asthmatic bronchitis	Hypersensitivity pneumonitis	False (-)	NA	NA	[1] Knowledge base
Garland et al. (2004) (35)	Cohort study (prospective) A nested case-control study	1975-2001	The Navy Lung Disease Assessment Program in the US	Sarcoidosis	Occupational interstitial lung disease	False (-)	NA	Pathology	[1] Knowledge base
Fireman et al. (2003) (36)	Case series (prospective)	NA	In a hospital in Israel	Sarcoidosis	Chronic beryllium disease	False (-)	Pulmonology and allergy	Pulmonology and allergy OEM	[1] Knowledge base
Kucenic et al. (2002) (37)	Case series (retrospective)	1994-1999	In a hospital in the US	Non-allergic irritant contact dermatitis	Allergic contact dermatitis (Occupational allergen)	False (-)	Dermatology OEM	Dermatology OEM	[3] Complete work-ups
Hartman et al. (1998) (38)	Narrative review	NA	Published articles	Neurotoxicant exposure or primary psychiatric illness and multiple chemical sensitivity	Neurotoxicant exposure or primary psychiatric illness and multiple chemical sensitivity	False (+) and (-)	NA	NA	[1] Knowledge base
Kotloff et al. (1993) (39)	Case report	1989	A dental laboratory technician in the US	Sarcoidosis	Chronic beryllium disease	False (-)	Pulmonology and critical care	Pulmonology and critical care	[1] Knowledge base
Igata et al. (1993) (40)	Case series (prospective)	1990	Minamata city in Japan	Minamata disease or other diseases	Minamata disease or other diseases	False (+) and (-)	OEM	OEM	[4] Diagnosis
Black et al. (1993) (41)	Case series (prospective)	NA	US	Environmental illnesses or other diseases	Environmental illnesses or other diseases	False (+) and (-)	Psychiatry	Psychiatry	[4] Diagnosis
Kuratsune et	Case-control	1967-	Japan	Typical lung cancer	Occupational lung	False (-)	Pulmonology	Public health	[1] Knowledge

al. (1974) (42)	study	1969			cancer				base
Kerget et al. (2019) (43)	Case report	2012	Turkey	Other respiratory diseases	Silicosis	False (-)	Pulmonology	Pulmonology Radiology Pathology	[1] Knowledge base
He et al. (2019) (44)	Case report	NA	China	Other febrile diseases.	Tsutsugamushi disease (occupational origin)	False (-)	NA	NA	[1] Knowledge base
Wuellner et al. (2018) (45)	Interview investigation	2013-2014	US	Occupational injury and illness or Other diseases of non-occupational origin	Occupational injury and illness or Other diseases of non-occupational origin	False (+) and (-)	NA	NA	[6] Feedback
Waljee et al. (2018) (46)	Discussion	NA	US	Carpal tunnel syndrome	Nonspecific activity-related arm pain	False (+)	Orthopedics	Orthopedics	[4] Diagnosis
Dupas et al. (2013) (47)	Discussion	2007-2010	France	Asthma or allergic condition	Multiple chemical sensitivity	False (-)	NA	NA	[3] Complete work-ups
Schaumburg et al. (2005) (48)	Case series	NA	US	Neurotoxic disease	A naturally occurring nervous system disease, psychogenic illness	False (+)	Neurology	Neurology	[2] Heuristics
Egilman et al. (2004) (49)	Case report	1998	US	Asbestos-related malignant cancer	Bilateral parietal pleural plaque	False (+)	NA	NA	[6] Feedback
Menezes et al. (2003) (50)	Case report	NA	India	Other diseases	Lead poisoning (battery worker)	False (-)	Biochemistry	Biochemistry	[1] Knowledge base
Morgan et al. (1999) (51)	Discussion	NA	UK	Other diseases	Occupational diseases, general	False (-)	NA	NA	[1] Knowledge base

Corbett et al. (1999) (52)	Case series (retrospective)	1996-1997	South Africa	Pneumoconiosis or other lung diseases	Pneumoconiosis or other lung diseases	False (+) and (-)	Radiology	Pathology	[3] Complete work-ups
Hinchcliffe et al. (1997) (53)	Narrative review	NA	Published articles	Occupational noise-induced hearing loss or other hearing loss disease	Occupational noise-induced hearing loss or other hearing loss disease	False (+) and (-)	NA	NA	[1] Knowledge base
Laczniak et al. (2014) (54)	Exposure assessment	NA	US	Sarcoidosis	Chronic beryllium disease	False (-)	NA	NA	[1] Knowledge base
Riario Sforza et al. (2017) (55)	Narrative review	NA	Published articles	Idiopathic interstitial lung disease	Hypersensitivity pneumonitis	False (-)	NA	NA	[1] Knowledge base
Kadu et al. (2012) (56)	Narrative review	NA	Published articles	Other diseases	Lead poisoning	False (-)	NA	NA	[1] Knowledge base
Glazer et al. (2011) (57)	Narrative review	NA	Published articles	Idiopathic pulmonary fibrosis	Occupational or environmental interstitial lung disease	False (-)	NA	NA	[1] Knowledge base
Ansley et al. (2012) (58)	Case series (prospective)	2009-2010	UK	Asthma or exercise-induced bronchoconstriction	No lung function abnormality	False (+)	Sport and exercise science	Sport and exercise science	[3] Complete work-ups
Dudarev et al. (2013) (59)	Database analysis	1980-2010	Norway	Other diseases	Occupational diseases, general	False (-)	NA	NA	[1] Knowledge base
Kahan et al. (1996) (60)	Interview investigation	NA	Israel	Other diseases	Occupational diseases, general	False (-)	NA	NA	[2] Heuristics
Constantin et al. (2015) (61)	Case series (retrospective)	2000-2004	Romania	Other respiratory diseases	Occupational asthma	False (-)	NA	NA	[1] Knowledge base
Guarnieri et al. (2019) (62)	Case series	2016-2017	Italy	Sarcoidosis	Silicosis	False (-)	Cardiology	OEM	[1] Knowledge base

Ross et al. (2016) (63)	Case series	2012	UK	Other diseases	Methyl iodide and manganese poisoning	False (-)	Emergency	Psychiatry	[1] Knowledge base
Zhang et al. (2014) (64)	Case series	NA	China	Other diseases	N-hexane poisoning	False (-)	NA	NA	[1] Knowledge base
Lu et al. (2013) (65)	Narrative review	1985-2013	Published articles	Other lung diseases	Pneumoconiosis or silicotuberculosis	False (-)	NA	NA	[4] Diagnosis
Sauler et al. (2012) (66)	Discussion	NA	US	Other lung diseases	Chronic terminal airways and parenchymal lung disease	False (-)	NA	NA	[2] Heuristics
Baur et al. (2016) (67)	Case report	NA	Germany	Sarcoidosis	Chronic beryllium disease	False (-)	NA	NA	[1] Knowledge base
Rodriguez et al. (2005) (68)	Case report	NA	Mexico	Motor dysfunction disease	Musician's focal dystonia	False (-)	Rheumatology	Rheumatology	[1] Knowledge base
Shusterman et al. (1993) (69)	Narrative review	NA	US	Viral flu	Polymer fume fever	False (-)	NA	NA	[1] Knowledge base
Ryan et al. (1993) (70)	Case report	NA	US	Ulnar styloid fracture	Calcific tendinitis of the flexor carpi ulnaris	False (-)	Orthopedics	Orthopedics	[2] Heuristics
Tezer et al. (2011) (71)	Case series	NA	Turkey	A contagious infectious disease	Mercury poisoning	False (-)	Pediatrics	Pediatrics	[1] Knowledge base
Tonini et al. (2009) (72)	Case report	NA	Italy	Asthma	Irritant vocal cord dysfunction	False (-)	Pulmonology	OEM	[3] Complete work-ups
Chirico et al. (2016) (73)	National statistics analysis	1996-2011	Italy	Other psychiatric or stress disorder	Workplace adjustment disorder	False (-)	NA	NA	[2] Heuristics
Kales et al. (2006) (74)	Case series	2000-2003	US	Allergic reactions to natural rubber latex	Other diseases	False (+)	NA	NA	[2] Heuristics

Randhawa et al. (2010) (75)	Case series	NA	UK	Laryngopharyngeal reflux	Allergic laryngitis (Occupational origin)	False (-)	Otorhinolaryngology	Otorhinolaryngology	[1] Knowledge base
Ohtani et al. (2008) (76)	Case series	2001-2002	Japan	Idiopathic interstitial pneumonia	Chronic summer-type hypersensitivity pneumonitis	False (-)	Pulmonology	Internal medicine	[1] Knowledge base
Chan et al. (2008) (77)	Case report	NA	Ireland	Occupational overuse syndrome	Guyon's canal syndrome	False (+)	General practitioner	Hand surgery	[1] Knowledge base
Taskar et al. (2006) (78)	Narrative review	1990-2006	Published articles	Idiopathic pulmonary fibrosis	Interstitial lung disease (Occupational or Environmental origin)	False (+) and (-)	NA	NA	[1] Knowledge base
Liu et al. (2011) (79)	Case series	2000-2010	China	Other diseases	Mercury poisoning	False (-)	NA	NA	[1] Knowledge base
Galdi et al. (2005) (80)	Case report	2002	Italy	Reactive airway dysfunction syndrome	Irritant vocal cord dysfunction	False (-)	Pulmonology	Otorhinolaryngology OEM	[1] Knowledge base
Mirzaei et al. (2019) (81)	Case report	NA	Iran	Fractured orbital bone	A plastic foreign body (Occupational craniofacial injury)	False (-)	Neurosurgery	Neurosurgery	[1] Knowledge base
Papakonstantinou et al. (2017) (82)	Case report	NA	UK	Toxoplasmosis	Whipple’s disease	False (-)	Infection	Pathology	[1] Knowledge base
Mouawad et al. (2014) (83)	Case report	NA	US	Thoracic aortic rupture or dissection	Malignant mesothelioma	False (-)	Emergency department Vascular surgery	Vascular surgery	[2] Heuristics
Poole et al. (2008) (84)	Case report	NA	UK	Hand-arm vibration syndrome	Cold hemagglutinin	False (+)	OEM	OEM Hematology	[2] Heuristics

					disease				
Walusiak et al. (2002) (85)	Case report	NA	Poland	Bronchial asthma (occupational origin)	Carcinoid syndrome	False (+)	Pulmonology	OEM	[3] Complete work-ups
Greve et al. (2006) (86)	Case series	NA	US	Toxic exposure	Cognitive malingering	False (+)	OEM	Psychiatry	[2] Heuristics
Weber et al. (1999) (87)	Case report	NA	US	An insect bite or Child abuse	Phytophotodermatitis	False (-)	Emergency department	Emergency department	[1] Knowledge base
Rosal-Sanchez et al. (2002) (88)	Case report	NA	Spain	Tuberculosis	Pigeon fancier's lung	False (-)	NA	NA	[2] Heuristics
Greenspan et al. (1991) (89)	Narrative review	NA	Published articles	Other bone abnormalities	Condensing osteitis of the clavicle	False (-)	NA	NA	[2] Heuristics
Mazzei et al. (2019) (90)	Case series	2009-2017	Italy	Other lung diseases	Occupational interstitial lung diseases	False (-)	Radiology OEM	Radiology OEM	[1] Knowledge base
Center for Disease Control and Prevention (2013) (91)	Case report	2007-2009	US	Other lung diseases	Obliterative bronchiolitis (Occupational)	False (-)	Pulmonology OEM	Pulmonology OEM	[1] Knowledge base
Bouzgarrou et al. (2020) (92)	Case series	NA (6 years)	Tunisia	Allergic contact dermatitis	Occupational irritant contact dermatitis	False (-)	NA	OEM	[4] Diagnosis
Marinides et al. (2019) (93)	Case report	NA	US	Arterial gas embolism	Facial nerve baroparesis	False (-)	NA	OEM	[1] Knowledge base
Kerget et al. (2018) (94)	Case report	NA	Turkey	Sarcoidosis	Silicosis	False (-)	Pulmonology	Pulmonology	[2] Heuristics
Fiz Galende et al. (2018) (95)	Case series	NA	Spain	Virus infection	Leptospirosis	False (-)	NA	NA	[2] Heuristics

Akhter et al. (2018) (96)	Case series (prospective)	2017	Pakistan	Tuberculosis	Interstitial lung disease	False (-)	Pulmonology	Pulmonology	[1] Knowledge base
Preisser et al. (2017) (97)	Cohort study (prospective)	2012	Germany	Drug-resistant pneumonia	Allergic bronchopulmonary aspergillosis	False (-)	NA	OEM	[1] Knowledge base
Eovaldi et al. (2015) (98)	Case report	NA	US	Pelvic infection	Corpus cavernosum thrombosis	False (-)	Emergency department	Emergency department	[1] Knowledge base
Swathi et al. (2014) (99)	Case report	NA	India	Retrobulbar hemorrhage/edema	Intraconal foreign body	False (-)	Opthalmology	Opthalmology	[1] Knowledge base
Laurent et al. (2014) (100)	Cohort study (prospective)	2003-2005	France	Asbestosis Pleural plaques Fibrosis of the visceral pleura	Asbestosis Pleural plaques Fibrosis of the visceral pleura	False (+) and (-)	Pulmonology OEM	Pulmonology OEM	[4] Diagnosis
Larsen et al. (2013) (101)	Case series	2010-2012	US	Interstitial lung disease	Diffuse parenchymal pulmonary mesothelioma	False (-)	NA	Pathology	[1] Knowledge base
Mayer et al. (2011) (102)	Case report	NA	US	Chronic beryllium disease	Mycobacterium Avium-Intracellulare infection	False (+)	NA	NA	[2] Heuristics
Giannikas et al. (1998) (103)	Case report	NA	UK	A spiral fracture of the right tibia	Unrecognized foreign body (a piece of the grinder's blade)	False (-)	Orthopedics	Orthopedics	[4] Diagnosis

NA: Not Available in the article text
¶False (+) or (-) for Occupational Disease or Environmental Disease Category
€Causation model in the Methods section 2.6. Causation model for misdiagnosis of OD or ED

Table 7. Initial misdiagnoses, correct diagnoses, and the frequency

Clinical specialty (frequency)	Initial misdiagnosis	Correct diagnosis	Frequency
Dermatology or Allergy (13)	Nonallergic irritant contact dermatitis	Allergic contact dermatitis (Occupational epoxy)	2
	Allergic contact dermatitis	Non-allergic contact dermatitis	3
	Laryngopharyngeal reflux	Allergic laryngitis (Occupational origin)	1
	Asthma	Irritant vocal cord dysfunction	2
	Reactive airway dysfunction syndrome		
	Occupational asthma	No asthmatic reaction	1
	Asthma or exercise-induced bronchoconstriction	No lung function abnormality	1
	Bronchial asthma (occupational origin)	Carcinoid syndrome	1
	Other respiratory diseases	Occupational asthma	2
	No asthmatic reaction		
Pulmonology (30)	Sarcoidosis	Chronic beryllium disease	8
		Silicosis	
		Occupational interstitial lung disease	
	Asthma or asthmatic bronchitis	Hypersensitivity pneumonitis	2
	Idiopathic interstitial lung disease		
	Pneumoconiosis or other lung diseases	Pneumoconiosis or other lung diseases	2
	Idiopathic pulmonary fibrosis or other lung diseases (including Tuberculosis)	Occupational or environmental interstitial lung disease (pneumoconiosis, silicosis, silicotuberculosis, or pigeon fancier's lung)	8
	Other lung diseases	Chronic terminal airways and parenchymal lung disease, including obliterative bronchiolitis (occupational origin)	2
	Other lung diseases		
	Typical lung cancer	Occupational lung cancer	1
	Asbestos-related malignant cancer	Bilateral parietal pleural plaque	3
	Benign asbestos pleurisy	Malignant mesothelioma	2
	Thoracic aortic rupture or dissection		
	Drug-resistant pneumonia	Allergic bronchopulmonary aspergillosis	1
	Chronic beryllium disease	Mycobacterium infection (Avium-intracellulare)	1

Poisoning (10)	Other diseases	Poisoning (Lead, Methyl iodide and manganese, N-hexane, and Mercury)	6
	Neurotoxicant exposure or primary psychiatric illness and multiple chemical sensitivity	Neurotoxicant exposure or primary psychiatric illness and multiple chemical sensitivity	1
	Neurotoxic disease	A naturally occurring nervous system disease, psychogenic illness (including cognitive malingering)	2
	Viral flu	Polymer fume fever	1
Orthopedics or trauma (10)	Occupational overuse syndrome	Guyon's canal syndrome	1
	Other bone abnormalities	Condensing osteitis of the clavicle	1
	Motor dysfunction disease	Musician's focal dystonia	1
	Ulnar styloid fracture	Calcific tendinitis of the flexor carpi ulnaris	1
	Occupational injury and illness or Other diseases of non-occupational origin	Occupational injury and illness or Other diseases of non-occupational origin	1
	Carpal tunnel syndrome	Nonspecific activity-related arm pain	1
	Hand-arm vibration syndrome	Cold hemagglutinin disease	1
	Fractured orbital bone Retrobulbar hemorrhage/edema	A plastic foreign body (Occupational craniofacial injury)	2
	A spiral fracture of the right tibia	Unrecognized foreign body	1
Infection (5)	Toxoplasmosis	Whipple's disease	1
	An insect bite or Child abuse	Phytophotodermatitis	1
	Other febrile diseases.	Tsutsugamushi disease (occupational origin)	1
	Varicella-zoster virus infection	No infection	1
	Virus infection	Leptospirosis	1
Others (5)	Acute kidney injury	Normal kidney function	1
	Occupational noise-induced hearing loss or other hearing loss disease	Occupational noise-induced hearing loss or other hearing loss disease	1
	Other psychiatric or stress disorder	Workplace adjustment disorder	1
	Arterial gas embolism	Facial nerve baroparesis	1
	Pelvic infection	Corpus cavernosum thrombosis	1
General (6)	Other diseases	Occupational diseases, general	3
	Environmental illnesses (including Minamata disease) or other diseases	Environmental illnesses or other diseases	2
	Asthma or allergic condition	Multiple chemical sensitivity	1

Table 8. The number of articles according to each step of the causation model

Causation model						
Each step of the causation model	(ⅰ) Knowledge base	(ⅱ) Heuristics	(ⅲ) Complete work-ups	(ⅳ) Diagnosis	(ⅴ) Management	(ⅵ) Feedback
Frequency	42	14	14	7	0	2

Table 9. Misdiagnosis according to false-negative and false-positive

Clinical specialty (frequency)	False-negative (55)	Both false-negative and -positive (9)	False-positive (15)
Pulmonology	Occupational asthma (28, 61) Chronic beryllium disease (33, 36, 39, 54, 67) Hypersensitivity pneumonitis (34, 55, 76) Pigeon fancier's lung (88) Obliterative bronchiolitis (91) Malignant mesothelioma (83) Occupational lung cancer (42) Silicosis (43, 62, 65, 94) Interstitial lung disease (35, 57, 66, 90, 96) Mesothelioma (31, 101) Allergic bronchopulmonary aspergillosis (97)	Pneumoconiosis (52) Interstitial lung disease (32, 78) Asbestosis (100)	Occupational asthma (30, 58) Bronchial asthma (85) Asbestos-related cancer (49) Chronic beryllium disease (102)
Dermatology	Allergic contact dermatitis (25, 37) Phytophotodermatitis (87) Allergic laryngitis (75)		Latex allergy reaction (74) Allergic contact dermatitis (27, 92)
Orthopedics or trauma	Musician's focal dystonia (68) Calcific tendinitis of the flexor carpi ulnaris (70) A foreign body (81, 99, 103) Condensing osteitis in the	Workplace injury and illness (45)	Hand-arm vibration syndrome (84) Occupational overuse syndrome (77) Carpal tunnel syndrome (46)

	clavicle (89)		
Other clinical specialties	Tsutsugamushi disease (44) Methyl iodide and Manganese poisoning (63) N-hexane poisoning (64) Lead poisoning (50, 56) Mercury poisoning (71, 79) Polymer fume fever (69) Irritant vocal cord dysfunction (72, 80) Multiple chemical sensitivity (47) Adjustment disorder (73) Whipple's disease (82) Occupational disease, general (51, 59, 60) Facial nerve baroparesis (93) Leptospirosis (95) Corpus carvernosum thrombosis (98)	Noise-induced hearing loss (53) Minamata disease (40) Multiple chemical sensitivity (38) Environmental illness (41)	Acute kidney injury (26) Varicella-zoster virus infection (29) Neurotoxic disease (48) Cognitive malingering in toxic exposure (86)

The false-negative or false-positive was determined using an occupational or environmental disease as the standard.

3.1.3. Initial misdiagnosis, correct diagnosis, and the frequency for each clinical specialty

When classified according to each clinical specialty (Table 7), misdiagnoses were reported most frequently in Pulmonology (30 articles), followed by Dermatology or Allergy (13 articles). Reports in poisoning (10 articles) and Orthopedics or trauma (10 articles) were also common.

For each disease, the most frequently reported type was chronic beryllium disease, silicosis, and other occupational interstitial lung diseases (ILD) misdiagnosed as sarcoidosis initially (8 articles) and occupational or environmental interstitial lung disease misdiagnosed as idiopathic pulmonary fibrosis or other lung diseases (8 articles). Poisoning was also commonly misdiagnosed as other diseases (6 articles).

3.1.4. Classification according to each step of the typical framework and causation model

For the causation model, the first step, Knowledge base, was the most vulnerable step (42 articles). The next was the Complete work-ups step (14 articles) and the Heuristics step (14 articles). Diagnosis (7 articles) and Feedback (2 articles) steps were not free of misdiagnosis. The articles classified in each step can be checked out in Supplementary material C.

3.1.5. Classification according to false-negative and false-positive

The searched articles were classified according to false-negative and false-positive (Table 9). For reported articles, the frequency of false-negative (55 articles) outnumbered the frequency of false-positive (15 articles). Some articles reported misdiagnoses that can be false-negative or false-positive (9 articles).

3-2. RESULTS: AN ORIGINAL RESEARCH

3.2. The estimation of the magnitude of missed nonfatal occupational injury reporting

3.2.1. The result of descriptive analysis

Table 10 provides each value according to GDP classification of countries (provided in Table 5) and the ratification status of each convention. The ratification status of 0 means the ratification of the convention, and 1 means the non-ratification of the convention. Unavailable data were due to that no country exists for that specific status (the GDP classification of the country and the ratification status of the specific ILO convention).

For fatal occupational injuries per 100,000 workers, the maximum difference was 7.3 for C156, C122, C187, C102, and C097 with classification 9, and the minimum difference was -7.3 for C150, C155, and C161 with classification 9. The mean value was 0.50, and the median value was 0.7.

For nonfatal occupational injuries per 100,000 workers, the maximum difference was 4083 for C122 with classification 6, and the minimum difference was -4083 for C129, C001, C030, and C161 with classification 6. The mean value was -377, and the median value was -300.

For inspectors per 10,000 employed persons, the maximum difference was 2 for

C151 with classification 7, and the minimum difference was -5.2 for C161 and C102 with classification 7. The mean value was -0.34, and the median value was -0.2.

For labor inspection visits per inspector, the maximum difference was 306 for C098 with classification 5, and the minimum difference was -306 for C187 with classification 5. The mean value was 8.18, and the median value was 12.

3.2.2. The result of multilevel Poisson regression

Table 11 provides the risk ratios for each value according to the ratification status of each convention stratified by country classification. For fatal injuries, the results showed a statistically increased risk ratio for 13 conventions, an equivocal risk ratio for 10 conventions, and a statistically decreased risk ratio for 4 conventions. Statistically increased risk ratios mean that the ratification of the convention made fatal injuries reported to be decreased.

For nonfatal injuries, the results showed a statistically increased risk ratio for 6 conventions, an equivocal risk ratio for no convention, and a statistically decreased risk ratio for 21 conventions. Statistically decreased risk ratios mean that the ratification of the convention made nonfatal injuries reported to be increased.

For labor inspectors, the results showed a statistically increased risk ratio for 4 conventions, an equivocal risk ratio for 3 conventions, and a statistically decreased risk ratio for 20 conventions. Statistically decreased risk ratios mean that the ratification of the convention made the number of inspectors to be increased.

For labor inspection visits, the results showed a statistically increased risk ratio for 10 conventions, an equivocal risk ratio for no convention, and a statistically decreased risk ratio for 17 conventions. Statistically decreased risk ratios mean that the ratification of the convention made the number of labor inspection visits to be increased.

For the ratio of RR for nonfatal injuries to RR for fatal injuries, convention C105, C087, and C029 showed the least 3 ratio values (0.25 (95% CI 0.22-0.29) for C105, 0.28 (95% CI 0.25-0.32) for C087, and 0.32 (95% CI 0.26-0.38) for C029).

For convention 105, the RR was 1.10 (95% CI 0.97-1.24) for fatal injuries, and the RR was 0.28 (95% CI 0.27-0.28) for nonfatal injuries. The RR was 0.37 (95% CI 0.22-0.61) for labor inspectors and 0.75 (95% CI 0.73-0.77) for labor inspection visits.

For convention 087, the RR was 1.50 (95% CI 1.33-1.70) for fatal injuries, and the RR was 0.42 (95% CI 0.42-0.43) for nonfatal injuries. The RR was 0.38 (95% CI 0.24-0.59) for labor inspectors and 0.82 (95% CI 0.80-0.84) for labor inspection visits.

For convention 029, the RR was 1.90 (95% CI 1.59-2.28) for fatal injuries, and the RR was 0.60 (95% CI 0.59-0.60) for nonfatal injuries. The RR was 0.39 (95% CI 0.17-0.88) for labor inspectors and 0.14 (95% CI 0.13-0.16) for labor inspection visits.

Table 10. Each value according to country classification and the ratification status of each convention

Fatal occupational injuries per 100,000 workers (max: 7.3, min: -7.3, mean: 0.50. median: 0.7)																											
GDP classification	Ratification	C087	C098	C135	C151	C154	C029	C105	C100	C111	C156	C144	C150	C160	C081	C129	C122	C001	C030	C047	C014	C187	C155	C161	C102	C121	C097	C143
1	0	2.7	2.7	2.2	2.4	1.7	2.7	2.8	2.5	2.7	1.8	2.8	2.9	2.5	2.7	2.2	2.7	3.2	2.2	1.7	2.7	1.8	2.9	2.4	2.1	2.4	2.5	1.7
1	1	2.7	2.8	2.9	3.2	3.4	3.2	2.1	3.8	2.9	3.0	2.6	2.1	3.0	3.2	3.1	2.7	2.4	2.9	2.9	2.7	3.0	2.2	2.8	3.9	3.0	2.8	2.9
2	0	1.8	1.7	1.7	1.5	1.3	1.8	1.8	1.8	1.8	1.5	1.8	1.4	1.7	1.8	1.5	1.8	2.3	1.7	1.3	1.8	1.9	1.4	1.1	1.8	1.0	1.8	1.6
2	1	6.8	3.2	3.2	2.3	2.2	6.8	6.8	6.8	6.8	2.2	6.8	3.0	3.3	6.8	2.6	6.8	1.6	1.9	2.1	2.0	1.7	2.5	2.1	2.0	2.3	1.9	1.9
3	0	2.6	2.6	3.0	2.8	1.9	2.6	2.6	2.8	2.8	2.4	2.8	2.0	2.0	2.8	2.4	2.9	1.9	1.9	5.3	2.9	3.7	3.9	3.7	2.6	2.6	1.8	2.6
3	1	5.3	6.2	2.0	2.9	3.7	6.2	6.2	NA	NA	3.2	NA	3.7	4.4	NA	3.2	2.7	4.1	2.9	2.6	2.7	2.4	1.5	2.1	3.8	2.9	3.4	2.9
4	0	3.9	NA	4.0	4.0	4.4	NA	3.9	NA	3.9	4.5	NA	4.4	3.5	NA	3.7	3.8	4.2	3.7	5.8	4.0	NA	4.2	2.8	4.2	3.1	3.2	3.4
4	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.8	NA	NA	NA	NA	NA	NA	3.7	NA	NA	NA	NA	NA	NA
5	0	5.9	5.9	7.2	3.7	3.7	5.9	5.9	5.9	5.9	5.3	5.9	6.3	5.5	5.2	6.8	4.3	9.2	8.3	3.4	5.9	NA	5.5	7.7	5.8	NA	6.8	NA
5	1	6.8	NA	3.4	8.4	8.4	NA	NA	NA	NA	6.1	NA	4.2	9.9	7.8	5.5	8.3	5.1	4.3	8.2	NA	5.9	6.8	5.1	6.2	5.9	5.9	5.9
6	0	3.3	3.3	2.7	7.1	7.1	3.8	3.8	3.8	3.8	NA	3.3	7.2	3.3	3.3	6.9	3.4	6.9	6.9	NA	7.2	7.3	3.0	6.9	NA	NA	7.1	7.2
6	1	7.3	7.3	7.1	2.4	2.4	NA	NA	NA	NA	3.8	7.3	3.1	5.4	5.4	3.4	6.9	3.4	3.4	3.8	1.2	3.3	3.9	3.4	3.8	3.8	2.4	3.1
7	0	5.7	6.2	6.3	5.5	6.5	5.7	6.2	6.2	6.2	4.6	6.2	5.3	5.4	6.2	6.3	6.3	4.5	7.5	6.6	4.8	6.6	5.3	5.0	5.0	NA	6.2	5.4
7	1	NA	4.2	4.2	5.8	4.2	NA	4.2	4.2	4.2	6.3	4.2	6.2	6.0	4.5	4.6	4.3	6.2	5.7	4.3	7.0	5.5	6.2	6.0	6.0	5.7	5.6	5.7
8	0	5.1	5.1	NA	NA	5.1	5.1	5.1	5.1	5.1	NA	5.1	5.1	5.1	5.1	NA	5.1	NA	NA	5.1	5.1	NA	NA	NA	NA	NA	5.1	NA
8	1	NA	NA	5.1	5.1	NA	NA	NA	NA	NA	5.1	NA	NA	NA	NA	5.1	NA	5.1	5.1	NA	NA	5.1	5.1	5.1	5.1	5.1	NA	5.1
9	0	6.3	6.3	6.3	NA	NA	6.3	6.3	6.3	6.3	**0.0**	6.3	**7.3**	NA	6.3	6.3	**0.0**	6.3	NA	NA	6.3	**0.0**	**7.3**	**7.3**	**0.0**	NA	**0.0**	NA
9	1	NA	NA	NA	6.3	6.3	NA	NA	NA	NA	**7.3**	NA	**0.0**	6.3	NA	NA	**7.3**	NA	6.3	6.3	NA	**7.3**	**0.0**	**0.0**	**7.3**	6.3	**7.3**	6.3

Non-fatal occupational injuries per 100,000 workers (max: 4083, min: -4556, mean: -377, median: -300)																											
GDP classification	Ratification	C087	C098	C135	C151	C154	C029	C105	C100	C111	C156	C144	C150	C160	C081	C129	C122	C001	C030	C047	C014	C187	C155	C161	C102	C121	C097	C143
1	0	NA	NA	1395	NA	NA	NA	NA	NA	NA	1425	NA	NA	NA	NA	1581	NA	1924	1395	899	NA	1425	1496	1922	NA	1584	1417	899
1	1	550	562	NA	1048	1228	1116	383	695	1030	NA	1035	491	1494	1116	NA	1033	NA	NA	NA	550	NA	NA	NA	1123	NA	NA	NA
2	0	1832	1870	1870	1934	1997	1832	1832	1832	1832	1926	1832	1781	1732	1832	2044	1832	2270	2481	1165	1941	1721	1803	1487	2008	1710	2342	1119
2	1	6	913	913	1635	1677	6	6	6	6	1626	6	1848	2378	6	1182	6	1574	1646	2062	1455	1918	1791	1911	1234	1849	1356	1950
3	0	1022	1017	879	780	775	1017	1017	1017	1017	744	1017	1013	864	1017	1044	971	975	2200	767	1043	877	927	928	976	1616	1479	1616
3	1	767	NA	1848	1410	1247	NA	NA	NA	NA	1191	NA	1021	1256	NA	989	1362	1078	880	1022	852	1099	1125	1108	1277	938	760	938
4	0	1050	NA	1211	1585	893	NA	1050	NA	1050	1637	NA	1301	615	NA	1292	772	1656	2213	184	1209	NA	1301	1191	1223	2225	1629	1715
4	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4229	NA	NA	NA	NA	NA	NA	376	NA	NA	NA	NA	NA	NA
5	0	1959	1945	2979	141	141	1945	1945	1945	1945	3853	1945	2293	2067	1438	2910	1527	5085	2603	38	1945	NA	1471	3051	2452	NA	1578	NA
5	1	1578	NA	49	3975	3975	NA	NA	NA	NA	1396	NA	324	919	3235	1471	2603	1217	1527	3808	NA	1945	2910	1430	399	1945	1959	1945
6	0	616	616	25	1627	1627	589	589	589	589	NA	616	43	692	692	**4162**	**79**	**4162**	**4162**	NA	1287	404	24	**4162**	NA	NA	1627	43

6	1	404	404	2283	90	90	NA	NA	NA	NA	589	404	726	235	235	**79**	**4162**	**79**	**79**	589	18	616	652	**79**	589	589	90	726
7	0	346	435	428	628	307	346	435	435	435	572	435	408	72	312	60	223	477	4805	61	550	79	408	72	72	NA	688	525
7	1	NA	17	106	213	436	NA	17	17	17	229	17	281	531	444	805	584	300	249	764	69	400	281	420	420	346	205	343
8	0	31	31	NA	NA	31	31	31	31	31	NA	31	31	31	31	NA	31	NA	NA	31	31	NA	NA	NA	NA	NA	31	NA
8	1	NA	NA	31	31	NA	NA	NA	NA	NA	31	NA	NA	NA	NA	31	NA	31	31	NA	NA	31	31	31	31	31	NA	31
9	0	476	476	476	NA	NA	476	476	476	476	1057	476	379	NA	476	476	1057	476	NA	NA	476	1057	379	379	1057	NA	1057	NA
9	1	NA	NA	NA	476	476	NA	NA	NA	NA	379	NA	1057	476	NA	NA	379	NA	476	476	NA	379	1057	1057	379	476	379	476
Inspectors per 10,000 employed persons (max: 2, min: -5.2, mean: -0.34, median: -0.2)																												
GDP classification	Ratification	C087	C098	C135	C151	C154	C029	C105	C100	C111	C156	C144	C150	C160	C081	C129	C122	C001	C030	C047	C014	C187	C155	C161	C102	C121	C097	C143
1	0	1.9	1.6	1.3	1.0	1.1	1.6	1.7	1.7	1.9	1.1	1.4	2.1	0.7	1.6	1.1	1.9	5.2	1.3	1.3	1.9	1.1	1.6	0.7	0.8	0.4	0.9	1.3
1	1	0.6	0.8	1.5	1.7	1.5	0.1	0.3	0.7	0.2	1.5	1.4	0.6	2.4	0.1	1.5	0.6	0.7	1.5	1.5	0.6	1.5	1.0	1.5	1.9	1.7	1.6	1.5
2	0	0.9	1.1	1.1	1.1	1.1	0.9	0.9	0.9	0.9	1.1	0.9	1.2	1.0	0.9	1.2	0.9	0.6	1.3	1.1	0.9	0.9	1.1	1.3	1.0	1.3	1.2	0.6
2	1	NA	0.1	0.1	0.8	0.8	NA	NA	NA	NA	0.8	NA	0.6	0.8	NA	0.5	NA	1.1	0.8	0.9	1.1	1.1	0.8	0.7	0.9	0.7	0.8	1.0
3	0	0.7	0.7	0.7	0.7	1.0	0.7	0.7	0.7	0.7	0.8	0.7	0.7	0.8	0.7	1.0	0.7	0.9	0.7	0.6	0.7	0.6	0.8	0.9	0.7	0.7	0.6	0.8
3	1	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.3	0.4	0.5	0.3	0.6	0.5	0.3	0.5	0.3	0.5	0.6	0.7	0.5	0.7	0.5	0.5	0.4	0.6	0.7	0.6
4	0	1.0	1.0	1.1	0.9	1.1	1.0	1.0	1.0	1.0	1.1	1.0	1.1	1.1	0.9	1.0	1.1	1.2	0.9	1.6	1.1	0.7	0.8	1.1	1.1	1.0	0.8	0.7
4	1	0.3	NA	0.8	1.0	0.9	NA	0.3	NA	0.3	0.9	NA	0.9	0.9	1.5	0.9	0.6	0.8	1.0	1.0	0.7	1.1	1.1	0.9	0.9	1.0	1.0	1.0
5	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.4	0.6	0.5	0.7	0.5	0.1	0.6	0.4	0.5	0.2	0.1	0.5	0.3	0.8	0.3
5	1	NA	0.5	0.4	0.5	0.5	NA	NA	NA	NA	0.6	NA	1.0	0.7	0.1	0.5	0.2	0.5	0.6	0.5	1.0	0.5	0.7	0.6	0.5	0.5	0.4	0.5
6	0	0.5	0.5	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	1.1	0.5	0.5	0.3	0.5	0.4	0.3	NA	0.4	0.2	0.6	0.3	0.4	0.3	0.4	1.1
6	1	0.2	0.2	0.3	0.5	0.5	NA	NA	NA	NA	0.5	0.2	0.4	0.4	0.4	0.5	0.3	0.5	0.5	0.4	0.5	0.5	0.4	0.5	0.5	0.5	0.5	0.4
7	0	1.1	1.2	2.0	**0.4**	2.7	1.1	1.2	1.2	1.2	2.2	1.4	2.0	2.0	1.7	2.0	1.2	0.1	0.1	2.7	2.4	0.7	2.0	**5.5**	**5.5**	NA	0.4	0.1
7	1	NA	0.1	0.1	**2.4**	0.2	NA	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.1	0.1	0.1	1.4	1.2	0.2	0.4	1.2	0.1	**0.3**	**0.3**	1.1	1.6	1.4
8	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9	0	0.1	0.1	NA	NA	0.1	0.1	0.1	0.1	NA	0.1	0.1	NA	0.1	0.1	NA	0.1	NA	NA	0.1	NA	NA	0.1	NA	NA	NA	NA	NA
9	1	NA	NA	0.1	0.1	NA	NA	NA	NA	0.1	NA	NA	0.1	NA	NA	0.1	NA	0.1	0.1	NA	0.1	0.1	NA	0.1	0.1	0.1	0.1	NA
Labor inspection visits per inspector (max: 306, min: -306, mean: 8.18, median: 12)																												
GDP classification	Ratification	C087	C098	C135	C151	C154	C029	C105	C100	C111	C156	C144	C150	C160	C081	C129	C122	C001	C030	C047	C014	C187	C155	C161	C102	C121	C097	C143
1	0	162	144	40	216	79	169	177	98	187	86	136	166	176	169	86	169	158	138	40	182	86	153	132	88	121	303	40
1	1	162	212	175	133	186	25	71	327	60	175	256	158	151	25	175	154	163	166	175	132	175	178	165	206	172	124	175
2	0	125	141	141	115	115	125	125	125	125	110	125	121	128	125	117	125	93	119	83	88	116	115	104	158	104	144	102
2	1	NA	10	10	131	131	NA	NA	NA	NA	137	NA	129	69	NA	137	NA	138	127	141	174	185	131	142	46	142	114	127
3	0	112	112	112	129	159	120	128	103	116	132	103	59	86	110	172	94	135	87	19	129	42	124	131	104	143	115	201
3	1	60	60	82	83	73	17	32	100	38	82	100	140	121	14	59	158	83	104	111	46	142	77	81	98	91	94	87

4	0	126	125	134	153	155	125	126	125	126	155	125	157	93	125	132	108	154	185	57	124	184	163	93	158	160	140	176
4	1	108	NA	101	102	104	NA	108	NA	108	108	NA	98	157	114	114	173	99	106	126	126	102	97	135	96	120	121	118
5	0	128	**101**	99	61	61	128	128	128	128	74	128	170	107	117	64	117	179	158	29	107	**407**	142	150	149	113	93	113
5	1	125	**407**	260	151	151	NA	NA	NA	NA	170	NA	59	178	158	162	158	99	117	149	205	**101**	116	116	29	129	142	129
6	0	64	64	61	53	16	56	56	56	56	126	64	5	60	79	18	67	58	18	NA	41	12	19	18	126	123	38	5
6	1	12	12	52	58	69	NA	NA	NA	NA	41	12	58	53	16	67	18	55	67	56	72	64	66	67	41	52	64	58
7	0	115	86	89	104	46	115	86	86	86	87	92	87	94	80	94	90	172	55	47	119	61	87	28	28	NA	82	114
7	1	NA	230	141	131	151	NA	230	230	230	134	174	141	130	160	130	186	91	122	141	111	125	141	127	127	115	137	115
8	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9	0	9	9	9	NA	NA	9	9	9	9	NA	9	9	NA	9	9	NA	9	NA	NA	9	NA	9	9	NA	NA	NA	NA
9	1	NA	NA	NA	9	9	NA	NA	NA	NA	9	NA	NA	9	NA	NA	9	NA	9	9	NA	9	NA	NA	9	9	9	9

GDP classification: GDP classification of countries provided in Table 5.
NA: Not Available. No country exists for the specific status.
Max: maximum difference, min: minimum difference, mean: the mean of difference, median: the median of difference.
Bold indicates the values for which the difference between the ratification status of zero and the ratification status of one is maximum or minimum.

Table 11. The risk ratios for each value according to the ratification status of each convention stratified by country classification (multilevel Poisson regression)

	Freedom of association			Collective bargaining		Forced labor	
	C087	C098	C135	C151	C154	**C029**	**C105**
Fatal injuries	**1.50 (1.33-1.70)**	1.12 (1.00-1.27)	0.86 (0.79-0.94)	1.17 (1.10-1.25)	1.12 (1.05-1.20)	**1.90 (1.59-2.28)**	**1.10 (0.97-1.24)**
Nonfatal injuries	**0.42 (0.42-0.43)**	0.37 (0.37-0.38)	0.57 (0.57-0.57)	0.86 (0.86-0.86)	1.32 (1.31-1.32)	**0.60 (0.59-0.60)**	**0.28 (0.27-0.28)**
Labor inspectors	**0.38 (0.24-0.59)**	0.46 (0.29-0.73)	0.54 (0.41-0.71)	1.38 (1.10-1.72)	0.66 (0.53-0.81)	**0.39 (0.17-0.88)**	**0.37 (0.22-0.61)**
Labor inspection visits	**0.82 (0.80-0.84)**	1.29 (1.26-1.32)	1.04 (1.01-1.06)	0.82 (0.81-0.84)	1.07 (1.05-1.09)	**0.14 (0.13-0.16)**	**0.75 (0.73-0.77)**
	Equality of opportunity and treatment			Tripartite consultation	Labor administration		
	C100	C111	C156	C144	C150	C160	
Fatal injuries	1.00 (0.87-1.16)	0.99 (0.87-1.12)	1.11 (1.04-1.19)	0.95 (0.82-1.09)	1.02 (0.95-1.09)	1.43 (1.34-1.53)	
Nonfatal injuries	0.33 (0.33-0.34)	0.46 (0.46-0.47)	0.62 (0.61-0.62)	0.51 (0.51-0.52)	0.70 (0.70-0.71)	1.61 (1.60-1.61)	
Labor inspectors	0.37 (0.21-0.65)	0.25 (0.14-0.44)	0.73 (0.59-0.91)	0.47 (0.26-0.85)	0.55 (0.44-0.69)	0.95 (0.76-1.18)	
Labor inspection visits	2.47 (2.40-2.54)	0.78 (0.75-0.80)	0.98 (0.97-1.00)	1.54 (1.50-1.59)	0.98 (0.96-1.00)	1.29 (1.27-1.32)	
	Labor inspection		Employment policy	Working time			
	C081	C129	C122	C001	C030	C047	C014
Fatal injuries	1.11 (1.01-1.23)	1.08 (1.01-1.15)	1.18 (1.09-1.28)	0.96 (0.90-1.03)	0.91 (0.83-0.99)	0.95 (0.88-1.03)	1.00 (0.92-1.09)
Nonfatal injuries	1.92 (1.91-1.93)	0.66 (0.66-0.67)	1.76 (1.75-1.77)	0.46 (0.46-0.46)	0.46 (0.46-0.47)	3.80 (3.78-3.83)	0.47 (0.47-0.48)
Labor inspectors	0.36 (0.22-0.58)	0.63 (0.50-0.80)	0.39 (0.27-0.56)	0.61 (0.49-0.76)	1.15 (0.86-1.53)	0.53 (0.40-0.71)	0.54 (0.42-0.70)
Labor inspection visits	0.95 (0.92-0.98)	0.98 (0.97-1.00)	1.35 (1.32-1.38)	0.73 (0.71-0.74)	0.90 (0.88-0.92)	2.93 (2.80-3.06)	0.95 (0.93-0.97)
	Occupational safety and health			Social security		Migrant workers	
	C187	C155	C161	C102	C121	C097	C143
Fatal injuries	0.84 (0.78-0.91)	0.94 (0.88-1.00)	1.03 (0.96-1.11)	1.28 (1.05-1.21)	1.47 (1.30-1.65)	1.10 (1.01-1.19)	1.11 (0.99-1.25)
Nonfatal injuries	0.61 (0.61-0.61)	0.93 (0.93-0.94)	0.84 (0.83-0.84)	0.67 (0.67-0.68)	0.74 (0.74-0.74)	0.58 (0.58-0.59)	1.02 (1.02-1.03)
Labor inspectors	1.43 (1.08-1.90)	0.73 (0.58-0.91)	0.56 (0.44-0.70)	0.74 (0.59-0.93)	1.18 (0.88-1.60)	1.33 (1.03-1.71)	1.51 (1.03-2.20)
Labor inspection visits	1.13 (1.10-1.15)	0.89 (0.87-0.90)	1.12 (1.10-1.15)	0.86 (0.84-0.88)	0.94 (0.92-0.97)	0.85 (0.83-0.86)	0.87 (0.85-0.90)

The values are risk ratios with a 95% confidence interval in parentheses.
Bold indicates the 3 conventions for which the ratio of RR for nonfatal injuries to RR for fatal injuries is the least. (0.25 (95% CI 0.22-0.29) for C105, 0.28 (95% CI 0.25-0.32) for C087, and 0.32 (95% CI 0.26-0.38) for C029

3.2.3. The estimation of the magnitude of missed nonfatal occupational injury reporting

Given the RR calculated in Table 11 and the specific values provided in Table 10, a proxy magnitude of missed nonfatal occupational injury reporting can be calculated. Table 12 provides the estimated magnitude calculated from the given data.

(ⅰ) For convention 029, the mean of fatal injuries was 4.2 for the ratified group and 5.4 for the non-ratified group. The mean of nonfatal injuries was 890.86 for the ratified group and 561 for the non-ratified group. (ⅱ) For these already-discovered nonfatal injuries for the non-ratified group (561), the anticipated reduced nonfatal injuries due to the ratification of the convention were calculated using the reverse of RR for fatal injuries provided in Table 11 (1.90 (95%CI 1.59-2.28)). (ⅲ) And then, the calculated values were subtracted from the mean of nonfatal injuries for the ratified group (890.86) to calculate nonfatal injuries additionally discovered due to the ratification of the convention. (ⅳ) After that, these values were multiplied by the RR for fatal injuries used in the first step (1.90 (95%CI 1.59-2.28)) to calculate anticipated undiscovered nonfatal injuries before the ratification of the convention. (ⅴ) Finally, the ratio of discovered nonfatal injuries (561) to total nonfatal injuries (discovered + anticipated undiscovered, 561 + 1131.63 (95% CI 855.46-1470.15)) was calculated. This ratio was 0.33 (95% CI 0.28-0.40).

The same processes were applied to convention 105 and convention 087. The calculated ratio of discovered nonfatal injuries to total nonfatal injuries was 0.13 (95% CI 0.12-

0.15) for C105 and 0.48 (95% CI 0.42-0.54) for C087.

Table 12. The estimated missed OD diagnosis calculated from the given data

Convention	C029		C105		C087	
Ratification	0	1	0	1	0	1
Fatal injuries (mean)	4.2	5.4	4.27	4.8	4.14	5.8
Nonfatal injuries (mean)	890.86	561	921.88	135.3	916.5	661
(ⅰ) Anticipated reduced nonfatal injuries (already discovered)	295.26 (246.05-352.83)		123 (109.11-139.48)		440.67 (388.82-496.99)	
(ⅱ) Nonfatal injuries newly discovered	595.59 (538.03-644.80)		798.88 (782.39-812.76)		475.83 (419.51-527.68)	
(ⅲ) Anticipated undiscovered nonfatal injuries before ratification	1131.63 (855.46-1470.15)		878.76 (758.92-1007.83)		713.75 (557.95-897.05)	
(ⅳ) The ratio of discovered nonfatal injuries to total nonfatal injuries	0.33 (0.28-0.40)		0.13 (0.12-0.15)		0.48 (0.42-0.54)	

4-1. GENERAL DISCUSSION

In this study, firstly, the author built up a conceptual serial diagnostic framework in OEM. In this framework, the role of each sub-components of the social system as a mold for the diagnostic processes was emphasized.

Secondly, as a classification framework for the causes of misdiagnoses, the causation model was devised. This causation model is composed of 6 steps, and each step reflects a serious error in a continuous process of diagnosis in OEM. With the first conceptual serial diagnostic framework and the classification framework for the causes of misdiagnoses combined, the system perspective model in OEM was devised.

Thirdly, in the scoping review, misdiagnoses reported in published literature were summarized (a total of 79 articles). The major study type was case report and case series (25 articles respectively). The initial diagnosis team included OEM physicians only in 9 articles, but the final diagnosis team included OEM physicians in 17 articles. For clinical specialty, Pulmonology (30 articles) and Dermatology or Allergy (13 articles) specialty were most frequent. For each disease, occupational and environmental interstitial lung diseases (ILD), misdiagnosed as sarcoidosis (8 articles), and other lung diseases (8 articles) were most frequent. For the typical framework, the most vulnerable step was the first step, Evidence of a disease (38 articles). For the causation model, the first step, Knowledge base, was the most vulnerable step (42 articles). For reported articles, the frequency of false-negative (55 articles) outnumbered the frequency of false-positive (15 articles).

Fourthly, for the estimation of the magnitude of missed nonfatal occupational injury reporting, the ratio of discovered nonfatal injuries to total nonfatal injuries was 0.33 (95% CI 0.28-0.40) for C029, 0.13 (95% CI 0.12-0.15) for C105, and 0.48 (95% CI 0.42-0.54) for C087. In other words, about 52 to 87% of nonfatal injuries are not being reported.

4-2. DISCUSSION: A SCOPING REVIEW

4.1. ‘Medical misdiagnosis’ versus ‘Causal misdiagnosis’: the probability of causation

As stated in subsection 1.2, misdiagnoses in OEM are classified into 2 classes: ‘medical misdiagnosis’ and ‘causal misdiagnosis.’ The published articles usually focused on the first ‘medical misdiagnosis’ cases, and ‘causal misdiagnosis’ cases were scarcely reported. The reason for this might be the difficulty in calculating a correct probability of causation. The ‘medical misdiagnosis’ is rather clearly defined and can be identified easily. However, the ‘causal misdiagnosis’ is the main area in which various disputes about compensation occur (104). Case by case and physician by physician, the calculated probability of causation can be different, and this differently calculated probability of causation causes a different decision whether this disease is of an occupational or environmental origin or not.

For example, for radiogenic cancers in the US, the probability of causation/assigned share can be calculated using a web-based official tool (105, 106). In this case, the possibility of disputes for compensation is rare (mainly on the upper credibility limit of the probability of causation) (105). In South Korea, this criterion was applied successfully for occupational radiogenic cancers (107). For occupationally acquired contact dermatitis, the Mathias criteria can be applied to calculate the probability of causation (108). As seen in these examples, for some ODs or EDs with established criteria for the calculation of the probability of causation, the possibility of a subjective decision by a physician or a judge can be minimized. However, for most ODs and EDs, the established criteria for the calculation of the probability of causation do not exist. Those cases are prone to disputes for the establishment of occupational or environmental causation.

4.2. The confusion between the probability of causation and rate fraction (attributable fraction)

The difference between the probability of causation and rate fraction (or attributable fraction) was dealt with in detail by Greenland (1999) (10). In the below equations, A_T is the total exposed individuals, A_0 is the unaffected individuals, A_1 is the individuals with an accelerated disease occurrence, and A_2 represents the individuals with an all-or-none occurrence of a disease. These equations illustrate why these two concepts are different in algebraic terms.

$$\text{Rate Fraction (attributable fraction, attributable risk)} = A_2/A_T$$

$$\text{Probability of Causation (etiologic fraction)} = (A_1+A_2)/A_T$$

If the cases with accelerated occurrence are not considered, the rate fraction will be an underestimated value of the 'true' probability of causation. Even worse, for an accurate calculation of A_0, A_1, and A_2, a plausible biologic model is needed, based on enough domain knowledge on the biologic mechanisms of a disease occurrence.

For ODs and EDs, the standpoint for making a diagnosis should be the probability of causation and not the relative risk (or rate fraction). In other words, whether the probability of causation exceeds 50% or not should be the gold standard for making a specific OD or ED diagnosis. However, usually in legal actions, whether the exposure exceeded the doubling dose or not (relative risk over 2) is regarded as the typical standpoint for making a specific diagnosis of OD or ED. Relative risk over 2 (rate fraction of 50%) is not the same concept with the probability of causation over 50% because of the aforementioned unconsidered accelerated occurrence.

A more complicated problem is the variation of the probability of causation and rate fraction according to other associated factors like genetic variants or susceptibility factors. However, for the accurate estimation of the distribution of these two values, a complete understanding of the biological mechanisms of a disease occurrence is required.

4.3. Dose-response relationship and causal inference in OEM

For the calculation of a reliable probability of calculation, understanding the correct dose-response relationship between occupational or environmental exposure and an outcome is an essential prerequisite. However, according to the exposure assessment method (109, 110) and applied biological dose-response model (111), the dose-response relationship can be markedly different. For example, a prospective cohort study revealed that cumulative vibration doses constructed from unweighted root-mean-square acceleration performed better for the prediction of vibration-induced white finger (112).

The imperfect exposure assessment is another essential problem. Crude exposure assessment using only ever/never exposed or the duration of exposure cannot capture the accurate exposure dose of subjects. Particularly when dealing with subtle health effects, the intensity, duration, and route of exposure should be assessed meticulously to avoid an invalid dose-response relationship (113).

Finally, the interaction between a genetic factor (a susceptibility factor) and a hazardous environmental exposure should be considered enough for causal inference. Some subpopulations with a genetic variant could be more susceptible to environmental or occupational exposure than other subpopulations (114). For these subpopulations, the dose-response pattern would be different from that for other subpopulations. In genetic epidemiology, this gene-environment interaction study has been conducted frequently (115). The relative risk distribution for an environmental exposure would be varied according to each type of genetic variant, and this can be calculated and plotted using a recent Bayesian simulation technique (116). For an accurate dose-response relationship calculation and a correct causal inference, this genetic factor (susceptibility factor) and environmental exposure interaction should be considered in future studies.

4.4. Misdiagnosis in general medicine versus misdiagnosis in OEM

In our analysis, misdiagnosis in OEM was most frequent in the first step (knowledge base) of the causation model. The collection of appropriate exposure information and the OEM knowledge base of a treating physician was critical in making a correct diagnosis in OEM. However, according to Graber et al. (2005) (24), misdiagnoses in general medicine were more frequent in the 'synthesis of collected information' step, which corresponds to the second, third, and fourth steps in our causation model. This difference is because OEM usually uses the type 2 systematic and analytic approach to make a diagnosis, while general medicine also uses the type 1 heuristic and intuitive approach more commonly than OEM (117). The heuristics approach makes the initial decision of physicians faster but is more susceptible to various cognitive pitfalls (23). Because OEM practice is basically based on epidemiologic principles, it requires complete information about the exposure status of a patient and a causal interpretation based on this information. This analytic trait of OEM makes OEM practices rely on the type 2 analytical approach more commonly than general medicine.

4.5. The role of education and training for treating physicians

Previous literature mainly focused on misdiagnoses in general medicine or internal medicine (23, 24, 118-120). However, in this study, the author focuses on misdiagnoses in OEM. ODs and EDs usually have very different features compared to typical medical diseases: identifying potential hazardous occupational or environmental exposures is paramount in making a correct diagnosis. This includes an accurate exposure assessment for the patient. In addition, to confirm a causal relationship between an exposure and a disease, the treating physician should have knowledge about possible occupational or environmental exposures. However, most physicians in the world are not receiving adequate education and training in OEM (121).

Although the second Heuristics step and the third Complete work-ups step were responsible for some misdiagnosis cases, the fundamental problem of most misdiagnoses is the lack of knowledge base about OD and EDs. Without an adequate knowledge base about OEM, the treating physician cannot come up with potential differential diagnoses of ODs and EDs. This causes a significant cognitive trap in the diagnostic process. Faulty heuristics and a wrong decision not to conduct further diagnostic work-ups are usually caused by this insufficient knowledge base. The lack of feedback on the tentative diagnosis or treatment and preventive measures are the problem of the medical culture. Furthermore, the unique and special characteristics of OD and EDs considered, this problem is also because of the lack of knowledge about OEM in treating physicians and policymakers.

Because of this pervasive lack of knowledge about OEM, false-negative misdiagnoses are common. Particularly without sufficient occupational or environmental history taking, a treating physician will miss the possibility of OD or ED and simply make a diagnosis of a general medical illness. However, there is also a possibility of false-positive diagnosis, particularly when a patient's occupational or environmental history is so distinctive that a treating physician falls into a heuristic trap. However, these cases were relatively uncommon than false-negative cases.

4.6. Intentional behaviors of stakeholders

An important feature of ODs and EDs is that there are various intentional behaviors of stakeholders (122). Because practical benefits like worker's compensation or accident and sickness benefits exist in most countries, cognitive malingering could be prevalent in a specific workplace or country. This also causes false-positive cases. On the other hand, for employers, concealing industrial accidents or occupational diseases is favorable for their profits. Therefore, they usually try to elucidate no relationship between a specific working environment and an OD. This is the same for most EDs (123). For these ED cases, the citizen acts the role of workers, and the company or the government who is responsible for having made an environmental hazard acts the role of employers.

In addition, some environmental illnesses do not have definitive diagnostic criteria, and this causes both false-negative and –positive misdiagnoses (38, 40, 41). As the solution for Minamata disease (40), a quantitative score can be instituted for diagnosis. Discriminant values in principal component analysis or classic machine learning methods are good examples of calculating this score.

4.7. Risk of bias: case report and case series studies

This scoping review included 25 case report studies and 25 case series studies, respectively, among 79 total included studies. With case report and case series studies which have no comparison group, one cannot conclude the magnitude of a particular type of misdiagnosis (124). However, these study types could provide an overall picture of the misdiagnosis profile in OEM. This scoping review could be a basement for future quantitative studies about a particular type of misdiagnosis in OEM.

4.8. Other limitations of this study

There are some limitations to this scoping review. Firstly, this study only included published misdiagnosis cases. Therefore, there will be some degree of publication bias in reported misdiagnosis cases. In particular, the misdiagnosis with fatal consequences concerning the treating physician might not be reported in the literature. In addition, considering the aforementioned confusion between the probability of causation and relative risk, the acknowledged OD or ED might have been a small percentage of overall true OD or EDs. Particularly, of 3 categories of misdiagnosis aforementioned, only the first 'delayed diagnosis' and second 'wrong diagnosis' categories would have been reported in the literature. The third 'missed diagnosis' category is the major part that future researchers should deal with. As for the first 'delayed diagnosis' category, for an occupational or environmental disease case is reported in the literature, a tentative initial wrong diagnosis is usually reported. However, in reality, delayed diagnosis cases without an initial wrong tentative diagnosis would exist. Therefore, when the delayed diagnosis category is considered, this classification characteristic should be considered in advance.

Secondly, there would be numerous misdiagnosis cases that were not revealed because of dynamics in workplaces or intentional behaviors of employers or employees. Sometimes, the government of a country is unfavorable to OD or EDs for economic growth (particularly developing countries). In this culture, the diagnosis of an OD or ED cannot be made properly.

4-3. DISCUSSION: AN ORIGINAL RESEARCH

4.9. Causes due to employers, employees, and the government, respectively

Rappin et al. (2016) analyzed the reasons for missed occupational injuries and illnesses reporting from the position of employers (17). Noncompliance with record-keeping rules and reporting instructions were the main reason. Employers sometimes considered some occupational injuries as of non-occupational origin.

Taylor et al. (2013) analyzed the reasons for missed occupational injury reporting from the position of employees (125). The most frequent reason was that employees considered their occupational injuries as ‘small’ and ‘a natural part of the job.’ Another important reason was the concern for losing their job by reporting occupational injuries. The concern for being labeled as a complainer by colleagues was also a major reason. The time and efforts for filing a worker’s compensation was another reason.

Lowry et al. (2010) analyzed the reasons for missed occupational injury reporting from the position of the government (126). Particularly for precariously employed persons like day laborers, the occupational injury surveillance system was incomplete and inconsistent. Leigh et al. (2004) indicated another source of underreporting of nonfatal occupational injuries, excluded categories for some professional groups (government workers and the self-employed) (15).

4.10. The role of occupational health and safety system of the society

As stated in the Introduction section, Probst et al. (2010) indicated that poor organizational safety climate and incomplete supervisor safety enforcement are two major reasons for missed occupational injury reporting. In addition, in the former subsection 4.1, we dealt with the reasons for missed reporting caused by each subsection (employers, employees, and the government). However, from the perspective of the entire society, the society's occupational health and safety system itself influences all these specific reasons and the ultimate missed reporting rate of nonfatal occupational injuries of the society.

ILO conventions are legally binding international treaties that may be ratified by member states (127). These conventions are drawn up by representatives of governments, employers, and workers. New conventions are adopted at the annual International Labor Conference. Once a standard is adopted, member states are required to submit it to their Parliament within a year for consideration for ratification. If it is ratified, a Convention generally comes into force for that country one year after the date of ratification. Ratifying countries undertake to apply the convention in national law and practice and to report on its application at regular intervals. Complaint procedures can be initiated against states for violations of a Convention that they have ratified.

A worker in a country in which a number of ILO conventions ratified would experience an improved occupational health and safety system (128, 129). This improved occupational health and safety system would reduce the missed reporting rate of nonfatal occupational injury.

4.11. Limitations

The analyses conducted in this study are based on a number of assumptions: (ⅰ) The effect of ILO convention ratification is restricted to only 2 effects, the preventive effect and the discovering effect. (ⅱ) The possibility of non-reporting of fatal occupational injuries would be low, so convention ratification would only have a preventive effect for the occurrence of these fatal occupational injuries with no discovering effect. (ⅲ) The preventive effect of convention ratification for fatal injuries would be applied for nonfatal injuries with the same magnitude. (ⅳ) The effects of convention ratification would be various: for some conventions, the preventive and discovering effect could be relatively poor, and for other conventions, both effects could be good. Under this assumption, only 3 conventions with the least ratio of RR for nonfatal injuries to RR for fatal injuries were selected for analyses.

However, considering that these limitations are reasonable and logical for the estimation of the missed nonfatal occupational injury reporting, the quality of the study results would be acceptable.

5. CONCLUSION

In conclusion, firstly, the author built up a conceptual diagnostic framework in OEM, emphasizing the role of each sub-components of the social system, which functioned as a mold for diagnostic processes.

Secondly, the causation model was devised as the classification framework for the causes of misdiagnoses in OEM.

Thirdly, in the scoping review, we briefly overlooked the distribution of misdiagnosis articles through each medical specialty, false-negative or –positive, and each diagnostic step of OEM. A total of 79 articles were included in the scoping review. For clinical specialty, Pulmonology (30 articles) and Dermatology or Allergy (13 articles) specialty were most frequent. For each disease, occupational and environmental interstitial lung diseases (ILD), misdiagnosed as sarcoidosis (8 articles), and other lung diseases (8 articles) were most frequent. For the typical framework, the most vulnerable step was the first step, Evidence of disease (38 articles). For the causation model, the first step, Knowledge base, was the most vulnerable step (42 articles). For reported articles, the frequency of false-negative (55 articles) outnumbered the frequency of false-positive (15 articles). In the discussion, various disputes and controversies regarding misdiagnosis in OEM were dealt with deeply and thoroughly. Without the established criteria for the probability of causation, compensation disputes surrounding the OD or ED case would occur. The clarification of the concept between the probability of causation and relative risk is needed. According to the exposure assessment method and applied biological model, the dose-response relationship can be markedly different. Imperfect exposure assessment is another essential problem. OEM education and training for treating physicians and understanding the intentional behaviors of stakeholders are important. This scoping review might contribute to the improvement of understanding for misdiagnosis in OEM.

Fourthly, in the original research, the fact that about 52 to 87% of nonfatal occupational injuries are not being reported can be confirmed. By applying this estimation to the occupational disease reporting, we can infer that about 52 to 87% of total occupational diseases are not being reported.

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Abstract in Korean

서론: 비록 이전까지의 많은 연구들에서 일반 의학 관점에서의 오진은 많이 다루어졌지만 직업환경의학에서의 오진은 제대로 다루어지지 않았습니다. 이 연구의 목표는 4가지입니다. 첫째는 직업성 질병과 환경성 질병의 진단에 관한 순차적인 개념적 틀을 정립하는 것입니다. 두 번째는 직업환경의학에서의 오진을 그 원인에 따라 분류하는 개념적 틀을 정립하는 것입니다. 세 번째는 직업환경의학에서의 지연된 진단과 잘못된 진단에 관한 주제범위 문헌고찰을 수행하는 것입니다. 네 번째는 비치명적인 직업성 손상의 누락 규모를 세계 노동 기구 직업성 손상 데이터를 사용하여 추정하는 것입니다.

순차적인 진단의 개념적 틀 및 원인 분류의 개념적 틀: 인간 인지 과정의 2가지 종류 및 사회 시스템 세부 구성 요소의 각 역할에 따라 순차적인 진단의 개념적 틀이 정립되었습니다. 일반 의학에서의 오진에 관한 문헌들과 직업환경의학의 독특한 특성을 고려하여, 진단의 각 세부과정 6개 단계에 따라 오진 원인 분류의 틀이 정립되었습니다.

잘못된 진단에 대한 주제 범위 문헌 고찰 (지연된 진단을 포함): 총 79개의 문헌이 주제범위 문헌고찰에 포함되었습니다. 임상 과목에 따라서 분류하면 호흡기내과가 30개 문헌으로 가장 많았고, 다음이 피부과와 알러지내과로 13개의 문헌보고가 있었습니다. 개별 질병에 따라 분류하면 유육종증 (8개 문헌) 및 다른 폐질환 (8개 문헌)으로 잘못 진단된 직업성 또는 환경성 간질성 폐질환이 가장 많았습니다. 앞서 정립한 원인 분류의 개념적 틀에 따르면 (causation model), 첫 번째 단계인 '기반 지식 (knowledge base)' 단계가 가장 오진이 많이 일어난 단계였습니다 (42개 문헌). 이렇게 수집된 문헌을 기반으로 했을 때,

위음성의 빈도가 55개 문헌으로 위양성의 문헌 빈도인 15개 문헌보다 훨씬 많았습니다.

비치명적 직업성 손상의 누락 규모에 관한 원저: 비치명적인 직업성 손상의 총 빈도수에서 보고된 케이스의 분율은 국제 노동 기구 29번 조약에 대해서는 0.33 (95% 신뢰구간 0.28-0.40) 이었고, 국제 노동 기구 105번 조약에 대해서는 0.13 (95% 신뢰구간 0.12-0.15) 였으며, 국제 노동 기구 87번 조약에 대해서는 0.48 (95% 신뢰구간 0.42-0.54) 였습니다. 다른 말로 하면 총 비치명적 직업성 손상의 52~87%가 보고되지 않고 누락되고 있음을 추정하였습니다.

전반적 고찰: 인과 확률 (probability of causation)에 대한 확립된 기준이 없다면, 직업성 질병과 환경성 질병을 둘러싼 보상에 관한 분쟁이 발생할 여지가 높습니다. 인과 확률 (probability of causation)과 상대위험도 (relative risk)의 정의에 대한 분명한 구분이 필요합니다. 노출 평가의 방법과 적용된 생물학적 모델에 따라 용량-반응 관계가 유의미하게 달라질 수 있습니다. 불완전한 노출 평가는 또 다른 중요한 오진의 원인입니다. 직업환경의학에 대한 교육과 수련이 의사 양성 과정에서 필수적이며, 각 이해관계자의 의도적인 행동도 충분히 고려되어야 합니다. 마지막 원저 부분에 대해서는 비치명적 직업성 손상이 누락되는 원인에 대한 선행 문헌들의 분석을 제시하였는데, 고용주, 노동자, 그리고 정부 측에서 기인한 원인을 각각 요약 제시하였습니다. 마지막으로 한 사회에서 누락되는 비치명적 직업성 손상의 분율을 줄이기 위한 직업 건강 및 안전 시스템의 역할이 강조되었습니다.

Disclosure

The contents of this Ph.D. dissertation (a scoping review and an original research) are under consideration for publication in the *Journal of Occupational Medicine and Toxicology* (ISSN: 1745-6673).

The contents of this Ph.D. dissertation (theoretical reviews) are under consideration for publication in the *Journal of Preventive Medicine and Public Health* (pISSN: 1975-8375).