Original paper

Epidemiological model of COVID-19 in healthcare workers: occupational vs. environmental disease

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Abstract

This study aims to estimate the occupational etiology of COVID-19 in the healthcare sector and obtain a risk matrix for the burden of disease across occupations and specific activities. The study population included 4515 cases and 133077 controls. We have used an epidemiological model that included data collected over one year from employed persons with confirmed SARS-CoV-2 infection, age group 20-64, and residing in Sibiu County. We measured the incidence rate (IR), relative risk (RR), and risk of COVID-19 attributable to the occupational exposure (AR), respectively, statistical analysis based on frequency distribution and the portion of cases to compute the risk levels in social- and healthcare workers. According to this model, approximately 70.5% of COVID-19 risk could be attributable to occupational exposure. The workplace is a strong predictor of infection risk (RR 3.4), particularly in residential long-term care facilities, hospitals, and ambulance services. The highest-risk job functions are nurse, nursing assistant, ambulance worker, and dentist. In conclusion, we believe in having demonstrated that epidemiological modeling may be helpful for risk management and notification of COVID-19 as an occupational disease in frontline staff and essential healthcare personnel.

Keywords: COVID-19, healthcare workers, medical-social workers, occupational disease

Introduction

The field of occupational epidemiology faces challenges, primarily since the severe acute respiratory syndrome (SARS) attributed to a new strain of coronavirus affected healthcare workers in Southeast Asia in March 2003. Most infections resulted from exposure to patients in health care services [1]. At the time, researchers estimate that a single case of SARS will infect 2.6 secondary cases on average

in the population by nosocomial transmission [2]. Outbreak data are the best data sources available to record the magnitude of health effects and infectivity. There were expected two or more different waves of cases when person-to-person transmission became important. Therefore, the ongoing COVID-19 pandemic poses anxiety and concerns about the future. In this regard, elementary and straight forward mathematical models may provide notation, concepts, intuitive understanding, and foundation for considering more refined models [3]. In the current

crisis of the corona pandemic, epidemiological modeling was used for real-time forecasting and evaluation [4]. When deciding how to intervene, outputs from these analyses should be considered as a vital tool for structuring information policies and public health measures at the national level [5]. In environmental exposure, the shape of the exposure-response curve as a daily updated dynamic model is the first issue in risk assessment. It highlights the level of or the need for control in geographical locations. By contrast, in occupational exposure – defined as high exposure – the risk assessment is focused on the nature of the exposure-response relationship. Occupational clusters have a greater chance than environmental clusters of representing a common cause [6].

The definitions for COVID-19 cases may vary between countries, but individuals who develop the clinical disease can be triaged into mild/moderate and severe/critical cases [7]. The NICE Guideline developed three clinical definitions: acute COVID-19 (0 to 4 weeks), ongoing symptomatic COVID-19 (4 to 12 weeks), and post-COVID-19 syndrome (12 weeks or longer), but there is no long-term evidence base [8]. Ongoing efforts try to clarify the immunopathological mechanisms underlying the severe disease. Based on epidemiological and statistic modeling of data, this paper aimed to provide the relationship between workplace exposure and SARS-CoV-2 infection in healthcare workers and to design a risk-matrix as a valuable tool for improving risk assessment methods and as a reference tool for recognizing COVID-19 as an occupational disease among health and social health professionals.

Material and method

We designed a registry-based case-control study for 4515 healthcare workers in human health and social work activities performed in public and private institutions. The level of activity defined the selected institutions according to the statistical classification of economic activities in the European Community - NACE [9], as follows: hospital activities (8610); general and specialist medical practice activities (8621, 8622); other human health activities (8690); residential nursing care activities (8710); residential nursing care activities for the elderly and disabled (8730); other residential care activities (8790). We selected our subjects from a preliminary data mining of COVID-19 reported cases in Sibiu County following the SARS-CoV-2 daily counts between March 2020 and 31 of December 2020 (Table 1). We considered the following eligibility criteria:

confirmed SARS-CoV-2 infection; health and social work activities (nine public hospitals, medical offices, outpatient clinic, Sibiu County Ambulance Service, and four residential care facilities); occupation; employed persons; age group 20-64; mandatory respirator use, protective equipment, and safety procedures; mask-wearing compulsory requirement for the general population since May 2020.

We assume that the probability of a healthcare worker getting infected is proportional to the occupational exposure for a constant host population size represented by the number of employees. We considered COVID-19 to be a categorical (yes/no) variable. Our job matrix for occupational exposure includes physicians, nurses, nursing assistants, housekeepers, ambulance workers, and auxiliary staff.

1.1. We performed a document analysis method by extracting quantitative data from the existing database records and documents from local and national public institutions, namely from the local public health authority (no. of COVID-19 cases in Sibiu County), the County Statistical Directorate (no. of employees; population), and the National Institute of Public Health (total no. of COVID-19 cases in health care personnel).

1.2. Risk factor-disease relationships. We calculated the incidence rate (IR), relative risk (RR), and the attributable risk (AR) according to the following formulas [10]:

Indicator	Formula	Meaning
IR	$\frac{\text{No. of new cases} \times 1000}{\text{No. of employees}}$	Shows the number of new cases in the population at risk over a period of time.
RR	$\frac{\text{IR in occupational exposure}}{\text{IR in non - occupational exposure}}$	Shows the probability of an event occurring in the exposed group <i>versus</i> the probability of the event occurring in the non-exposed group.
AR	$\frac{(\text{RR} - 1) \times 100}{\text{RR}}$	Shows the proportion of the risk in exposed individuals that can be attributed to the exposure.

Interpreting RR of a disease: $\text{RR} > 1$ shows a positive association (possibly causal). The strength of association can be weak (1.2-1.5); moderate (1.5-3); and strong (3-10) [11]. Interpreting AR as the occupational etiologic fraction: $\text{AR} > 20\%$ shows a positive association between the workplace risk factor and the outcome - disease [12]. In this paper, AR should be regarded as the excess risk of the disease.

1.3. Statistic modeling of data. The frequency distribution, relative portion, and skewness of COVID-19 cases were displayed graphically in the form of a statistic chart histogram in Excel for Microsoft Office 2019. We used a percentage calculation to compute the risk level of work-related exposure in this model.

Results

In the study population, the 1-year IRs of COVID-19 were as follows: 297‰ in occupational exposures; 86.5‰ in non-occupational exposures; 93.4‰ in all employed persons; 36‰ in the general population of Sibiu County. The relationship between disease and risk factors in the workplace was expressed by absolute (IR, mortality) and relative (RR, AR) measures of association (Table 2). The infected healthcare workers accounted for 7.9% of the total cases registered in Sibiu County. The differences in infection numbers via dynamic modeling show a significant increase in the second half of 2020 (Fig. 1). Because Romania recorded the highest number of cases per day in the second

wave of infections, especially in October and November, we followed the dynamics of the disease in our geographical location (Fig. 2) to evaluate the soundness of our model compared to the real-time trends. Cumulative IR per 14 days was computed and officially reported since October 2020. Statistic modeling of SARS-CoV-2 infections, both in the type of health care activity and job functions, resulted in a positively skewed distribution (to the right) for hospital activities and professional nurses (Fig. 3-4). To categorize job functions into the high, medium, and low-risk levels of exposure, we designed a risk matrix of work-related exposure to COVID-19 by health consequences based on the portion of cases (%) in the workplace. (Table 3).

Table 1. Contingency table regarding COVID-19 cases by exposure status

Exposure status	COVID-19 cases		Total
	Yes	No	
Occupational exposure	1341	3174	4515
Non-occupational exposure	11521	121556	133077

Table 2. Workplace – COVID-19 relationship in occupational exposure

Workplace	IR (‰)	Mortality (‰)	RR	AR (%)
Hospitals	303.5	1	3.5	71.4
Medical-social units	475	0	5.4	81.4
Outpatient clinic	160	0	1.8	44.4
Ambulance service	275.7	0	3.1	67.7
Total	297	0.88	3.4	70.5

Figure 1. Time-dependent distribution of COVID-19 in healthcare workers

Figure 2. Time-dependent distribution of cumulative IR (‰) in Sibiu County

Figure 3. Distribution of COVID-19 in healthcare workers, by activities

Figure 4. Distribution of COVID-19 in healthcare workers, by job-functions

Table 3. Risk dimension according to COVID-19 frequency in the matrix of jobs for health care activities

Risk level	High 1	2	Medium 3	4	Low 5
<i>Hospital care</i>	nurses (43.2%)	physicians (17.7%)	auxiliary staff (16.9%)	nursing assistants (14.3%)	housekeepers (7.4%)
<i>Primary care: outpatient clinic</i>	nurses (40.3%)	nursing assistants (22.2%)	auxiliary staff (22.2%)	physicians (15.3%)	-
<i>Primary care: medical offices*</i>	physicians (80%)	-	nurses (20%)	-	-
<i>Medical-social care</i>	nursing assistants (44.2%)	nurses (23.2%)	auxiliary staff (13.9%)	housekeepers (7%)	physicians (2.3%)
<i>Ambulance service</i>	ambulance workers (37.3%)	nurses (30.5%)	auxiliary staff (20.3%)	physicians (10.1%)	housekeepers (1.7%)

* dental office, family medicine office

Discussions and conclusion

The distribution of COVID-19 in healthcare workers is asymmetric across occupations and healthcare activities; respectively, a significant proportion of infections have occurred in nurses and hospitals. Predictive models suggest the highest risk occupations are in healthcare, particularly dental [13]. In Romania, dental offices were closed for a while, and family medicine offices focused on telemedicine. Physicians – in particular dentists – ranked the highest risk in our model concerning medical offices. Infections among healthcare employees followed the trajectory of infections in the general population, respectively significant in the second half of 2020 when our country experienced much worse the second wave of the ongoing pandemic. Sibiu County was quarantined between November 13 and December 13, when cumulative IR per 14 days exceeded 7‰ [14].

The epidemiological exposure-response model highlights a strong association between the workplace and COVID-19 in healthcare and social care activities (RR 3.4; AR 70.5%). Two issues of concern arise from this model, namely COVID-19 as an occupational disease and the burden of this occupational disease across activities and job functions. According to the World Health Organization considerations in the context of COVID-19, high exposure scenarios include health facilities and transportation of persons known or suspected to have COVID-19 in enclosed vehicles [15]. Our results on nine hospitals (RR 3.5) and ambulance service (RR 3.1) confirm this scenario. Here, we recognize the frontline staff, especially nurses and ambulance workers, due to the risk-matrix. On the other hand, in residential long-term care facilities, the likelihood of nosocomial transmission of COVID-19 is high because residents are among the most vulnerable populations [16]. This scenario is confirmed by the maximum value of RR and AR for occupational exposure – here, we recognize social workers as essential personnel, especially nursing assistants. Consistent with our findings, patient-facing healthcare workers in the United Kingdom were three times more likely to be admitted with COVID-19 than non-patient-facing healthcare workers during the first wave of the pandemic [17]. Moreover, another British cohort study suggests a higher risk of severe COVID-19 in healthcare workers (RR 7.43) relative to non-essential workers [18]. Due to the current community transmission of the virus, it is prudent to consider each case of infected workers and the source of contamination in addition to other evidence.

COVID-19 acquired at the workplace in a substantial

portion, for example, 19.4% in Italy [19], may impact the return to and fitness for work in vulnerable employees [20]; therefore, regional models are essential in risk management. Of the total cases, Romania reported 12.3% cases in medical staff on June 30, 2020, respectively 1.5% cases in medical staff on December 31, 2020 [21], so this model cannot be generalized outside the study population, or at least not in communities with less than 7% infected healthcare workers of the total cases in the area. Further research will be helpful to evidentiate how the dose-response relationship reflects reality in health and social work activities because “microbial risk assessments are not academic exercises” [22]. In conclusion, this epidemiological model of COVID-19 in healthcare workers substantiates the occupational disease, helpful in dispute resolution in environmental and occupational medicine.

Disclosure Statement

The author reports no conflicts of interests.

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