

The Prevalence of COVID-19 Among Health Care Personnel in a University Hospital by the End of 2020, and Ambient Air CO₂ in Hospital Rooms Ventilated by Window-Opening in 2021/22

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In autumn and winter 2020/21 and again in 2021/22 Slovenia has ranked among countries with the highest incidence of COVID-19 per million inhabitants and high excess mortality over the average of previous years. Many patients on non-COVID-19 hospital wards were in fact infected by SARS-CoV-2. Health care personnel at the University Medical Centre Ljubljana (UMCL) were falling ill by Covid-19 in large numbers despite wearing surgical masks and eye protection when dealing with patients. We compared the prevalence of COVID-19 among health care personnel of the Division of Internal Medicine, UMCL by the end of December 2020 with the national average of Slovenia. After instructions had been issued to increase room ventilation by opening windows every hour for at least 10 minutes, ambient air CO₂ was measured in an intensive care room and in an outpatient clinic room during a 10-month period, from April 2021 to February 2022. The prevalence of COVID-19 by the end of December 2020 was 42 % among nurses, 21 % among registered nurses and 17 % among medical doctors, whereas the national average of the population was significantly lower at 5.5 %. Between April 2021 and February 2022, the average CO₂ (ppm) in the intensive care was 633 (standard deviation 198, range 376 to 1540), while in the outpatient clinic the average was 552 (standard deviation 199, range 380 to 1910). During 2020, before the instructions for the use of personal protective equipment were up-graded and before regular window-opening was advised, the prevalence of Covid-19 among health care personnel at the Division of Internal Medicine, UMCL exceeded the national average by 3- to 8-fold. After regular window-opening was advised, the peak CO₂ levels still often exceeded the recommended "safe" level of 750 ppm.

Key words: COVID-19, prevalence, airborne spread, room ventilation, CO₂ level

Highlights

- The importance of airborne transmission of SARS-CoV-2 has been recognized by the World Health Organization rather late into the pandemic.
- During the second wave of the pandemic by the end of December 2020, the prevalence of COVID-19 was 3 to 6 times higher among nurses at the Division of Internal Medicine, UMCL, than the national average, indicating that airborne transmission in poorly ventilated hospital rooms with infected patients had been taking place.
- Relying on improving ventilation by instructing personnel to open windows for at least 10 minutes every hour does not work consistently, as evidenced by CO₂ measurements at the Department of Vascular Diseases, UMCL.
- Airborne virus transmission should be recognized as a serious public health threat that should be systematically addressed, just as contaminated water and food have been addressed and successfully dealt with in the past.

0 INTRODUCTION

During the second wave of the COVID-19 pandemic in the autumn and winter 2020/21, Slovenia reported one of the worldwide highest incidences per million inhabitants. In November 2020, Slovenia suffered a more than 100 % increase in all-cause mortality compared with the monthly average of previous years (Fig. 1) [1]. To a slightly lesser degree, the situation repeated itself in the autumn and winter 2021/22, a year after effective anti-Covid-19 vaccines had already been available.

More than a year into the COVID-19 pandemic, the World Health Organization (WHO) still considered Covid-19 to be spreading mainly by droplet transmission – through "large" (> 5 µm in diameter)

infective droplets, exhaled, sneezed or coughed out by an infected person, reaching the respiratory tract or eyes of the susceptible next person in close contact, at distances of up to 1.5 m to 2 m. The WHO long acknowledged airborne (aerosol) transmission only under special circumstances of aerosol-generating procedures, such as noninvasive high-flow oxygenation, and added transmission by aerosols in poorly ventilated or crowded rooms to their website at the end of April 2021 [2]. Accordingly, until the end of December 2020, the recommendations to health care personnel of the University Medical Centre Ljubljana (UMCL) dealing with "non-Covid" patients, many of whom were in fact infected with SARS-CoV-2, only advised on wearing a surgical mask and eye protection - goggles or a face shield. However, a surgical mask

Excess mortality: Deaths from all causes compared to average over previous years

The percentage difference between the reported number of weekly or monthly deaths in 2020–2022 and the average number of deaths in the same period over the years 2015–2019. The reported number might not count all deaths that occurred due to incomplete coverage and delays in reporting.

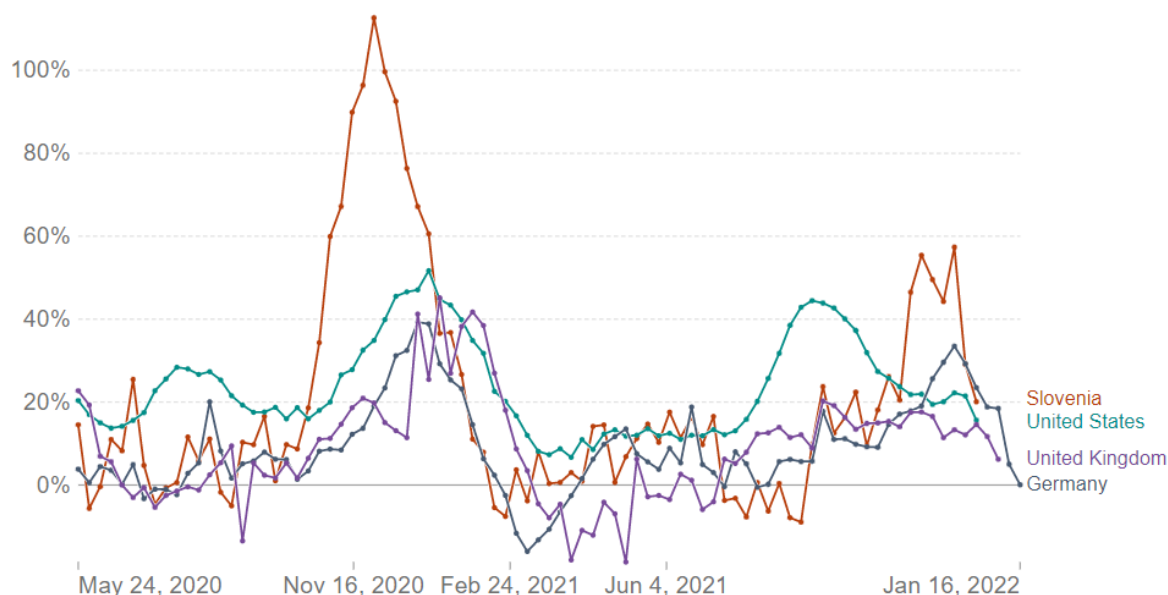


Fig. 1. Excess mortality in November 2020 and January 2022 in Slovenia exceeded that of the United States of America, United Kingdom and Germany [1]

only shields others against droplet transmission from the wearer, but not the wearer against inhaling infective aerosols. By the end of December 2020, all medical personnel at the UMCL were encouraged to wear FFP2 masks when dealing with possibly infected patients, and instructions were given to improve hospital room ventilation by opening windows for at least 10 minutes every hour.

In this paper, we provide the comparison of Covid-19 prevalence among health care personnel at the Division of Internal Medicine of the UMCL with the prevalence among the general population of Slovenia by December 24, 2020. As a surrogate marker of the adequacy of room ventilation in the UMCL, we present data on CO₂ content in ambient air of two hospital rooms between April 2021 and February 2022.

1 MATERIALS AND METHODS

1.1 Prevalence of Covid-19

Data on the number of employees who took a mandatory sick-leave because of confirmed infection by SARS-CoV-2 from January 1 to December 24,

2020, before instructions on up-grading of personal protective equipment and instructions on regular window-opening were issued, were obtained from the records of the Division of Internal Medicine, UMCL.

The prevalence of confirmed infection by SARS-CoV-2 in the general population of Slovenia by December 24, 2020, was calculated from data obtained from [3].

The prevalence of confirmed Covid-19 among nurses, registered nurses and medical doctors of the Division of Internal Medicine, UMCL, was compared with the prevalence of Covid-19 among the general population of Slovenia in the same period by the chi-square test.

1.2 CO₂ Content in Ambient Air

Air-quality sensors WAVEplus (Airthings, Norway) were kindly provided by MIK d.o.o., Slovenia, and installed in selected rooms of the Department of Vascular Diseases, Division of internal Medicine, UMCL. Data from the sensors were obtained from [4].

In the Intensive Care Unit (ICU) of the Department of Vascular Diseases the CO₂ content of ambient

room air was measured between April 4, 2021, and February 18, 2022, and 91,048 measurements were taken. The ICU room had an area of about 36 m², a ceiling height of about 3.6 m, housed up to 4 patients and up to 3 nurses or medical doctors, was connected via a large opening in the wall to a symmetrical ICU room, and was equipped by air-conditioning. The ICU had windows that could be opened.

In the Outpatient Angiology Clinic of the Department of Vascular Diseases the CO₂ content of ambient room air was measured between April 15, 2021, and February 18, 2022, and 87,192 measurements were taken. The Outpatient Angiology Clinic room had an area of about 20 m², a ceiling height of about 3.6 m, housed up to 1 patient, 1 nurse and 1 medical doctor, did not have air-conditioning, but had windows that could be opened.

2 RESULTS

The prevalence of Covid-19 by December 24, 2020, among personnel of the Division of Internal Medicine, UMCL, compared with the general population of Slovenia is presented in Table 1.

The average, standard deviation, minimum and maximum values of CO₂ in ambient air of the ICU and Outpatient Angiology Clinic are given in Table 2.

Table 1. The prevalence of Covid-19 by December 24, 2020, among nurses, registered nurses and medical doctors at the Division of Internal Medicine, UMCL, compared with the general population of Slovenia [3]

	Total number	Confirmed cases of Covid-19	Prevalence of Covid-19 (%)	p-value (compared to the population of Slovenia)
Nurses	292	122	42	< 0.00001
Registered Nurses	471	99	21	<0.00001
Medical Doctors	282	47	17	0.0008
Population of Slovenia	2,079,000	113,886	5.5	-

Table 2. CO₂ [ppm] measured between April 2021 and February 2022 in the Intensive Care Unit and in the Outpatient Angiology Clinic of the Department of Vascular Diseases, UMCL

CO ₂ [ppm]	Intensive Care Unit (ICU)	Outpatient Angiology Clinic
Average	633	552
Standard deviation	198	199
Minimum	376	380
Maximum	1540	1910

Large-scale graphs of the 10-month measurements of CO₂ and room temperature are shown in Fig.

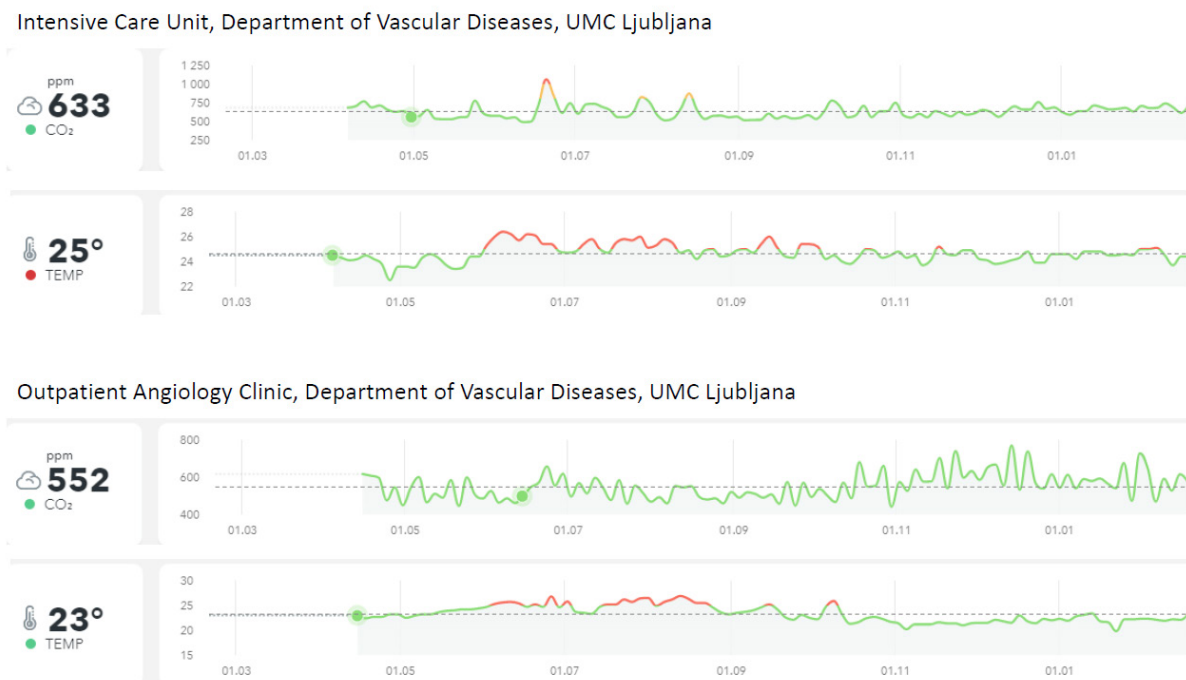


Fig. 2. 10-month measurements of CO₂ [ppm] and room temperature [°C] in the Intensive Care Unit and the Outpatient Angiology Clinic of the Department of Vascular Diseases, UMCL

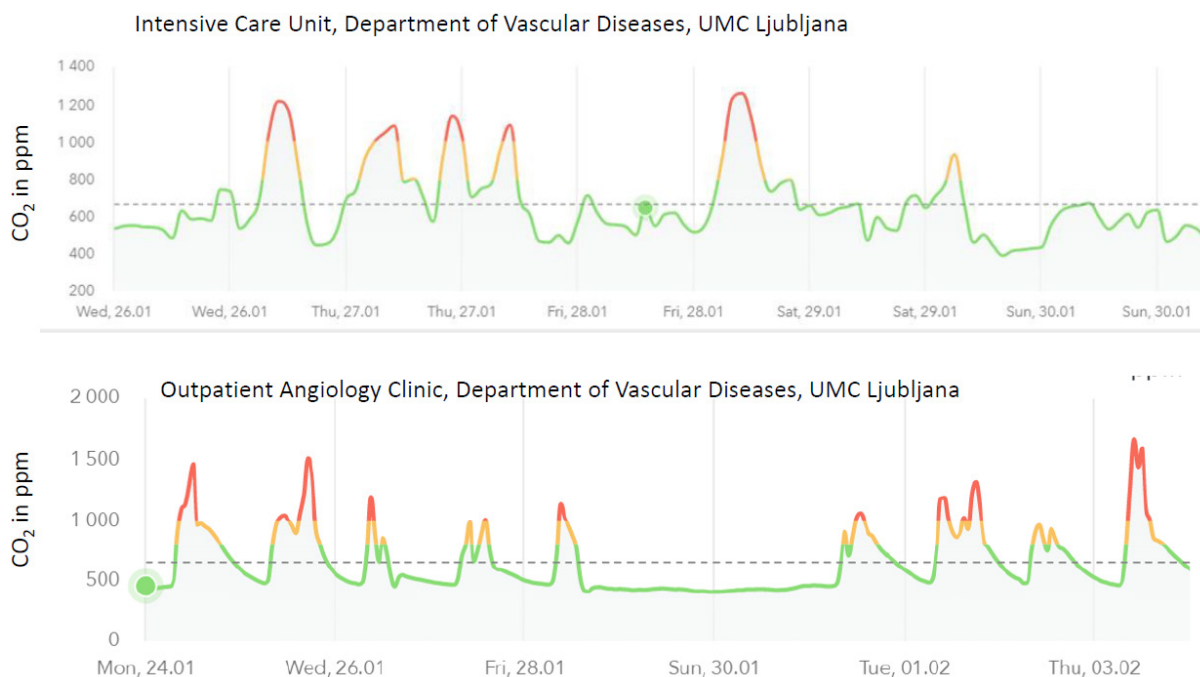


Fig. 3. Day to day measurements of CO₂ [ppm] in the Intensive Care Unit and the Outpatient Angiology Clinic of the Department of Vascular Diseases, UMCL

2. Since occasional peaks of CO₂ cannot be seen on the large-scale graph, an example of day-to-day measurements is presented in Fig. 3.

3 DISCUSSION

The prevalence of COVID-19 by December 24, 2020 was 3- to 8-times higher among health-care personnel of the Division of Internal medicine than among the general population of Slovenia. It seems unlikely that lack of adherence to protective protocols has been the only reason for the high infection rates. The highest prevalence of COVID-19 among nurses, who spend the most time in patient rooms, speaks in favor of airborne transmission of SARS-CoV-2 in hospital rooms with infected patients. Aerosol scientists have long known that there is no clear boundary between droplet transmission and aerosol transmission [5]. People exhale droplets with a continuous distribution of sizes, most of which are smaller than 1 μm in diameter [6]. With air-flow velocities typical of indoor spaces, droplets up to 5 μm in diameter may travel several tens of meters before falling to the ground [7]. An invited commentary for Clinical Infectious Diseases by Morawska and Milton [8], endorsed by 239 scientists from all over the world, summarized these facts in July 2020, explicitly warning of SARS-CoV-2 transmission in poorly ventilated indoor spaces.

Their message was presented to the lay public by the New York Times [9] and to the scientific community by Nature [10]. In October 2020, airborne transmission of SARS-CoV-2 was addressed by a letter published in Science [11], claiming that droplets not only up to 5 μm but up to 100 μm in diameter contributed to infective aerosols, and that airborne transmission was the major route of spreading COVID-19 [11]. Poorly ventilated indoor spaces where an infected individual resides for a longer time are prone to become sites of airborne COVID-19 transmission [11] and [12]. A review of studies testing air samples from hospitals for the presence of SARS-CoV-2 RNA found the highest concentrations in toilets, bathrooms, inner rooms for personnel and in hallways /waiting rooms without windows [13]. Weighing the evidence for and against the probability of airborne transmission has given SARS-CoV-2 a high probability score of 8- on a 9-point scale, together with tuberculosis and influenza [14].

Authors from the Massachusetts Institute of Technology (MIT) [15] have developed a mathematical model predicting the probable time to airborne infection in confined spaces with an infected individual, considering the number and activity of other people in the room, the volume of the confined space, ventilation, air filtration, air humidity and some other variables. Based on this model, an

interactive internet application was developed [16]. The authors assumed an infective dose of a few tens of SARS-CoV-2 virus particles [15] and [16], which is in accordance with recent estimates [17] and [18]. Admittedly, we do not know the precise infective dose of SARS-CoV-2 in humans, since all assumptions rely on animal data and on modeling [17]. However, our experience at the Department of Internal Medicine, UMCL, agrees with predictions of the MIT model: in a poorly ventilated room, where an infected individual has resided long enough to create stationary conditions of the infective aerosol, another person entering the room without protective equipment becomes infected after only 3 minutes on average [15].

At the request of the Medical Director of the UMC Ljubljana, a lecture on airborne transmission of SARS-CoV-2 was presented to the Medical Board of the UMCL on December 21, 2020 [19]. The lecture was summarized in [20], and a mini-review has been published [21].

Immediately following the lecture to the Medical Board of the UMCL, all medical personnel were encouraged to wear FFP2 masks when dealing with possibly infected patients, and instructions were given to improve hospital room ventilation by opening windows for at least 10 minutes every hour. However, the initial interest in improving room ventilation and installing air-filtration systems in the UMCL decreased immediately after effective COVID-19 vaccines became available.

Paralleling developments in the community, efforts were mainly focused on promoting vaccination, which was important and commendable, but not sufficient to bring the COVID-19 pandemic under control. In the autumn of 2021, the numbers of SARS-CoV-2 infected residents of Slovenia, hospital patients and personnel at the UMCL rose again sharply. Especially with the overwhelming wave of the omicron variant, vaccination against the original Wuhan strain of SARS-CoV-2 no longer protected against symptomatic infection, although it still strongly protects against severe illness requiring hospitalization [22].

In parallel with the decreasing efficacy of existing anti-Covid-19 vaccines against symptomatic infection, the enthusiasm for ventilating patient rooms by regularly opening the windows every hour also decreased, as evidenced by the occasionally excessive concentrations of CO₂ at the Department of Vascular Diseases of the UMCL (Fig. 3). The concentration of CO₂ in indoor air approximates the concentration of exhaled aerosols and the recommended “safe level” of

CO₂ in the air is less than 750 parts per million [23] and [24].

Vaccines against SARS-CoV-2 have been developed in record time and especially mRNA vaccines have proven to be very safe and effective against the early strains of SARS-CoV-2 [25] and [26]. Unfortunately, at first due to the limited supply of vaccines, and later due to vaccine hesitancy, vaccination has been proceeding much too slowly to result in herd immunity. Vaccination rates in many parts of the world remain very low, which creates the opportunity for infectious mutant virus strains, such as omicron, to rapidly spread around the globe [27]. Additionally, there are other respiratory pathogens besides SARS-CoV-2 that are transmitted by aerosols, among which influenza is the most well-known [28] and [29]. It is therefore prudent to address prevention of airborne spread of infective respiratory diseases in addition to promoting large-scale vaccination against Covid-19.

From the public health perspective, it is wise to promote outdoor activities, which however is not a reasonable alternative for hospitals and nursing homes that urgently need adequate ventilation and air filtration systems. Morawska and co-workers [30] have appealed in their science paper that airborne virus transmission should be recognized as a serious public health threat which should be systematically addressed, just as contaminated water and food have been addressed and successfully dealt with in the past.

4 CONCLUSIONS

During 2020, before the instructions for the use of personal protective equipment were up-graded and before regular window-opening was advised, the prevalence of Covid-19 among health care personnel at the Division of Internal medicine, UMCL exceeded the national average by 3- to 8-fold. We have not proven a causal relationship between airborne transmission and the high number of Covid-19 cases because many potential confounding factors have not been accounted for. However, the association remains highly suggestive. After regular window-opening was advised in UMCL, the peak CO₂ levels still often exceeded the recommended “safe” level of 750 ppm. Adequate ventilation /air filtration systems should be installed and maintained in hospitals, nursing homes and other densely populated public buildings in order to assure good air quality and minimize airborne hazards to human health.

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