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The Prague General University Hospital

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The hospital, which is on the verge of its third century of existence, has employed dozens of famous personalities in medicine and health care.

The surgical and medical procedures carried out at the hospital have received international recognition on par with those produced in controlled laboratory settings.

All of the above contributed to making the hospital a special place in the Czech Republic.

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Medical inpatient facilities' susceptibility within the context of the COVID-19 pandemic. Case study of the Czech Republic!

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KEYWORDS

Risk management
Inpatient medical facility
Domino effect
Threat
COVID-19

ABSTRACT

One of the key conditions for the effective protection of residents is ensuring the sufficient capacity and functionality of inpatient medical facilities. However, they can fail or even collapse in some situations for many reasons, such as external disasters, internal dysfunctions, and also because of the surrounding infrastructure's malfunction or an overloaded health system. This vulnerability, which was often overlooked in the past, proved critical during the COVID-19 epidemic, but it can still manifest itself in a variety of other crisis situations. The "domino effect" is also a significant phenomenon, i.e., the spread of impacts to other facilities. Inpatient-oriented medical facilities thus have a function as infrastructure at the level of a large territorial unit, and the experience with COVID-19 provides the knowledge that it is in fact a critical infrastructure. These conclusions are illustrated in the presentations of case studies in the Moravian-Silesian Region of the Czech Republic.

1. INTRODUCTION

Critical infrastructures are systems with complex links that directly interfere with disaster risk reduction and prevent not only life loss and damage to health but also provide the background that an economic, physical, social, cultural, and environmental society needs. But each system can, and even must, react with other systems in different ways, including by reacting to the possibility of a cascading so-called "failure chain" or "domino effect" (United Nations Office for Disaster Risk Reduction [UNISDR], 2017).

Many states, cities, or municipalities can identify their critical systems, but only a few can understand how interconnected they are. Indeed, in an extreme case, it may also be "the infrastructure of infrastructures." Achieving critical infrastructure resilience requires efforts to identify and evaluate these links, but the required data may be in different ownership than, for example, the relevant authorities, i.e., another public authority or even the private sector. Critical infrastructure resilience must be treated as a process in which levels change and are restored or degraded over time, if only because, for example,

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climate or societal changes occur. This means that resilience must be understood in terms of resilience as an adaptive process and not as the often-used notion of resistance as a passive property. Therefore, all risks need to be regularly assessed and comprehensively addressed. As a result, many developed countries include all risk areas that may endanger their populations, including health care, in their critical infrastructure. In the Czech Republic, the health sector falls under the so-called crisis legislation, especially in Laws No. 240/2000 Coll., No. 241/2000 Coll., and No. 239/2000 Coll., and in related regulations, implementing decrees, and government regulations. The operator must take several measures to ensure that the operation of such equipment is not interrupted, even in the event of an emergency or extraordinary event, including the establishment of criteria for identifying a critical infrastructure element.

Health is regulated only by the fact that the cross-cutting criteria are, among other things (Štěpán, 2018, p. 11–12):

> *The public's impact is limited to a significant reduction in the provision of necessary services or other significant interference in daily life affecting more than 125,000 people.*

However, most regional hospitals, let alone even smaller health establishments, do not meet this criterion. Thus, formally, it follows that an in-patient medical facility, e.g., with a catchment rate of perhaps 50,000 inhabitants, is not important. But according to the sectoral criteria of the regulation (point IV, "health"), a medical establishment whose total number of acute beds is at least 2500 is considered an element of critical infrastructure. However, our health service has no officially critical infrastructure element, and hospitals and/or inpatient health facilities do not then have to process crisis preparedness plans, which is in dramatic contrast to the experience of the COVID-19 crisis (Štěpán, 2018).

2. HISTORICAL MEDICAL FAILURES

We present the great Lisbon earthquake of 1755 as the imaginary dividing line for determining the first modern disaster. This event was also the trigger for some of the first scientific research into the causes of earthquakes and whether these disasters can be predicted and thereby ensure greater population safety (Etkin, 2015). Historical records describe events that were associated with disease disasters that ended in the deaths of large populations. Most of the time, they were called epidemics, and when they were recorded, they were called the plague or "Black Death" and were said to be God's punishment.

One of the earliest accounts of an epidemic believed to be an actual plague was the Antonine Plague (165–180 AD). The so-called Justinian Plague, which occurred in 558 AD, was the next recorded event. Millions died in this epidemic, with 5-10,000 people dying every day in the capital city of Constantinople alone, and the health service was completely destroyed at the time. In the Middle Ages, the plague hit all of Europe, and also the Czech Republic in three waves. In 1357-1363, the first documented wave hit Europe and the Czech Republic. The consequences were catastrophic. An estimated one-third to one-half of Europe's population has died. The second, stronger wave in Europe, which also affected the Czechs, was in 1380-1382. Its effects were no longer as drastic for the Czechs, but preserved records suggest tens of thousands of casualties. More plagues came in 1711-1715 and struck most of Europe. Around 200,000 people died of this disease in the Czech Republic alone. All these events were accompanied by the health service ceasing to perform its normal functions at the time level. After 1828, plague epidemics were no longer present in Europe, but other insidious diseases began to appear, such as cholera, which reached Europe by sea from India (Svoboda, 1995). In all the major plagues, the failure of health services has also proved to be part of the crisis.

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Modern pandemics in the 20th and 21st centuries include the Spanish flu (1918–1920). Hospitals were hopelessly overcrowded during the epidemic and faced shortages of doctors and nursing staff. There were as many deaths as patients admitted in a day. Other disciplines were closing, e.g., otorhinolaryngology and dentistry, and specialists had to switch to general practice. People often died at home without medical care or assistance, which was also lacking due to wartime events. There were major shortages in medicines and raw materials necessary for the manufacture of medicines, mainly quinine at the time, such as sweeteners, alcohol, and preparations, or even the necessary production aids, e.g., medical glass. Here is a parallel with the lack of oxygen during the COVID-19 pandemic. The unbearable situation occurred in the congestion of cemeteries, as there were few gravediggers, and carpenters. Small morgues were overcrowded, and some of the deceased remained outside. Due to the lack of coffins, the dead were buried in communal, so-called "mass graves" (Salfellner, 2017). Other pandemics in the world included, e.g., the Asian flu (1957–1958), Hong Kong influenza (1968–1969), the swine flu pandemic caused by the H1N1 influenza virus (2009–2010), and COVID-19 (SARS-CoV-2) which commenced in 2019.

Disasters affecting the health service are innumerable, which is why only a small sample of selected disasters since the beginning of the 21st century that have interfered with the activities provided by health services were included. Disasters include floods that forced the evacuation of patients and led to the closure of critical services at Burkina Faso's main hospital in the capital, Ouagadougou (9/2009). National and local health systems providing health services to millions of people have been affected by the damage and destruction of thousands of medical facilities in Gujarat, India (2001), the northern Indonesian province of Aceh (2004), Pakistan (2005), and Myanmar (2008) (The Department of Health of the Philippines, 2013). The earthquake that struck China (2008) damaged or destroyed more than 11,000 medical facilities.

In Haiti in 2010, an earthquake left 230,000 people dead, and cholera spread, killing 10,000 people and then spreading to the neighbouring Dominican Republic (Štětina, 2014). In August 2021, another large earthquake occurred in Haiti, as the local doctor reported (Kedroň, 2021, p. 4):

> *We didn't have time to count the dead and we treated many of the wounded. There were cracks in the walls of the emergency department at the hospital; so, we worked in the yard of the hospital for fear of collapse.*

Hurricanes and typhoons also cause disasters. A typical example is Hurricane Katrina (2005), which damaged protective dams and completely flooded the city of New Orleans with water from the ocean and nearby Lake Pontchartrain. Before the impending catastrophe there was a failure to evacuate the city in time, infrastructure collapsed, including health care, and civil unrest occurred. The lights in the hospitals were without emergency backup power, the use of toilets was forbidden, water had to be saved, and every patient was equipped with a flashlight. Patients were given a zero-dry diet and bottled water from reserves, according to United Nations Disaster Assessment and Coordination (UNDAC) standards (Baldwin et al., 2006).

About 432 medical facilities were damaged by Typhoon Haiyan (Yolanda) in the Philippines in 2013, including 296 barangay medical stations, 97 rural health units, and 38 hospitals in the Eastern Visayas region, including the office of the Ministry of Health (The Department of Health of the Philippines, 2013). Tropical Storm (Allison, 2001) devastated southeast Texas. Most of the damage was downtown, where water flooded hospitals and other buildings. There were floods along Allison's passage, and the resulting electrical failure forced the evacuation of University Hospital, Houston. The hospital had 450 adult beds and 150 children's beds. 169 patients were discharged, and 406 were gradually evacuated to

29 hospitals (Cocanour et al., 2002). During the three-week emergency in the Gaza Strip in 2008–2009, 16 medical workers were killed and 25 injured in the line of duty, 15 hospitals, 41 primary health centres and 29 ambulances were damaged (Štětina, 2014). Cyberattacks are becoming more common these days, including in the Czech Republic; health workers and medical facilities tend to be targeted by attackers or terrorists.

When Russian Federation troops attacked Ukraine in early 2022, many medical workers who worked in hospitals and war zones were killed. Neither the children's hospital nor the maternity hospital in Mariupol, as well as the psychiatric hospital in the Kharkiv region, escaped the military aggression. Not only staff but also newborns, children, parents, and patients were killed or seriously injured in medical facilities (iROZHLAS, 2022). Births of newborns also took place in shelters, such as the Kyiv metro. Ukrainian doctors tried to get as many children as possible to Western Europe who were in an advanced stage of oncological disease or patients who required immediate care, which they could not receive during the ongoing conflict (e.g., dialysis). The doctors were in contact with several international medical organizations and, with their help, tried to transport the sick. Currently, the numbers of all the deaths in the war are not accurately counted. In March 2022 alone, according to the WHO, there were 72 attacks on medical facilities in Ukraine, with 71 dead and 37 injured. These were mostly attacks on hospitals, medical convoys, and convoys with supplies of medical supplies, but there are also suspicions of the kidnapping of medical personnel and patients (Novinky. cz, 2022). It can therefore be summarised that inpatient healthcare facilities are generally vulnerable to a variety of disasters and events, and their possible dysfunction exacerbates the crisis.

3. THE IMPORTANCE OF INPATIENT HEALTH FACILITIES FOR THE POPULATION AND THEIR PROTECTION

Medical facilities are premises intended for the provision of medical services. Health services can be divided according to the form and type of health care provided. Bedside care is health care that cannot be provided on an outpatient basis, requires the patient to be hospitalized, and is provided as part of a continuous operation. The buildings of medical facilities, which are specific, are also very important. These are frequently combined outpatient facilities (polyclinics) and institutional care facilities (hospitals with inpatient units, examination and treatment units, and other spaces required for the medical facility's operation, such as warehouses, boiler rooms, garages, outbuildings, and so on). In hospitals, there are many people of various ages who may be in a critical health condition, patients after major operations, immobile patients, or mentally ill patients. At the same time, there are patients under the influence of pharmacological treatment, including mothers and newborns, in hospitals at any hour of the day or night. Persons moving into these spaces are not only patients but also other people who are not medical professionals but contribute to the running of the organization, e.g., nonmedical staff of the facility, employees of construction companies, maintenance, shops, and also people accompanying the sick, visitors, etc.

The function and importance of health facilities to the population are primarily to provide health care, which consists of a set of activities such as prevention, detection, and elimination of disease; maintenance, restoration, or improvement of health and function; maintenance and prolongation of life and suffering; provision of palliative care; assistance in reproduction and delivery; and provision of preventive, diagnostic, therapeutic, therapeutic rehabilitation, and nursing care. Its other activities include educational, scientific-research, economic, operational, technical, investment, administrative, and pharmacy care provision.

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Losses of function, such as the critical vulnerability of inpatient health facilities, include threats that are external, e.g., floods, prolonged droughts, extreme temperatures (heat waves), extreme wind, epidemics (COVID-19, influenza, etc.), disruption of large-scale electricity supply (blackouts), or internal threats such as fires, a lack of qualified staff, and inadequate logistical security (e.g., oxygen, pharmaceuticals, water, food, materials, etc.). Other things that could go wrong at an inpatient medical facility include an attack by a hostile person, either in person or online. This could be in the form of a booby trap, a violent crime with a gun, which could be done by a terrorist or a person with a mental illness, or a cyberattack on the hospital's information system.

When inpatient medical facilities don't do what they're supposed to, it can set off a chain reaction that can lead to the collapse of the system (e.g., a lack of medical staff) and cause devastation, full beds, a breakdown in logistics, an economic impact on health care, etc.

4. EXAMPLES OF VULNERABILITY DURING THE COVID-19 EPIDEMIC, INCLUDING THE DOMINO EFFECT

Mapped data shows that hospitals are vulnerable to both internal and external risks, which often lead not only to the failure of a single hospital but also to the collapse of the entire health system, which can have fatal results.

> *Due to the closeness of devices, objects, or groups of objects and the location of dangerous substances, there could be a domino effect that makes it more likely that a major accident will happen or that its effects will be worse. (Major Accident Prevention Act in the Czech Republic, Section 2, p. 2763)*

In the current coronavirus epidemic, there is also a domino effect in health care. A result has been a collapse of the system and consequent problems such as a shortage of medical staff and a lack of beds, not only in intensive care units, which are not sufficient in their capacity, but also in dissection rooms and morgues. Doctors may find it difficult to choose which patients to provide artificial pulmonary ventilation, a bed, oxygen, or medication. Other downstream health needs that are necessary to maintain activity and functionality are the supply of pharmaceuticals, food, medical supplies, especially sterile ones, laundry, waste collection, and also energy supply (water, electricity, heat, etc.) that can go into logistical meltdown.

During the COVID-19 epidemic, overloading of incinerators with infectious waste from health care increased due to the increased use of protective equipment during the epidemic. This was due to infectious materials, surgical or bandage materials, sharp objects, drug residues, protective equipment, etc., which must be largely burned as they are considered hazardous waste. At the University Hospital in Ostrava, for instance, the amount of waste increased by seven tonnes. The collection company had to transport infectious waste three times a day. In normal operation, the waste is collected once or twice a day (Vlčková, 2021).

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5. COVID-19 AS AN EXAMPLE OF INPATIENT HEALTH FACILITIES' VULNERABILITY AND INFRASTRUCTURE

5.1 Participants

At the beginning of the COVID-19 epidemic in March 2020, the Dashboard application was created by the regional office of the Department of Health of the Moravian-Silesian Region for immediate access to information about free capacities and the state of hospitals in the region, which were regularly evaluated by the crisis staff. Data were entered daily by the selected staff of 22 inpatient medical facilities, who were the only ones with access to the application. Access passwords were generated by the IT of the Moravian-Silesian Region Regional Office.

All the results of the entered data in the dashboard application were accessed by selected employees of the health department, who constantly checked all the data, and when the situation worsened, they immediately informed the management of the health department. At the same time, the management of the health department, the governor, the Integrated Security Center of the Moravian-Silesian Region, representatives of the regional hygiene station, and hospital directors could check the data.

5.2 Procedure

The data collection offered data on all inpatient organizations in the region and the most important information for the management of the epidemic. It provided data on the total bed capacity, allocated beds for COVID patients, and occupancy (hospitalization) of both intensive and standard wards for COVID positive patients, including information on suspected patients in whom the disease has not yet been confirmed in a laboratory, but symptoms of this disease have already appeared, or it was assumed that they were in contact with a sick person and their state of health already required hospitalization. The load was presented in the form of a wheel and for easier orientation. It was coloured and there was immediately visible signalling for all persons who had access to the dashboard application that the situation was serious and required an urgent, timely and fast solutions.

5.3 Analysis

At the same time, the data collected information on the number of patients connected to artificial lung ventilation, extracorporeal membrane oxygenation, oxygen and the number of devices still available. Another section was information on current stock (protective work equipment, medical material, disinfection, etc.) for a period of 2 months, the absence of medical personnel (medical and nonmedical - nurses, including other important employees who do not have a medical education), the workload of laboratories, which were testing for COVID-19. This data was further converted into a visual form through a dashboard application. The application presented the current situation using pie charts. At the same time, percentage parameters were given for faster and easier orientation in the displayed data, e.g., in the case of insufficient capacity of standard beds, the entire figure was coloured yellow (60% of capacity exhausted) and in the case of exhausted/almost exhausted staff capacity was coloured red (80% or more of capacity exhausted). The white colour of the "tile" showed that the capacity was within the norm. Thanks to these indicators, the state of the entered items was immediately visible upon opening the application, and any crisis had to be resolved immediately, e.g., by increasing the capacity of beds or searching for capacity in another medical facility or region. Other steps taken according to the results from the dashboard application included the Administration of state material reserves and equipment transfers to increase the capacity of laboratories (approaching private companies - laboratories), and moving medical personnel from closed departments to acute beds.

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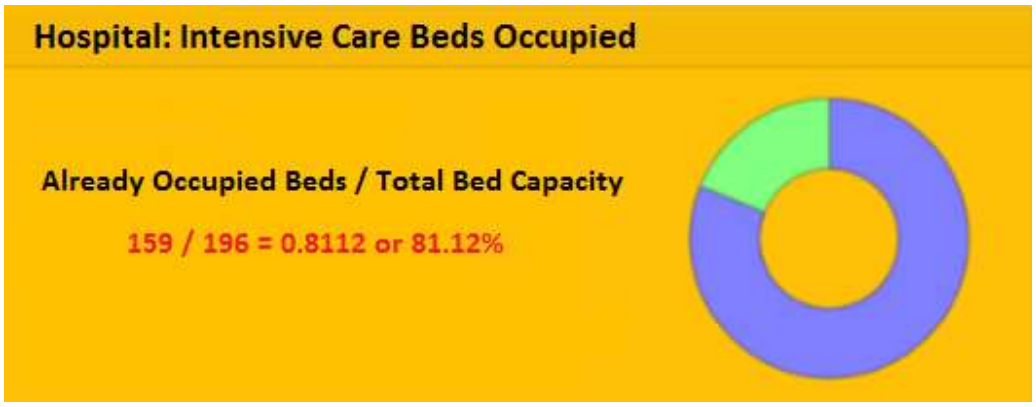

Figure 1. Data gathering example from the dashboard application in the Moravian-Silesian Region, Czech Republic, 2020

Figure 1 demonstrates that the 60% occupied intensive care bed capacity was surpassed. The "tile" was yellow in color.

5.4 Results

As an example of the vulnerability of inpatient medical facilities, data from the application of the COVID-19 dashboard portal, created by the Moravian-Silesian Region, are presented, when up to 1,013 standard beds were occupied by COVID-positive patients (Figure 2), 189 intensive care beds and 120 breathing apparatus were in use for artificial pulmonary ventilation (Figure 3).

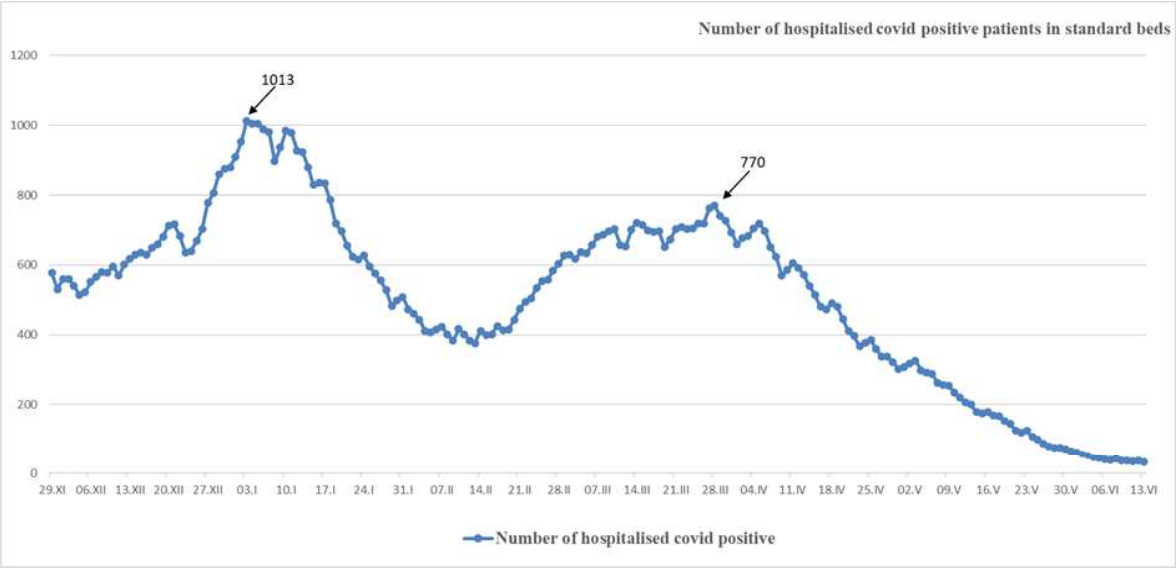

Figure 2. Number of hospitalized patients in the COVID-19 department of standard beds in the Moravian-Silesian Region of the Czech Republic (29/11/2020 — 13/06/2021)

The graph shows that there are 22 in-patient health facilities providing acute in-patient care in the Moravian-Silesia Region, the total capacity of beds by the date 31.05.2021 was, 6773 (updated by the Moravian-Silesia Health Department). According to the Czech Statistical Office, till 31.12.2020, there were 1 192 834 inhabitants in six districts in the territory of the Moravian-Silesia Region (Dehner, 2020, pp. 1-2).

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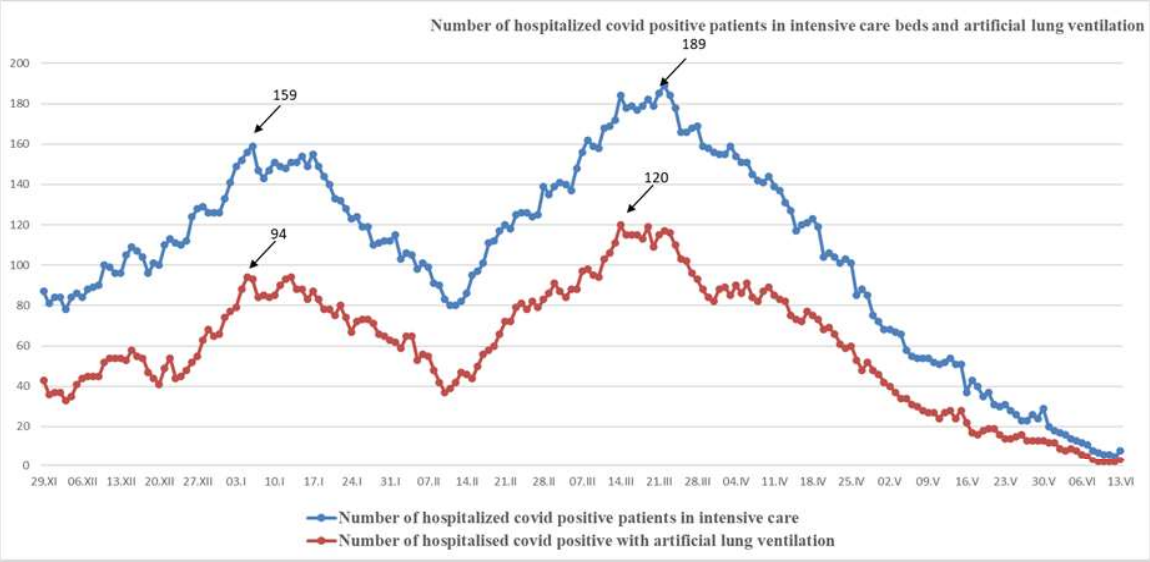

Figure 3. Number of hospitalized patients in intensive care units and on artificial pulmonary ventilation during COVID-19 in the Moravian-Silesian Region of the Czech Republic (29/11/2020 — 13/06/2021)

Another vulnerable link during the epidemic was the absence of medical staff due to COVID-19 (disease, quarantine, caring for a family member). Up to 149 doctors (Figure 4) and 886 nonmedical staff - nurses (Figure 5) were absent in the Moravian-Silesia Region. There was also a monitored group of nonmedical staff (not medical education - for example, economists, and accountants) also involved in the functioning of the organization.

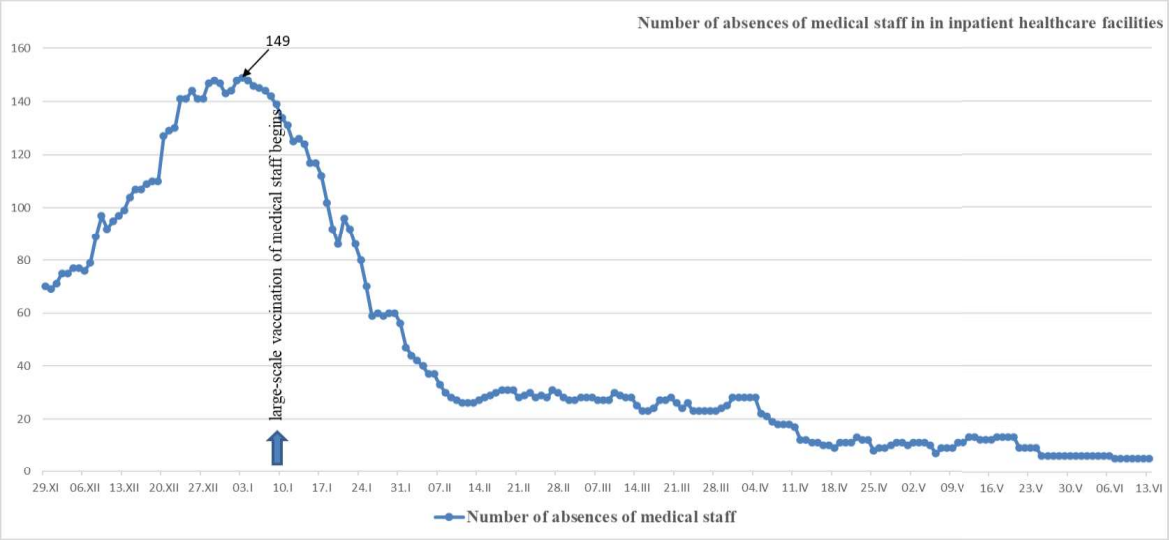

Figure 4. Medical staff absence due to COVID-19 — medical personnel (doctors) at Moravian-Silesian inpatient health facilities (29/11/2020-13/06/2021).

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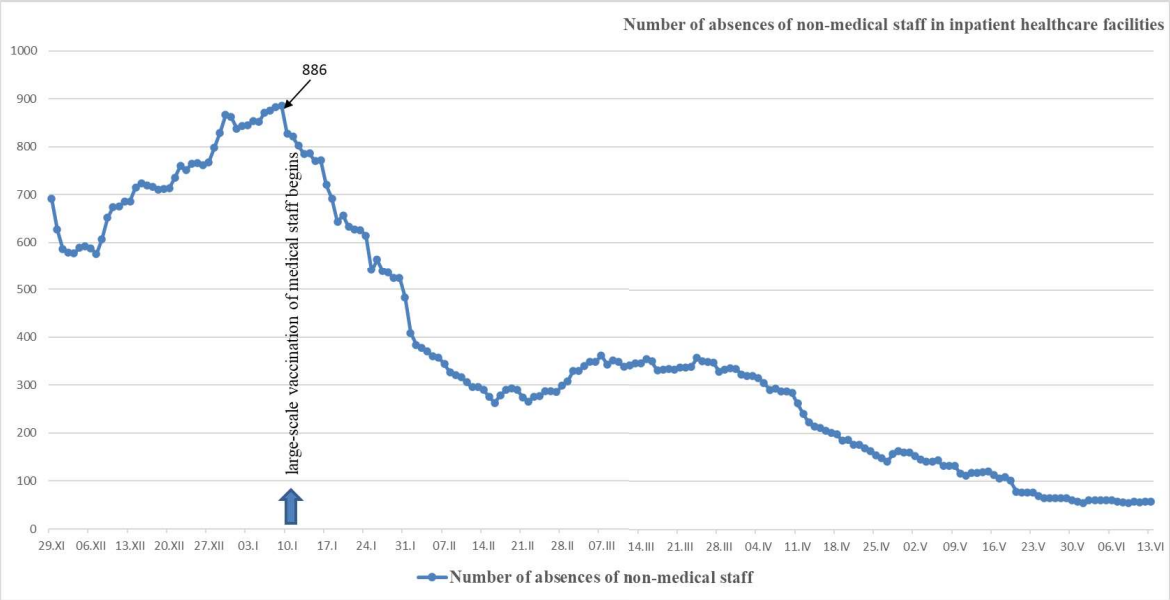

Figure 5. Medical staff absence owing to COVID-19 — nonmedical medical personnel (nurses) at Moravian-Silesian inpatient health facilities (29/11/2020-13/06/2021). (Moravian-Silesian Region, the Czech Republic, 2020).

In In-patient medical facilities there were no planned operational services, specialised departments were closed, and staff were concentrated in wards with acute care beds or earmarked so-called COVID-19 departments. Only emergency care was provided by a government order. Hospital visits were banned or individual visit exceptions (e.g., palliative care) were provided. In the first week of January 2021, the vaccination of medical staff began to increase and the absence from inpatient health facilities decreased sharply, as shown in both Figures 4 and 5. Despite the vaccination of medical staff, nonmedical staff remain absent in greater numbers during the spring months of 2021, due to the still persistent lockdown, closure of schools, nurseries and use of the infirmary, as nonmedical staff are mainly composed of women (nurses). Therefore, there was also a significant social impact.

The created application of the dashboard portal also presented other sections important for maintaining the activity of the network of inpatient health facilities in the Moravian Region, namely the already presented overview of bed aberrations of COVID-positive patients, including prospects, an overview of missing staff, a supply of protective work equipment and medical supplies, the number of COVID-19 tests performed, and the workload of laboratories. The provided data from the dashboard was used for decision-making by the crisis staff during the epidemic.

6. NEED FOR A SYSTEMATIC SOLUTION, INCLUDING THE INCLUSION OF A WIDER SOCIETY

For many decades, international organisations have sought to reduce the risks of disasters, for example by holding regular conferences. In 2015, the Third World Conference took place in Sendai, Japan, establishing the Sendai Disaster Risk Reduction Framework 2015–2030, which it calls for in its Priority 3 concept: invest in disaster risk reduction leading to resilience, aiming at investing in disaster prevention and reduction. At that point, the Sendai Framework directly seeks to reduce disaster risks for inpatient healthcare facilities, which means improving the resilience of national healthcare systems, including integrating disaster risk management into primary, secondary, and tertiary healthcare, especially at the local level; developing the capabilities of health professionals to understand disaster risks and implement

disaster risk reduction approaches in their work; supporting and strengthening resources for disaster medicine training; and supporting health in communities through disaster risk reduction approaches in health programs (Sendai, 2015). In the Czech Republic, the Sendai Framework for Disaster Risk Reduction is implemented by the Ministry of the Environment and is also dedicated to environmental safety. The basic document consists of the Concept of Environmental Safety 2021–2030 with a view to 2050 (Ministertvo životního prostředí, 2020).

7. HELPING A SOCIETY IN CRISIS – CONCRETE EXAMPLES

An example of the possibility of helping companies have business continuity is the RESIMAS Security Research Project. It includes the involvement of Local Action Groups and the creation of working teams to create a local disaster risk reduction platform. Verification of the effectiveness of crisis planning through tactical exercises in Moravian Region regional hospitals (exercises already completed in 2015-2019), analysis of the emergency impacts on the Moravian-Silesian Region population, and incorporation into the crash plan. Additional support for large-scale process electronification and projects (e.g., training of health professionals, ambulances) is one of the current challenges in the Moravian-Silesian Region, which also includes IT systems, emergency revenue construction, and so on. This project is continuing to make further use of collaborations with scientists and doctors, components of the Integrated Rescue System, the army of the Czech Republic, and by developing emergency plans for the Moravian-Silesian Region.

8. CONCLUSION

Bedside health facilities are an integral part of the protection of residents and critical infrastructure and should be understood as such. Governments wishing to implement the Sendai framework must keep many critical infrastructure systems operational, including health, which is essential for the country's population. Monitoring the health system is crucial for managing emergencies and evaluating risk areas. Equally important are human resources, which form a strong link between the health service, their continuing education, and ensuring their safety and quality, which are essential for their work. The work of health professionals, and sometimes even their lives, are threatened by natural disasters, epidemics, and attacks, which are often also located on healthcare buildings and consequently lose their function (providing health care). Other difficult situations for health workers include waves of migration, difficulty in evacuating the sick due to threats, or insufficient logistical supply of key health commodities, which are important components and form a complex part of the health care they provide for the population of a given country. For the overall monitoring of the healthcare system, the essential link is the medical staff, who are key to handling both extraordinary events and the standard operation of the healthcare facility. An application control panel can be used to monitor these risk areas.

9. LIMITATIONS

Data collection continued until April 1, 2022, and even though there was a re-increase in hospitalized patients during the fall and winter of 2021, the values indicated in the figures were no longer exceeded, and therefore additional figures are not presented. All data on the COVID-19 situation was subsequently converted into national statistics, and it was no longer necessary to collect data for the regions. Still, at the start of the epidemic, the application and the information that could be found right away about how the epidemic was going in inpatient medical facilities in the area were very important for the crisis staff to make decisions.

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