COVID-19-related Capacity Building in the Health Sector

An Overview of Key Measures and Policies Influencing Health Sector Capacity to Deal with COVID-19 in Germany, Iran and around the World

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Acronyms

ADRU	Academy of the Disaster Research Unit
AI	Artificial Intelligence
ARDS	Acute Respiratory Distress Syndrome
CDC	Centers for Disease Control and Prevention
COVAX	Covid-19 Vaccines Global Access
COVID-19	Coronavirus disease 2019
DEMIS	Deutsches Elektronisches Melde- & Informationssystem für den Infektionsschutz
ECDC	European Centre for Disease Prevention and Control
ECMO	Extracorporeal Membrane Oxygenation
ELISA	Enzyme-linked immunosorbent assay
EMA	European Medicines Agency
GHRP	Global Humanitarian Response Plan
ICU	Intensive Care Unit
IT	Information Technology
LMIC	Low- and middle-income countries
PPE	Personal Protective Equipment
PCR	Polymerase chain reaction
RKI	Robert Koch-Institut
PRC	Peoples Republic of China
SAGE	Strategic Advisory Group of Experts on Immunization
SARS-CoV	Severe acute respiratory syndrome coronavirus
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
SORMAS	Surveillance Outbreak Response Management & Analysis System
SPRP	Strategic Preparedness and Response Plan
STIKO	Ständige Impfkommission
UN	United Nations
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNISDDR	United Nations International Strategy for Disaster Reduction
USA	United States of America
WHO	World Health Organization
WTO	World Trade Organization

Executive summary

COVID-19 poses significant challenges to all aspects of society and an extraordinary burden on healthcare systems. In response to the pandemic, countries and communities have been forced to develop and adapt innovative approaches, measures, and policies in situations where the data base for those decisions is not always conclusive.

On an international level, apart from financial aid and advice provided by internationaleconomic bodies, the World Health Organization (WHO) played a particularly significant role. Not only did the WHO provide research and guidance, but it also delivered rapid response through its vast network of technical experts and initiated global instruments like the ACT-Accelerator and its vaccination pillar, the COVAX initiative. Those efforts contributed significantly to the global pandemic response, not least by attempting to ensure that Lower-Income-Countries are not left behind in the race for COVID-19 vaccines and medicines. In terms of national and local measures, material procurement was an enormous challenge for many countries at the beginning of the pandemic. COVID-19 exposed bottlenecks in the global supply chain for personal protective equipment (PPE) and other essential material and medical devices. The pandemic also unveiled shortcomings in pandemic preparedness at national and local levels. It also, however, showed remarkable adaptability to the crisis at local, national, and international level, particularly with regards to re-directing production capacity to COVID-19 supplies (from local distilleries producing hand sanitiser to international pharmaceutical competitors joining forces to upscale vaccine production).

Hospital capacity, and Intensive Care Unit (ICU) capacity specifically, are certainly one of the most pressing concerns for healthcare systems during the pandemic. To increase capacity here, additional treatment centres have been set up around the world and hospitals have shut down non-essential diagnostic and treatment procedures to free up capacities for the critically ill. Testing strategies needed to be developed and updated over time to meet the changing epidemiological requirements and needs of the population, while testing devices improved and new methods evolved. A critical factor affecting adequate capacity to respond to COVID-19 is the inadequate health workforce stemming from a pre-existing global gap in health care staff. Additionally, since health care workers are particularly vulnerable not only to the virus but also to burn-out and depression, hospitals are often required to run on limited staffing capacity, reallocate staff between units and (re-)train them according to current needs. Additional human power was often mobilised to support the professional workforce and ranged from the use of reserve forces and military to traditional volunteer services and ad hoc platforms established to provide a wide range of support at individual and communal levels. A plethora of (mostly virtual) COVID-19 trainings for professionals and laypersons became accessible, often at no cost.

Unprecedented efforts in worldwide research collaboration enabled the development and approval of vaccines at unprecedented speed. However, vaccination campaigns create considerable challenges for most healthcare systems, ranging from supply chain, transport, and storage issues to mobilising a highly sensitised and often sceptical population based on tiered vaccination plans. Identification and treatment of COVID-19 was possible through techniques that have long been used in addressing health challenges around the world. These includes the use of Dexamethasone in the management of severe COVID-19, a steroid that was first used in the early 1960s, and the use of telemedicine to reach people in remote locations with medical advice and aiding diagnostics. These efforts, coupled with the rapid development of new technologies and an unprecedented level of collaboration within and between nations, international organisations, global alliances, and the private sector, allowed for much to be achieved in upscaling capacity in response to the SARS-CoV-2 pandemic. This report shares some of these capacity-building efforts to establish a baseline for future processes and progress mapping alongside the epidemiological development of the pandemic.

1. Introduction

COVID-19 has thrown the world into turmoil like no other event in recent decades and has often been described as the biggest public health crisis since the Second World War (Budryk 2020; The Japan Times 2020). Continuous comparisons have been made to the catastrophic H1N1 pandemic of 1918, the so-called Spanish flu. According to CDC estimates (CDC 2020d), the 1918 influenza pandemic killed at least 50 million people in the immediate aftermath of the First World War, and around one-third of the world's population was infected with the virus between 1918 and 1920.

Then, as now, drastic measures were taken to protect the population from the virus and prepare health facilities for large numbers of sick people. In both cases, face masks were mandatory in many parts of the world, schools were closed and social gatherings had to be restricted (Staub et al. 2021; Little 2020).

Since 1918, however, thanks to progress in science and globalisation, the means to understand and tackle the pandemic have significantly improved. Not only was it possible to analyse the genome of the virus within weeks after its first appearance, but accurate testing devices and impactful vaccines have also been developed with unprecedented speed.

Medical technology and knowledge have improved the treatment of the sick while IT enables facilities and policymakers to collaborate closer than ever. But even with these advantages, COVID-19 remains one of the greatest challenges to public health our generations have witnessed. Due to the high transmission rates and incidences, it became clear early that health systems (and indeed almost all other areas of society) would have to upscale their capacities to an unprecedented extent and with yet unknown means. Furthermore, the nature of the virus itself, with its ability to cross borders and reach even remote areas, required a level of collaboration and a joint effort between countries and on a supranational level that had not yet been exercised.

2. Background

This report is part of the ADRU project ***INCREASE-HEALTH-CORONA*** "Real time analysis of the global response to the SARS CoV 2 pandemic and identification of best practices to strengthen health systems in Iran and Germany".

The INCREASE-HEALTH-CORONA project aims to conduct a real-time analysis of the events surrounding the global pandemic with specific attention to actions taken in Germany and Iran. Within the ***project framework***, the developments, measures, and their effects were evaluated on an international comparative basis and formulated into "best practices" to identify options for action and possible development paths. The findings then served as the basis for exchange between actors in Germany and Iran, in addition to the expertise of experts to be included according to currentproblems or questions. The project consisted of the following interlinked ***research priorities.*** These were studied in real-time as the pandemic developed over the duration of the project (July 2020-May2021):

- the analysis of the complex direct and indirect consequences of the pandemic
- the identification of measures to combat the pandemic in both countries
- the description of developments and their projected courses in the future to generate uncertainty-reducing orientation knowledge and
- the intensive exchange about different practices, weak points, needs and the analysis (monitoring) of the effects of steps taken and their consequences.

One work package within the project focusses, in addition to the observation of epidemiological events, on the ***analysis of measures to increase capacity in the health system***, both internationally (in various countries and at WHO level) and nationally with a special focus on Germany and Iran. For this purpose, this state-of-the-art report is developed, taking into account global strategies and the importance of national health systems to be able to classify current epidemiological events as well as current and future measures in the health system against this background. A special focus is placed on measures and approaches developed or implemented in Iran and Germany to increase capacity in the health sector. This report does not aim to be a comprehensive analysis of all capacity enhancement measures, but rather to highlight the challenges and possible solution strategies based on some illustrating examples.

The pandemic situation in Iran and Germany

The experience of disease outbreaks over the past 20-30 years has contributed significantly to global progress in integrated pandemic management. The outbreak of SARS-CoV in 2003 (Collier 2016, 134–36) and recurrent epidemic outbreaks of various avian influenzas provided significant impetus for the improvement and further development of global pandemic preparedness, for example through the revision of the WHO International Health Regulations 2005 and the adaptation of national Preparedness and Response Plans (CDC 2020a; Dingermann 2020). Nevertheless, global, and local deficiencies in prevention, surveillance and management of epidemic situations persist, some of them glaring, as the Ebola outbreak in 2013/2014 showed (Jamison et al. 2017). Moreover, the implementation of the solution strategies that have emerged from the experiences and analyses of recent years can be described as deficient in many aspects (Moon et al. 2015).

The emergence of the novel coronavirus in December 2019 in China led to still greater challenges, not only in the fields of epidemic control and medicine but in all sectors of society. After one year of tOne year into the SARS-CoV-2 pandemic, on 31 December 2020, the world had already witnessed more than 83.52 million confirmed cases of COVID-19 and, sadly, more than 1.82 million deaths.

Before taking a closer look at measures to increase capacity in the health sector in the following chapters, it seems advisable to take a brief look at the development of the SARS-CoV-2 pandemic situation in Germany and Iran. This consideration should also serve to frame the capacity enhancement mechanisms presented as examples in the following chapters in the context of the respective country. In the following, basic data on the number of infections and deaths associated with SARS-CoV-2 will be presented very briefly to generate an overview of the pandemic dynamics.

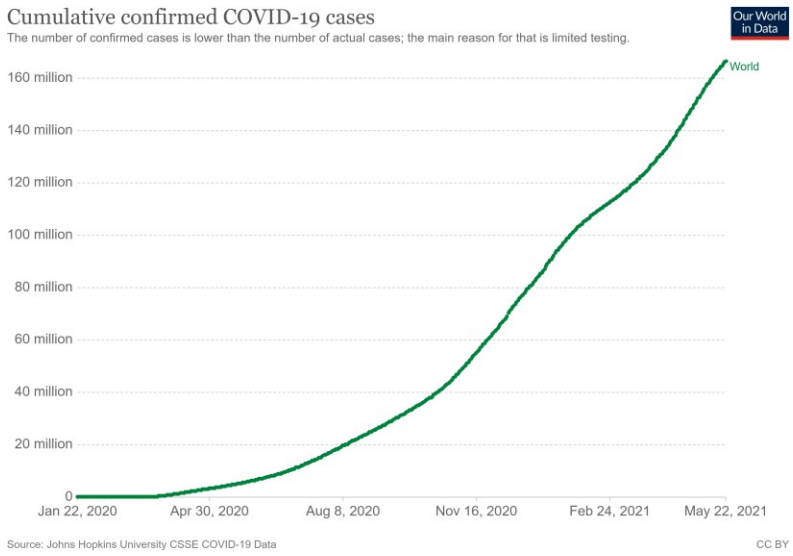

Figure 1 Cumulative COVID-19 cases worldwide (Our World in Data 2021a)

Germany

On 27 January 2020, the first case of the novel coronavirus was detected in Germany: A 33-year-old man had contracted the virus from a Chinese colleague who had come to Germany for a few days on a business trip (Böhmer et al. 2020; Merlot 2020). From this primary case and others, the number of cases increased rapidly in the spring of 2020, which is why the federal government took at times drastic measures to contain the pandemic from March 2020 (Bundesgesundheitsministerium 2021a).

As expected, the number of cases declined gradually over the summer months. Warmer temperatures, but also the fact that people spent less time indoors and had become somewhat accustomed to infection control measures, provide some explanation (Toy 2020), although it should be noted that this trend did not occur everywhere in the summer months (ibid).

There was a lot of criticism, particularly in the early phase of the pandemic, for the German federal government and the Ministry of Health, owing to the fact that, in the view of some experts, the procurement of personal protective equipment (face masks, gloves) and respirators did not proceed fast enough (see chapter 4.2.2). In the summer, on the other hand, the same decision-makers were criticised due to (supposedly) too much protective equipment and respirators, the storage options for which had not always been clarified and had been purchased quite expensively (Mayr 2020).

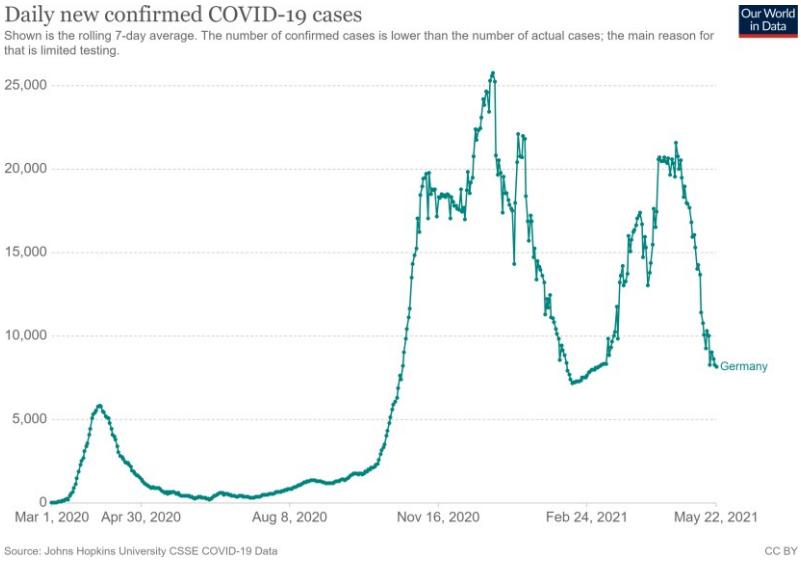

Figure 2 Daily new confirmed COVID-19 cases in Germany (Our World in Data 2021a)

In early autumn, the number of cases began to rise again, and in the winter months, the rate of new infections reached unprecedented heights in Germany. At the same time, even more so than in the spring of 2020, health care facilities approached, and in some cases, exceeded their capacity limits. The number of patients treated in intensive care units also reached a new high and, associated with this, the number of fatalities rose to more than 1000 per day in December 2020/January 2021.

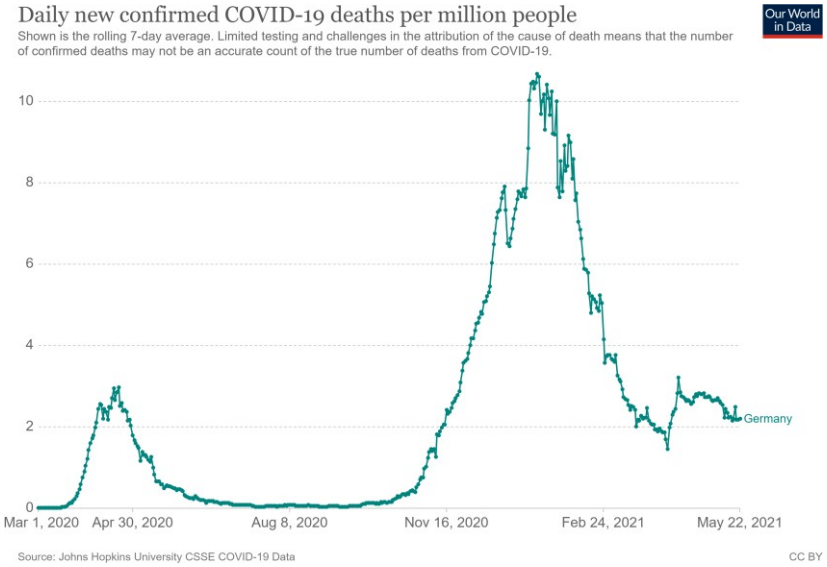

Figure 3 Daily new confirmed COVID-19 deaths in Germany (Our World in Data 2021b)

As a result of significantly tightened pandemic control measures, case numbers began to decline in February 2021. Supposedly due to the new virus variant B.1.1.7 and an easing of the strict lockdown restrictions, the daily new confirmed cases were beginning to increase again in March 2021 (tagesschau.de 2021). The Robert Koch-Institute therefore expected even higher case numbers at the beginning of April 2021 than in December 2020 (Robert Koch-Institut 2021e). While numbers continue to decline, and restrictions are easing, vigilance remains essential to prevent additional spikes in the outbreak.

Iran

Iran was among the first countries to be hit hard by the coronavirus pandemic in early 2020 (Krüger 2020). The first two cases of the novel coronavirus in Iran were confirmed on 19 February 2020 in the central province of Qom (Associated Press 2020), although there were at least some rumours of even earlier cases of the disease that were not officially confirmed as COVID-19 cases (Filkins 2020). About one person died every ten minutes in Iran in March 2020 as a result of coronavirus infection, according to Iranian Health Ministry spokesperson Kianush Jahanpur. The emergency director of the World Health Organization (WHO), Rick Brennan, on the other hand, suspected that the number was actually at least five times higher (von Hein 2020a).

The course of the pandemic in Iran is in some ways similar to the situation in Germany. It should be noted, however, that Iran stagnated at a somewhat higher caseload level in the summer months and the increase in autumn began somewhat earlier than in Germany.

In the early months of 2021, Iran faced severe challenges due to the spread of the mutated and more infectious coronavirus variant first discovered in Britain, known as 20I/501Y.V1 or B.1.1.7 (Financial Tribune 2021). The official number of new infections has been rising again since the beginning of February and has been in decline since. As of 22nd May, 2021, almost 78,400 people have died in in Iran connection with the COVID-19 disease. However, these statistics only include patients who tested positive for the coronavirus in hospitals. Due to low testing capacity, the Iranian Medical Association assumes that the real number of deaths is three to four times higher (von Hein 2021).

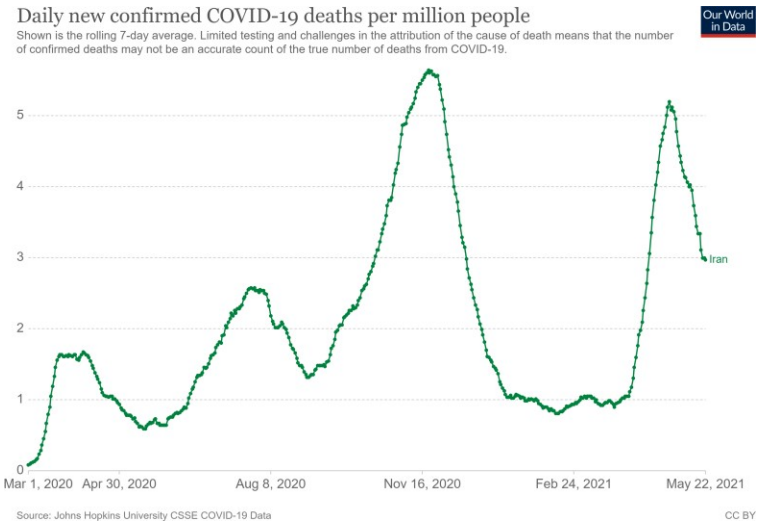

Figure 4 Daily new confirmed COVID-19 cases in Iran (Our World in Data 2021a)

At the same time, it should be noted that the reported case numbers are highly dependent on the testing capacity of the country and the respective reporting system.

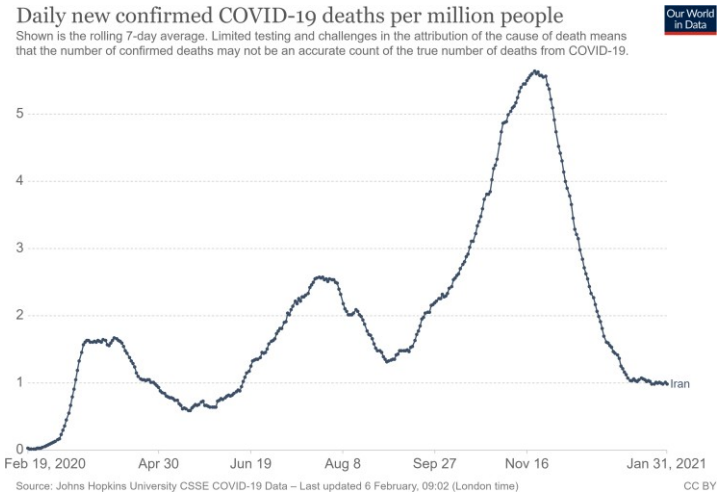

Figure 5 Daily new confirmed COVID-19 deaths in Iran (Our World in Data 2021b)

Due to the lack of transparency of politicians, the population sometimes received the government's measures with distrust. Iran's leadership was partially accused of downplaying and covering up the coronavirus epidemic, or of blaming external enemies (often the USA) for adding extra strain to the difficulties of dealing with the pandemic. Since the numbers of deaths in Iran reported to the World Health Organization were above average in relation to the number of infected people, press reports also suspected a high number of unrecognised or unreported infections with SARS-CoV-2 (Fassihi and Kirkpatrick 2020; Hosseini 2020; Reuter 2020). The US sanctions also left Iran without the much-needed medical infrastructure to combat the pandemic (BBC News Reality Check Team 2020; Koelbl, Popp, and Reuter 2020). On several occasions, doctors and other health professionals reported a lack of hospital capacity in the north of the country and insufficient supplies of personal protective equipment, causing infections and deaths among medical staff (Hosseini 2020; Reuter 2020). In early April 2020, representatives of the British and Iranian health authorities reported the impact of the sanctions on the health system. Iran was the economically weakest country among the ten most affected by the pandemic. As a result, funding for prevention and treatment measures as well as the necessary diagnostic possibilities were very limited (Murphy et al. 2020). This was the reason for the call by experts and politicians for the suspension of the US sanctions (Knipp 2020).

3. Methodology

General considerations

There is no universally valid and comprehensive definition of the term "capacity building". The term is defined and applied variably by different sectors and scientific disciplines and often used interchangeably with the term "capacity development" (Potter and Brough 2004). Some understand "capacity building" as limited to the qualification of personnel, while others use the term in a more comprehensive and holistic sense that includes all measures of an organisational unit that serve to increase capacities in specific areas. The United Nations Office for Disaster Risk Reduction (UNDRR), at that time titled the United Nations International Strategy for Disaster Reduction (UNISDR), for example, defines ***capacity development*** as "*the process by which people, organizations and society systematically stimulate and develop their capability over time to achieve social and economic goals, including through improvement of knowledge, skills, systems, and institutions – within a wider social and cultural enabling environment*" (UNISDR 2009, 6). In contrast, the UNDDR defines ***capacity*** as the *"combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve agreed goals"* (UNISDR 2009, 5).

Since this report focuses on measures to enhance capacity in the health sector, a definition used by the World Health Organization is also consulted:

The World Health Organization defines capacity building as

"*the development of knowledge, skills, commitment, structures, systems and leadership to enable effective health promotion...[with] actions to improve health at three levels: the advancement of knowledge and skills among practitioners; the expansion of support and infrastructure for health promotion in organizations, and; the development of cohesiveness and partnerships for health in communities"* (Smith et al., 2006).

The United Nations Development Programme (UNDP) distinguishes between five ***stages of capacity development*** that must be completed in order to achieve a sustainable increase in capacity. First, stakeholders must be involved in the process and become committed to achieving the agreed-upon goal (UNDP 2015, 22). Second, the existing capacities need to be assessed to establish the baseline from which progress should be measured (UNDP 2015, 23–25). In a third step, a capacity development response is formulated before it is then implemented in a fourth step (UNDP 2015, 27–31). The last step then measures and evaluates the conducted capacity-building efforts (UNDP 2015, 32).

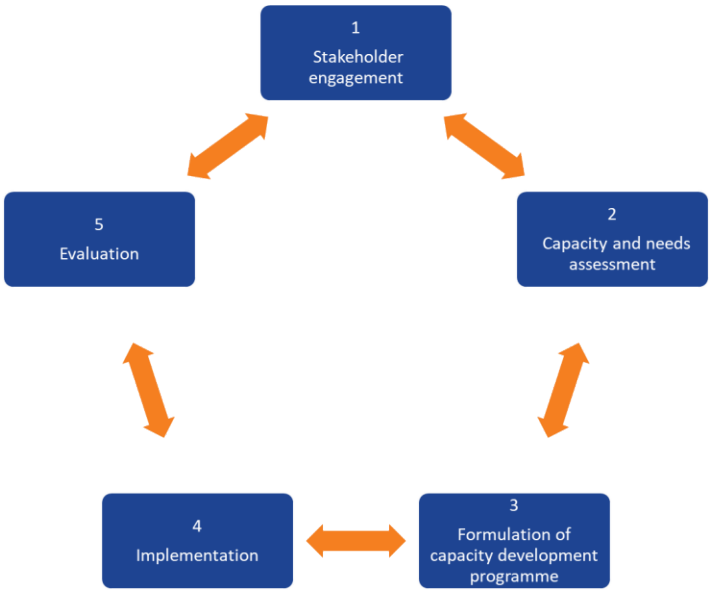

Figure 6 UNDP capacity development cycle

Media monitoring process

A media monitoring process was conducted to collect a variety of innovative or previously known and practised approaches, measures, and policies that were developed, adjusted, or implemented during the SARS-CoV-2 pandemic with the aim of increasing the health sectors capacity to deal with the pandemic. The monitoring process was established between October 2020 and March 2021. News sites, reports, articles, scientific publications, press releases and other forms of media communication were monitored regularly. Where possible, special focus was placed on measures that had been developed, applied, or discussed in Iran and Germany.

Certain areas of interest were identified a priori and expanded and updated over the course of the project. However, the media monitoring process was not scientifically standardised, nor was it guided by hard, objectifiable inclusion criteria and allocation rules. Since it was a part of the real-time analysis of a dynamic crisis, flexibility and adaptability were the guiding principles for the media scanning and informed the selection of articles.

In addition to the media monitoring, the authors conducted an exploratory and orientated literature search in the pubmed database "Covid-19 + capacity building" and Covid-19 + capacity development" to identify relevant papers and articles published between 2010 and 2021. A similar literature search was conducted via the search engine Google Scholar with the search terms "Covid-19 + capacity building + health" and "Covid-19 + capacity development + health".

Potential Bias

It is important to note some effects that have further impacted the selection of articles. Only information from articles in German and English were included. Although articles in other languages (including Persian) were also monitored, these had to be translated with the help of an online translation tool, which meant that translation errors could not be ruled out. Therefore, information and data from these articles were only included if the information was also available in German or English and could thus be verified. It follows that measures, approaches or solutions mentioned

exclusively in articles written in other languages could not be included and are therefore missing in the analysis. Furthermore, it must be assumed that articles in German and English primarily consider those solutions and approaches that the authors consider relevant and particularly innovative and from which they expect a special interest of their respective audience (depending on the platform, e.g., medical professionals, political leaders, or the public). Also, it cannot be ruled out that a publication bias partly prevents the identification of measures and policies that turned out to be unsuitable, ineffective or even harmful.

Structure

The literature selected was then added to a database, accumulating over 600 entries at the end of the media monitoring period on 15 March 2021. The items were then classified according to the level at which they targeted capacity building.

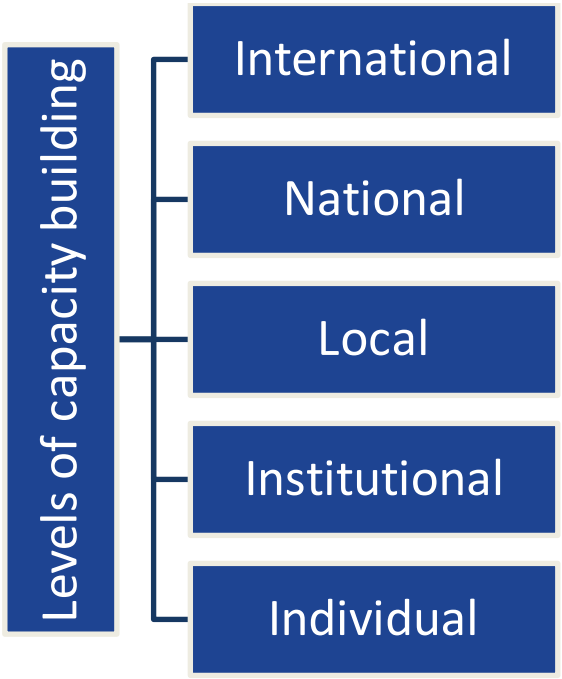

Figure 7 Levels of capacity building

Items were attributed to the ***international level*** if they focused on the international level (e.g., UN, WHO,EU), or if they were addressing multilateral measures or cooperation between different nations or supranational institutions that exceeded national matters.

Measures and approaches were assigned to the ***national and sub-national level*** if they referred to a certain country, city, region, or county. Items were also allocated to this category if they referred to approaches and measures that applied to individual institutions or facilities such as hospitals, or if they focused the individual level.

It should be noted, however, that due to the high level of interdependence and interconnectivity, many items could not always be distinctly and exclusively assigned to a single level (international, national, local, institutional, individual) and/or to a particular sub-topic. Rather, they often overlap and influence each other, which means that their intended and unintended effects can be extend to multiple areas and levels.

4. Results

In the following chapter, selected results of the media monitoring process on capacity building measures in the SARS-CoV-2 pandemic, which aim to relieve the burden on and support the health systems, will be presented. Given the wide range and diversity of all measures taken worldwide, it was only possible to cover a part of them in the media monitoring conducted. The presentation in this report concentrates on those measures that were most frequently applied, appear particularly promising or were particularly innovative. Measures and approaches that were particularly prominent in the academic discourse and media discussion were also considered. However, it must be noted that the success (or failure) of most measures can only undergo a comprehensive and valid evaluation after the pandemic when non-intended side effects and impacts can be considered, and the measures taken canbe considered in the overall context and in their interconnection with other measures and policies against the background of epidemiological developments. In the following, examples of measures and strategies to increase capacity in the health sector are presented for the different levels of capacity building.

4.1. International Level

Pandemics are by definition a global problem that transcends national borders. Therefore, effective measures in pandemic control and coordination must not be limited to individual states but take into account the interdependences and interactions of our globalised world. Some researchers, however, have come to a bitter conclusion about the success of international collaboration in the fight against COVID-19:

"Despite the logical imperative to collaborate and the long heritage of attempts to do so, one year into the COVID-19 pandemic and transmission rages on, with nearly 100 million cases and over two million deaths by January 2021. The ongoing devastation has raised questions about the effectiveness of international collaboration in health and shone a powerful spotlight on WHO and other multilateral agencies with interests in disease control" (Bump, Friberg, and Harper 2021).

4.1.1 Efforts of international organisations and alliances

As one of the largest and most important international alliances, the ***United Nations*** (UN) represents a central authority in the international COVID-19 response. With its specialised organisations and agencies, the UN attempted to address the pandemic situation internationally in a variety of ways, and focal points were assigned to a number of relevant sub-organisations. There are three overarching components to the UN response to the SARS- CoV-2 pandemic:

- Firstly, a comprehensive health response was conducted under the auspices of the WHO that naturally has a special role to play here, which is why its involvement in the pandemic response will be described in more detail below.
- Secondly, the UN conducted a far-reaching effort to protect lives and livelihoods through addressing the devastating socio-economic, humanitarian, and human rights aspects of the crisis. To save lives, and to preserve vital services, businesses, supply chains and institutions, immediate humanitarian assistance was provided to the most affected populations in 63 vulnerable countries. This was done through a Global Humanitarian Response Plan (GHRP) as well as financialsupport for more than 120 countries in alignment with the UN Development

framework. At the global level, the UN response also includes a series of policy briefs and strong advocacy for developing countries, including debt freeze policies and stronger support from international financial institutions. The protection of women and girls is also an important issue (United Nations 2020, 6).

- Thirdly the UN hopes to not only return to the status ante after the coronavirus pandemic but to take the chance *"to transition to renewable energy, sustainable food systems, gender equality, stronger social safety nets, universal health coverage and an international system that can deliverconsistently, effectively and universally – with the Sustainable Development Agenda as our guide"*(United Nations 2020, 6).

The overall strategy of the UN in the fight against the novel coronavirus is elaborated in a comprehensive strategy report that involved the entire UN system (United Nations 2020). The following section provides a closer look at selected aspects of WHO's work in pandemic response.

The ***World Health Organization (WHO)*** was founded in 1948 as the coordinating authority of the United Nations concerning international public health. For this reason, the activities of the WHO in combating the pandemic will be given special attention here in comparison with the efforts of other supra- and international organizations. WHO's objectives and mandate are vast and stretch over a broad spectrum of health-related concerns. They have been adapted and specified repeatedly throughout WHO's existence and are outlined in the following documents: The Constitution of the World Health Organization (WHO 1946), the Declaration of Alma Ata (WHO 1978) and the Ottawa-Charta (WHO 1986).

As the leading international health organization, WHO has central and unique responsibilities and tasks in a pandemic situation. One of them is certainly the early warning and notification of its member-states of infectious disease outbreaks as well as the global coordination of national and international activities in the fight against communicable diseases (Bundesministerium für Gesundheit 2021). According to its mandate to support member states in their efforts to ensure health for their populations, WHO also develops technical guidance documents and cost estimates on a broad variety of pandemic- related issues (WHO 2021b; Bump, Friberg, and Harper 2021). One of those documents is the ***"COVID-19 Strategic Preparedness and Response Plan (SPRP)"*** which was first issued in 2020 and has been published for 2021 in February 2021. The current SPRP builds on lessons learned in 2020 and includes new challenges such as the risks related to the new virus variants. The plan also provides guidance on how to achieve safe, equitable and effective delivery of diagnostics and vaccines as part of the overall strategy to successfully tackle the pandemic (WHO 2021b). Another important guidance document relevant to capacity building in the health sector is the so-called ***"Prioritization Roadmap".*** Based on the WHO "SAGE Values Framework for the Allocation and Prioritization of COVID-19 Vaccination" (WHO 2020h) the "Roadmap for prioritizing uses of COVID-19 vaccines" was designed to assist countries in developing public health strategies regarding vaccination planning and identifying and targeting priority groups for different levels of vaccine availability and epidemiological requirements. The Prioritization Roadmap offers three exemplary rationales for prioritization: a) Health workers at high to very high risk of becoming infected and transmitting SARS-CoV-2 in the community; b) Sociodemographic groups at significantly higher risk of severe disease or death, e.g. elderly people; c) Social/employment groups at elevated risk of acquiring and transmitting infection because they are unable to effectively physically distance (WHO 2020i).

A more practical tool for capacity assessment and enhancement for individual districts or even individual facilities, the ***WHO Hospital Readiness Checklist*** is of particular importance. It can be used to inform decision-making and (contingency) planning before, after and amid the pandemic. The checklist can help to determine current capacities and identify relevant gaps along 12 key components: Leadership and incident management, coordination and communication, surveillance and information management, risk communication and community engagement, administration, finance and business

continuity, human resources, surge capacity, continuity of essential support services, patient management, occupational health, mental health and psychosocial support, rapid identification and diagnosis, infection prevention and control (WHO 2020j) The Checklist comes with an Excel file to quantify and analyse a hospital's readiness (WHO 2020b).

The WHO also initiated the ***COVID-19 Solitary Response Fund*** (Usher 2020) and the WHO Foundation which is legally separate from WHO (WHO 2020c) to generate and facilitate additional funds for COVID-19 response.

As one of the main efforts in the fight against the pandemic the ***Access to COVID-19 Tools (ACT) Accelerator*** was launched under the auspices of the WHO. The ACT Accelerator is a novel collaboration that aims to achieve and accelerate development, production and equitable access to COVID-19 tests, treatments, and vaccines. The Accelerator was initiated in March 2020 and launched by WHO, the European Commission, France, and the Bill & Melinda Gates Foundation in April 2020. The collaboration brings together a wide variety of stakeholders from different branches and organisations that contribute to global efforts to fight the pandemic. Among the organisations involved are the Bill & Melinda Gates Foundation, CEPI, FIND, Gavi, The Global Fund, Unitaid, Wellcome, WHO, and the World Bank (WHO 2020d). The ACT accelerator comprises four pillars: diagnostics, treatment, vaccines and health system strengthening.

Against the background of the vaccines that are now available, the vaccine pillar, named the ***"COVAX arm"***, of the ACT accelerator (WHO 2021a) is of particular importance and has received the highest media attention of all the ACT Accelerator's pillars, since vaccine development was accompanied by huge public interest worldwide. The pandemic has been a stark reminder that in our interconnected world, a threat that affects one of us might affect us all. This globality aspect is especially true when it comes to the procurement and administration of vaccines. Sufficient protection of the world's population can only be guaranteed if a significant number of people are vaccinated across all continents. The COVAX arm initially aimed to secure the availability of vaccine dosages around the world, independent from the financial resources of individual countries. The aim was to ensure that not only citizens of wealthy countries received early vaccination, but that vaccine supplies were affordable and accessible everywhere and distributed equitably (WHO 2021a). In the autumn of 2020, the G20 states confirmed their commitment to sharing the vaccine doses available with poorer countries (Deutsches Ärzteblatt 2020t; 2020w) – however, some of this commitment seemed to have hollowed when the first vaccine doses arrived in September. Unfortunately, the efforts undertaken by COVAX are to some extent contradicted by the attempts of individual wealthy countriesto secure most of the world's vaccine supplies for their own people, and their people alone – a phenomenon that some call vaccine nationalism or vaccine colonialism (The Guardian, Olla, Akin 2021). By September 2020, the majority of the vaccines that could be produced in 2021 were already tied up inexclusive agreements that were concluded outside the "COVAX Facility" (Oxfam International 2020). This is the case even though, according to the vaccine initiative GAVI, 156 countries representing two- thirds of the world's population have already joined the initiative (GAVI 2020). COVAX hopes to address an unequal system of procurement in which wealthy countries have secured enough doses to vaccinate their populations many times over, while many poorer countries have received nothing at all so far.

Uneven vaccine distribution threatens to diminish the success in controlling the pandemic. In January 2021, World Health Organization Director-General Tedros Adhanom Ghebreyesus warned that "the world is on the brink of a ***catastrophic moral failure*** if wealthier nations do not ensure the equitable distribution of vaccines to combat the coronavirus pandemic" (Schemm and Hassan 2021). The price of this failure, he added, "will be paid with lives and livelihoods in the world's poorest countries" (Schemm and Hassan 2021). For this reason, various aid organisations, e.g. Médecins Sans Frontières, are demanding that the German government and the EU participate in ensuring funding for vaccines for poorer countries as well as for a humanitarian contingent (Ärzte ohne Grenzen 2020).

For 2021, COVAX aims to distribute two billion vaccine doses to 92 low- and middle-income countries (Gavi.org 2021a). But even if this distribution goal is met in 2021, the doses will have to be administered as well and vaccinating a majority of the world's most vulnerable people this year will be an immense challenge. In early March 2021, Gavi published further information about the first allocations of COVAX vaccines (Gavi.org 2021b). The first allocation includes 237 million doses of the AstraZeneca/Oxford vaccine to 142 countries, with projected deliveries through May 2021. Additionally, 1.2 million doses of the Pfizer-BioNTech vaccine will be distributed to countries that requested it and demonstrated the ability to manage the additional logistical requirements like for example ultra-cold freezer capacity (The Covax Facility 2021). However, even with the support for vaccine distribution through COVAX, the question remains when (and if) global vaccine equity will be achieved at all. *The Economist* Intelligence Unit reported in January 2021 that some parts of South America, Africa, and Asia will not achieve widespread vaccination coverage until 2023 (The Economist 2021).

One example of the ***ACT Accelerators treatment pillar*** are efforts to meet the oxygen demand in Low- and Middle-Income Countries (LMIC). More than half a million COVID-19 patients are estimated to require oxygen treatment every day in LMIC alone (path.org 2021). Oxygen is an essential medicine and crucial for the treatment of COVID-19 patients. However, many hospitals, especially in LMIC, have run out of their oxygen supplies during the pandemic and are facing challenges in the procurement of new oxygen supplies (Usher 2021). The ***COVID-19 Oxygen Emergency Taskforce*** brings together key organisations working on oxygen access under the ACT-A Therapeutics pillar. The taskforce aims at measuring oxygen demand, working with financing partners, and securing oxygen supplies and technical support for those countries´ most in need (WHO 2021c). Even though close cooperation between WHO and member states, especially during the pandemic is essential to promote public health and to control the pandemic there unfortunately seem to be some degree of mutual distrust between WHO and some of its member states, that impedes WHOs ability to respond to the pandemic (Bump, Friberg, and Harper 2021).

4.1.2 Efforts of international economic bodies

COVID-19 has been a major challenge for economic systems worldwide and almost every country has developed and approved economic relief package or financial stimulus bill in the wake of the pandemic. The ***World Trade Organization*** summarized them in a comprehensive table, comprising over 900 entries.

The table is to be considered an "informal situation report and an attempt to provide transparency with respect to support measures taken in the context of the COVID-19 crisis" (World Trade Or- ganization 2020).

European Union (France)	Adopted on 11 December 2020: €106.7 million restructuring aid and €30.2 compensation for damages suffered due to coronavirus outbreak in favour of French airline Corsair (SA.58125) (press release: IP/20/2398)	Permanent Delegation of the European Union to the WTO (26 April 2021). State Aid Measures adopted under Article 107(2)(b) TFEU.	
European Union (France)	Adopted on 4 March 2021: French guarantee scheme mobilising up to €20 billion support from private investors for companies affected by coronavirus outbreak (SA.58639) (press release: IP/21/812)	Permanent Delegation of the European Union to the WTO (26 April 2021). State Aid Measures adopted under Article 107(3)(b) TFEU.	
European Union (Germany)	COVID-19: Guarantee scheme (with a budget of up to €5 billion and an additional safety-net to cover up to €30 billion in total) to support the trade credit insurance market in the face of the coronavirus outbreak.	Permanent Delegation of the European Union to the WTO (24 April 2020). State Aid Measures adopted under Article 107(3)(b) TFEU. Decision date: 14.04.2020.	Start date 01 March 2020 to end date 31 December 2020.
European Union (Germany)	COVID-19: 2 aid schemes providing subsidied loans to companies up to €1 billion/company affected by coronavirus outbreak.	Permanent Delegation of the European Union to the WTO (24 April 2020). State Aid Measures adopted under the Temporary Framework (adopted on 19/03/2020). Decision date: 22.03.2020.	Start date 22 March 2020 to end date 31 December 2020.
European Union (Germany)	COVID-19: Guarantee scheme to further support economy in coronavirus outbreak.	Permanent Delegation of the European Union to the WTO (24 April 2020). State Aid Measures adopted under the Temporary Framework (adopted on 19/03/2020). Decision date: 24.03.2020.	Start date 24 March 2020 to end date 31 December 2020.

Figure 8 Excerpt: COVID-19 and World Trade – COVID-19 support measures

Most of those measures and policies can be attributed to the following four pillars of action defined by the ***International Labour Organization***: Stimulating the economy and jobs, supporting enterprises, employment, and incomes, protecting workers in the workplace, and facilitating a dialogue between government, workers, and employers to find solutions (International Labour Organization 2021). The different sub-sections of each pillar can then be further differentiated and adapted to the respective needs of individual countries. Due to the enormous amount and diversity of funding at the national and supra-national level, only a few examples can be presented in this report.

The ***World Trade Organization*** is, among other purposes, a forum aimed at negotiating trade agreements, responding to upcoming economic challenges, and coordinating with other international organisations (World Trade Organization 2021). Pursuant to these purposes, a resolution was introduced by India and South Africa that would allow WTO member states to suspend, for the duration of the pandemic, intellectual property rights on medical products needed in the fight against it. This would allow for a global expansion of the much-needed production of vaccines, tests, medicines, protective masks and respirators, and could provide faster protection for millions of people (Ärzte ohne Grenzen 2021). However, the resolution was blocked by several member states, including Germany, as of February 2021.

The ***World Bank*** Group's emergency support operations assist more than 100 developing countries in responding to the pandemic (World Bank 2020). Among other activities, the group also helps countries to access critically needed medical supplies by negotiating with suppliers on behalf of governments and supporting vaccine rollouts in developing countries (World Bank 2021). Furthermore, it has contributed to infectious disease control through its pandemic emergency financing and by issuing so-called "pandemic bonds" (World Bank 2016).

The ***International Monetary Fund*** (IMF) reacted to the COVID-19 crisis by supporting countries with policy advice and financial support. The funds´ actions comprise of the following components: Emergency financing, grants for debt relief, calls for bilateral debt relief, enhancing liquidity, adjusting existing lending arrangements, capacity development, and policy advice (IMF 2021). The IMF also conducted several analysis and published guidance documents and research papers on the matter.

4.1.3 Efforts of the European Union

Over the course of the pandemic, multiple joint agreements and measures between individual countries and alliances were established, aiming to combat the pandemic and cooperate in infection control. One such measure was to be the European Commission coordinating the joint ***Corona crisis response of the European Union***. Measures at national and European level are designed to support the health systems of the Member States and to cushion the socio-economic impact of the pandemic (European Commission 2021). The European Commission's Coronavirus response comprised different measures on multiple levels. Among the measures most relevant to capacity building in the healthcare sector were the following examples (European Commission 2021):

- Supporting research for vaccines, diagnostics, and treatment
- Supporting the supply of medical equipment, including by strengthening production capacities and joint procurement measures
- Development of guidelines for testing strategies and for preventing the spread of the virus and on rapid response measures for all Member States, perceived gaps in clinical management and the prioritisation of health care, civil protection, and other emergency services as well as strategic measures to address the long-term consequences of the Corona pandemic
- Provision of funding through the Coronavirus Response Initiative (Koopman 2020)
- Ensuring liquidity through the European Investment Fund

- Allowing exceptional fiscal support for, among other sectors, health systems by triggering the "escape clause"

To ***boost production and ensure the availability of personal protective equipment*****,** the Commission closely collaborates with the member states to assess the available stock of PPE in the EU, the current production capacity, and foreseeable needs. It ensures conformity assessment and market surveillance and discusses the conversion of production lines with industry and advises manufacturers on how to ramp up production of protective equipment and disinfectants (European Commission 2021).

In addition to the development of a ***European testing strategy***, the European Commission will provide 100 million Euro in funding through the ***Rapid Response Instrument*** for the purchase and implementation of tests in the EU Member States. Also, the Commission is launching a ***joint procurement procedure*** to help EU countries purchase more rapid tests. The Commission is also supporting the International Federation of the Red Cross/Red Crescent with €35.5 million to increase COVID-19 testing capacity in the EU, train volunteers and protect vulnerable people (European Commission 2021).

The European Commission's Public Health-related reactions to the Pandemic also led to the initiation of a ***"European Health Union"***, whose aim is to strengthen the role of key EU agencies in crisis preparedness and response and improve cooperation and coordination of EU structures in health crises (European Commission 2020b). To achieve these goals, the proposal envisages a stronger health security framework with harmonised local, national and European preparedness and response plans and an EU emergency system that would support *"increased coordination and rapid action to develop, stockpile, and procure the equipment needed to face the crisis"* (European Commission 2020b). Also, the mandate of the ***European Centre for Disease Prevention and Control and the European Medicines Agency*** are to be widened and a novel ***Health Emergency Response Authority (HERA)*** is to be created (European Commission 2020b). However, there is also massive criticism of the EU's performance so far in dealing with the coronavirus pandemic, particularly regarding the procurement of vaccines. According to a survey, the perceived failure of the institution in this regard has led to a loss of trust in the EU among German citizens (Spiegel.de 2021b).

The pandemic led to a number of ***bi- or multilateral collaborations between countries*** outside of alliances like the UN and the EU. For example, the heads of state of Austria, Denmark and Israel met in early March 2021 to discuss future collaborations in the research and development of vaccines (Eddy and Pronczuk 2021). However, criticism for the perceived poor performance of the EU in vaccine development and roll-out was also expressed during the meeting, however, for example by Austrian Chancellor Sebastian Kurz, who declared that the European Medical Agency had been too slow in its approval process and that he no longer wished for Austria to be reliant on the EU in terms of vaccine production (Eddy and Pronczuk 2021; Zdf.de 2021).

4.1.4 International Health Research Collaboration

COVID-19 has promoted and advanced international research in many ways and, in some respects, changed the way already existing collaborations work together and exchange their knowledge. World Health Assembly member states passed a resolution in May 2020 that reconfirmed the need for resource distribution and collective action in tackling the pandemic (WHO 2020a). This need also concerns science in this public health disaster.

Unprecedented amounts of financial means have been invested in research and the development of diagnostics, drugs and vaccines and other innovations that aim at tackling the pandemic (Deutsches Ärzteblatt 2020d; 2021b; 2021f). For example, the European Union alone planned to allocate € 1 billion in research and innovation to combat COVID-19 and its consequences in 2020 (European Union 2020).

Some compare the current commitment to the research efforts at the height of the HIV/AIDS epidemic in Europe and America in the 1980s and 1990s, although it has to be noted that today's technical possibilities naturally outnumber the efforts of that time (Apuzzo and Kirkpatrick 2020).

Many ***research platforms and scientific journals*** decided not to charge for articles and papers about COVID-19 and other pandemic related topics. Also, many research platforms developed special COVID-19 resource hubs where data and literature collections regarding COVID-19 were available free of charge (see for example National Library of Medicine 2021). By the end of December 2020, more than 81.000 publications have been written about SARS CoV-2 and COVID-19 in the medical field, according to Harvard Medical School's platform COVIDAuthors (Barlow 2021). A literature search on PubMed for articles on COVID-19 with filters set to include only articles that were published in the last year found 110.493 results on 18 February, 2021.

Preprint servers like ***bioRxiv*** (2021) and ***medRxiv*** (2021) enable the publication of potentially ground-breaking study results at unprecedented speed (Vergin 2020). On the one hand, the enormous abundance of articles and their mostly free availability gives experts and decision-makers direct access to a wealth of knowledge. On the other, this enormous wealth is difficult to keep track of and the quality of the articles is not necessarily obvious, especially for non-researchers (Deutsche Forschungsgemeinschaft 2020). There are also critical voices warning that the abandonment of a customary peer review process may undermine scientific quality and norms and may lead to the spread of misinformation (da Silva 2018; Nabavi Nouri et al. 2020). Some argue however, that the low threshold for publications could have an advantage: the otherwise frequently observed publication bias (i.e. the tendency that primarily positive study results with statistically significant outcomes are published, but studies that do not show any ground-breaking new findings or only minor effects tend not to be published) could be significantly limited (Vergin 2020).

A broad ***variety of international research collaborations*** in and across various fields and research areas was established over the course of the pandemic to bundle competencies and exchange knowledge. Some of these collaborations were formal and initiated by supranational and international organisations and stakeholders while others stemmed from pre-existing research networks in the respective fields. The logic behind this collaborative approach seems reasonable: *"There is strength in numbers. We learn more, and faster, together – and the pandemic is underscoring the critical role of international collaboration on the frontiers of science and technology"* (Kituyi 2020).

The WHO has partnered with the non-profit Magic Evidence Ecosystem Foundation (MAGIC) for methodologic support, to develop and ***disseminate living guidance for Covid-19 drug treatments***, based on a living systematic review and network analysis. This living guideline responds to emerging evidence from randomised controlled trials (RCTs) on existing and new drug treatments for COVID-19 (WHO and MAGIC 2021)

When it comes to access to vaccines for Lower-Income Countries, WHO and a number of governments and technical experts are calling for vaccine manufacturers to share relevant technologies, intellectual property and data, in order to expand production capacity and enable countries with fewer resources to scale up their vaccination capacities as well (Cheng and Hinnant 2021). This could be achieved in several ways. One option, supported by the WHO, is a "patent pool," like those established for HIV, tuberculosis, and hepatitis treatments. As of 22nd May 2021, to our knowledge, no company has offered its participation. Another proposal involves ***suspending intellectual property rights during the pandemic***. This plan is opposed by several vaccine developers and was rejected by the World Trade Organization by the US and European countries, despite support from at least 119 countries and the African Union (see Chapter 4.1.2). Vaccine manufacturers argue that wealthier nations should simply donate more vaccine doses, including through COVAX. Some countries are doing this – for example, China, Russia, and India have stepped up and agreed on bilateral agreements to obtain those nations' locally developed and approved vaccines (Heath 2021). India has launched a "friendship program"

which includes 49 nations (Heath 2021), China is delivering vaccine supplies to African nations, Turkey, and Afghanistan (Aljazeera 2021), while as many as 50 countries have made contracts with Russia for its Sputnik V vaccine (Ellyatt 2021).

4.2. National and Local Level

The SARS-CoV-2 pandemic poses unprecedented challenges for nations around the world. Solution strategies are often developed in an iterative process, as the evidence for the effectiveness of individual measures (e.g., lockdowns, mask-wearing) can only be generated to a meaningful extent with widespread application. Measures and policies that serve to increase capacity in the health sector cannot always be clearly distinguished from those that aim to reduce the number of infections in general. One reason for this is that every reduction in incidence also leads to lower utilisation of the health system and thus to a reduction in the use of strained resources, freeing up capacities for other patients and emergencies. In the following, we will look at some examples of measures taken at national and sub-national level to save health care resources or increase capacities during the pandemic. ***It should be noted, however, that a distinction between national and supra-national, national and local or even institutional measures and policies is not always possible due to the high degree of interconnectedness and interdependence***. As national and local entities (e.g., neighbourhoods, municipalities, states, and local government districts) are particularly closely interlinked and highly interdependent in terms of capacity building in health, they will be presented together in the followingchapter.

4.2.1 Lockdowns, contact limitations and travel bans

Lockdowns and/or shutdowns seem to have been effective in reducing community transmission of SARS-CoV-2 as some studies suggest (see for example Alfano and Ercolano 2020; Caselli et al. 2020; Krishan and Kanchan 2020; Lau et al. 2020). Almost all countries that were heavily affected by COVID-19 have introduced some form of lockdown over a certain period of time nationally or locally in 2020 and/or 2021 in order to prevent the further spread of the virus and to relieve the strain on their health systems (Giordano 2020) and buy time to prepare the health facilities and systems for large influxes of COVID-19 patients (Teslya et al. 2020).

Lockdowns can involve several components and differ to a certain extent between countries. Most countries, however, have issued restrictions on the free movement of their citizens and closed certain aspects of the economy and everyday life such as shops, restaurants, and cinemas. In some cases, further restrictions (variously described as stay-at-home orders or shelter-in-place orders, contact limitations and contact bans) have been implemented that limit the number of people with which an individual should come into contact. For example, lockdowns, curfews or stay-at-home orders were implemented in Germany (Deutsches Ärzteblatt 2020z; 2020n), Austria (Deutsches Ärzteblatt 2020ac), England (Deutsches Ärzteblatt 2021a; 2021e), Israel (Deutsches Ärzteblatt 2021c), Greece (Deutsches Ärzteblatt 2020o) Denmark and Portugal (Deutsches Ärzteblatt 2021g) and Iran (von Hein 2020c), to name just a few.

An analysis conducted by the International Monetary Fund (IMF) investigated the perceived need, felt apparently by some states, to choose between two evils, namely a strict lockdown and resulting economic collapse or endangering the health of the population by opening the economy (Sueddeutsche Zeitung.de 2020). The prevailing narrative that lockdowns always involve a trade-off between saving lives and shoring up the economy ought to be reconsidered according to the IMF analysis (Caselli et al. 2020). Relaxing the lockdown when the risk of infection is high does not bring

the desired economic benefits. It is in fact the other way around: Addressing health risks seems to be a precondition for a strong and sustainable economic recovery. The data from the countries studied showed that production, sales, and output restrictions could contribute considerably to a significant reduction in new infections. This is especially true if a country does not wait until the number of infections to reached a new height but instead reacts quickly and decisively (Hulverscheidt 2020).

In March 2020, the German Bundestag declared an "epidemic situation of national significance" („epidemische Lage von nationaler Tragweite") for ***Germany*** (DAZ.online 2020). On 27 March 2020, the Act on the Protection of the Population in the Event of an Epidemic Situation of National Significance ("Gesetz zum Schutz der Bevölkerung bei einer epidemischen Lage von nationaler Tragweite") came into force (Deutscher Bundestag 2020b), which was subsequently amended in November 2020 (Bundestag.de 2020). To contain the pandemic, the federal and state governments decided in mid-March 2020 to impose far-reaching restrictions on public life (Bundesregierung.de 2020a), as did many other countries around the world (International Monetary Fund 2021). In the summer months, the restrictions were partially lifted again due to low infection rates. Due to rising infection rates, contact restrictions and other pandemic control measures, these restrictions were tightened again in October and November 2020 (Bundesregierung.de 2020d). Since mid-December, significant restrictions on public life have again been in place in the form of a so-called lockdown that is still ongoing in March 2021 (Bundesregierung.de 2020c; Tagesspiegel.de 2021). The measures are intended to maintain sufficient capacity to treat COVID-19 patients and test suspected cases while ensuring infection protection for patients and staff (Leopoldina Nationale Akademie der Wissenschaften 2020).

Iran attempted to avoid a general lockdown, despite public health experts' warnings, until November 2020 (von Hein 2020c). Before then, as a local countermeasure, the governor's office of the Iranian capital had ordered the closure of all shops, except pharmacies and supermarkets, at the end of March 2020. Police checks are in place to ensure that the remaining residents of Tehran stay at home. Four million of residents had previously left the capital for the spring holidays (von Hein 2020a). Meanwhile, the government made uncareful individuals responsible for the surging infection rates (Böhme and Seibert 2020). In November 2020 however, the Iranian Government announced nationwide restrictive measures after a renewed surge in COVID-19 cases, without implementing a complete lock down (Motamedi 2020).

There are a few ***examples in favour of strict lockdowns*** to successfully curb the spread and relieve strained healthcare systems. As of March 2021, Australia seems to have managed to contain the pandemic in its territory due to, among other policies, hard lockdowns implemented early on (Gan 2020; Stobart and Duckett 2020). Another example often stated as a success story is New Zealand, whose Prime Minister Jacinda Ardern took the so far unprecedented step of closing the country´s borders almost entirely as early as March 2020, implemented an early and strict lockdown, and introduced a 4-stage alert system along with a broad and comprehensive (risk) communication campaign, all of which paired with a high level of trust in government at the time (Jones 2020; Hasel 2021).

Many countries also implemented ***mandatory mask-wearing*** at some point during the pandemic. Since the available evidence for the benefit of so-called community masks or fabric masks was still rather small, especially at the beginning of the pandemic, and the available medical masks were being "reserved" for medical personnel, a general obligation to wear masks was not introduced in Germany until April (Bundesregierung.de 2020e). The mask mandate initially only covered supermarkets and public transport but was extended to public spaces and occasions (e.g. church services) throughout the pandemic. When supplies of masks improved, and with little evidence of the necessary level of protection when wearing fabric masks, it became mandatory as of January 2021 to wear either a FFP2 mask or a medical mask on public transport and in shops. Individual federal states sometimes have different (stricter) regulations (Seeger 2021). Today, there is strong evidence for the use of clinical

masks to prevent the spread of SARS-CoV-2 and reduce the number of severe clinical courses (See for example D. K. Chu et al. 2020; Chan et al. 2020; Hemmer et al. 2021; CDC 2020b).

Along with the measures mentioned above, guidelines for social distancing and information on infection prevention measures was issued by many countries according to guidelines provided by WHO or the respective National Centres for Disease Control (see for example WHO 2020g; CDC 2021c).

In the course of the pandemic, two strategic positions have emerged in the scientific and public debate on lockdown measures: the Zero Covid initiative and the No COVID approach. In an appeal distributed online, the ***"Zero Covid"*** initiative calls for all direct contact to be kept to a minimum for a period of a few weeks, including and especially in the workplace. Factories, offices, businesses, construction sites and schools must be closed, and compulsory work suspended according to the authors so that the number of new infections can be "reduced to zero" (Sagmeister and Metzger 2021). The paper also calls for solidary financing approaches, the expansion of social health infrastructure and vaccines as a global common good that should be exempt from private profit financing (Zero.Covid.org 2021). The goal is to push the seven-day incidence per 100,000 population not only below 50, but close to zero (Deutschlandfunk 2021a).

The Zero Covid initiative describes itself as being based on the international call for the comprehensive containment of the Covid-19 pandemic in Europe, which was initiated by scientists on 19 December 2020 and published in The Lancet (Priesemann et al. 2021). This initiative is known as the ***No Covid*** approach (Spiegel.de 2021a). In contrast to the Zero COVID initiative, the supporters of the No Covid strategy see no compelling contradiction between a well-run economy and health protection. The authors of the No Covid strategy also demand that the procedure be standardised across the entire European continent due to the high number of cases and the new virus variants. They aim for a seven-day incidence below 10 per 100.000 population (Deutschlandfunk 2021a). It remains to be seen whether either of the two approaches, and which one, will prevail.

4.2.2 Material procurement and production collaborations

Early on in the pandemic the European Commission published a list of ***essential medical devices*** for the diagnosis and treatment of COVID-19 (European Commission 2020a). Unfortunately, however, these items were not always available in many countries, which led to severe material shortages and problems in ensuring adequate treatment for the sick and adequate protection for healthcare workers and the general population.

The ongoing pandemic ruthlessly exposed gaps, shortfalls, and inequalities in the global and regional supply mechanisms of essential medical products and life-saving equipment. With the start of the SARS-Cov-2 pandemic, personal protective equipment (PPE) such as face masks, medical gowns and goggles were suddenly in high demand almost everywhere. Crucially, however, most countries do not manufacture these items locally and are highly dependent on supply chains from, among other producing countries, China. The COVID-19 outbreak in China caused enormous supply chain disruptions e.g., in mask production, as roughly half the global production capacity is centred in the People's Republic of China (PRC). Some sources even indicate it could be as much as 80%–90% (C.-Y. Park et al. 2020). Trade restrictions and bans in some parts of the world also contributed to the problem and led multilateral development banks to help increase the PPE production and logistics capacities to support and strengthen the supply chain and trade finance programs (C.-Y. Park et al. 2020).

Nevertheless, the ***bottlenecks in the supply chains*** led to unprecedented shortages of PPE in many countries (Bailey 2020) and many of them found themselves competing with other nations for PPE and even ventilators, leading to "competitive purchases" of those items pushing prices up. This in turn forced many poorer countries to opt out of the purchasing process, as they simply could not compete

with the higher bidders, consequently forcing them to endanger their health care workers even more (WHO 2020e). The shortage in PPE led to several ***innovative solutions*** around the world, such as the manufacturing of face-shields out of plastic waste in Uganda (Deutsche Welle 2020). On the other end of the spectrum, several high-end masks with antimicrobial surface coatings and other features have been invented or adapted to the requirements (or perceived requirements) of the pandemic in industrialised countries (see for example Biospace.com 2020; BR24 2020; Devicemed.de 2020; Freie Universität Berlin 2020; MBS News 2020).

To increase production capacities for medical equipment such as PPE or ventilators at short notice, some ***companies that normally manufacture other products have turned to PPE production*****.** This often took place under the auspices of international alliances such as the EU or individual states, which made it possible to offer companies the prospect of corresponding incentives for this commitment. However, many companies from various industries and sectors around the world have done this voluntarily, in order to help in the pandemic and also able to continue to produce and sell products and thus generate profits (Miller 2020). For example, some automotive suppliers switched their production to protective gear in March 2020 and clothing manufacturers switched to the production of masks, while liquor manufacturers are assisting in the production of much-needed disinfectant (Kölnische Rundschau 2020; Miller 2020). Of course, frequent adjustments had to be made and the respective national laws and regulations had to be taken into account (Baker McKenzie 2020). Another more recent example is the pharma-giant Merck who, after mediation by US President Biden, agreed to assist in the production of the vaccine developed by its competitor Johnson and Johnson. Production capacities in Merck's industrial facilities are to be made available for this purpose. However, it will likely be several months before production can actually begin (LaFraniere et al. 2021).

The German government, and in particular the Ministry of Health, has been sharply criticised in the past for its handling of the procurement of PPE. Since 2005, Germany has had a ***National Pandemic Plan***, which the Robert Koch-Institute has drawn up on behalf of the Federal Ministry of Health. The plan has been updated twice and added special amendments for the novel coronavirus in March 2020 (Robert Koch-Institut 2017a; 2017b; 2020). The pandemic preparedness and response plan mandates that sufficient amounts of protective equipment have to be kept on hand in the event of a pandemic- unfortunately this demand was not met sufficiently (Wolf 2020). This, together with difficulties in procuring items on the international market due to the supply-chain issues, led to a massive ***shortage of medical face masks and other PPE*** in the early phase of the pandemic. This is also shown by an "overview of the demand reports of the Association of Statutory Health Insurance Physicians", which was calculated by the AOK Federal Association. According to the survey, around 115 million simple medical masks alone were missing in doctors' practices nationwide at the time of the survey. Additionally, there were almost 47 million FFP2 masks, about 63 million disposable protective gowns, about 3.7 million pairs of safety goggles and more than 55 million packs of disposable gloves in short supply. However, these figures only covered the needs of practising doctors. The quantities of protective clothing needed in hospitals, nursing and elderly people's homes and care services are not included in those figures (Beigel 2020). To "reserve" the masks available for the medical staff, the public was advised not to wear face masks in March 2020, while the government attempted to purchase masks and other equipment overseas and scale-up local production capacities. In addition, certification standards for masks were temporarily relaxed to allow clinics and research institutions to use their old stocks (Steinlein 2020). Furthermore, personnel was at times advised to re-use equipment that was initially intended for single use only (Steinlein 2020).

In view of this shortage situation, the ***open-house procurement procedure*** was drawn up in the German Ministry of Health at the end of March 2020. The aim was to obtain protective masks and equipment as quickly as possible in the wake of the Corona crisis. The federal government committed itself to conclude a contract with all suppliers who made an offer and to buy masks. However, because of the above-average purchase price – 4.50 € for FFP-2 masks and 60 cents for surgical masks – far more suppliers came forward than the Ministry of Health apparently expected, and more than 700

contracts were concluded and led to the purchase of far more masks than initially anticipated (Trappe 2021; Spiegel.de 2020).

In December 2020, the German Government decided to equip high-risk individuals in Germany with ***free FFP-2 masks*** to enhance their protection against the virus. In the so-called Corona Protective Mask Ordinance (Coronavirus-Schutzmasken-Verordnung) it is envisaged that pharmacies in Germany will dispense a total of more than 400 million protective FFP-2 masks to senior citizens and high-risk patients (Bundesgesundheitsministerium 2021b). From 10 February 2021, pharmacies will receive only 3.30 Euros plus VAT for protective masks, dispensed at state expense, instead of 6 Euros apiece as before. In addition, as announced, they are also to supply recipients of unemployment benefits and social assistance (Müller 2021).

Iran faced ***difficulties in material procurement due to economic sanctions*** that impacted their financial transactions and therefore prevented the government from purchasing PPE, ventilators, and other medical equipment on the international market. Some researchers argued in The Lancet that this significantly limited Iran's capability to deal with the pandemic and that:

"The harsh obstacles presented by US sanctions mean that Iran could bear a disproportionate share of this fiscal and health shock, leading to its probable economic collapse and inability to contain the virus that has implications for the entire world" (Murphy et al. 2020).

There were media reports that Iranian hospitals used older, sometimes outdated ventilators and other medical devices as new equipment could not be purchased easily on the global market (Paton Walsh et al. 2020). In October 2020, however, Iran received 150 ventilators and 100 polymerase chain reaction (PCR) thermal cyclers from WHO (Tasnim News Agency 2020). In addition, Iranian engineers developed an open-source ventilator to scale up the countries' capacities in this regard as well (IEEE Spectrum: Technology, Engineering, and Science News 2020; News.am 2020), although it is not clear to what extent those ventilators were implemented in hospitals.

4.2.3 Testing

Testing certainly is one of the most crucial components in the fight against the SARS-CoV-2 pandemic. As of March 2021, various COVID-19 tests are available, which can be distinguished not only according to their mode of functioning but also according to the objectives of their utilisation. ***PCR-testing*** (Polymerase Chain Reaction) is considered the gold standard for COVID-19 testing due to its low error-rate. PCR tests directly detect the genetic material of the SARs-CoV-2 pathogen. The disadvantage is that they must be performed by medically trained staff via nasal swab and analysed in a laboratory, which takes some time. The ***rapid antigen tests*** must also be performed by trained personnel via nasopharyngeal swab, however they can be evaluated directly on site. Antigen tests detect protein molecules that are characteristic of SARS-CoV-2. However, antigen tests are less specific and sensitive than PCR tests. The newly approved ***at-home antigen rapid tests*****,** however, can be conducted by laymen and have been available for purchase in supermarkets and drug stores in Germany since March 2020. There are several variants available, for example nasal swabs or spit-tests. However, it is important to keep in mind that those tests require a significantly higher amount of viral load to detect an infection, meaning that there is a significantly higher error rate compared to other forms of testing (Deutschlandfunk 2021b). ***Antibody tests,*** on the other hand, are not performed to detect a current infection, but to determine whether the individual has been infected with SARS-CoV-2 in the past. These tests, which are usually performed using the ELISA method, play a role in epidemiological assessments in particular (CDC 2020c).

Depending on the tests available and the needs of the population, comprehensive ***national testing strategies*** should be developed and implemented as the ECDC notes *the "Implementation of objective-*

driven and sustainable testing strategies for COVID-19 supports the overall public health response to the pandemic and helps mitigate its impact on vulnerable populations and healthcare systems, while ensuring that societies and economies can continue to function" (European Centre for Disease Prevention and Control 2020a, 1).

The ECDC further defined ***five key objectives of testing*** (European Centre for Disease Prevention and Control 2020a, 2)

- Controlling transmission
- Monitoring incidence and assessing severity over time
- Mitigating the impact of the disease in healthcare institutions and care facilities
- Identifying clusters and outbreaks
- Preventing (re-)introduction into regions that have sustained control of the virus

To meet these objectives, several testing strategies may be needed simultaneously, depending on the epidemiological situation. This might be the case when a country experiences multiple epidemiological situations or if different sub-groups of the population (e.g. migrants, the elderly, etc.) are particularly affected by the outbreak (European Centre for Disease Prevention and Control 2020a, 3).

The ECDC also states that the *"speed of testing and reporting of results to individuals and health authorities is critical for isolating cases and initiating contact tracing activities and other public health measures. Minimising the time between testing and the communication of results will help to maximise the impact of the respective testing strategy and facilitate timely contact tracing and contact management in order to limit ongoing transmission. Determinants for successful implementation of a testing strategy include access to testing, supply and logistics"* (European Centre for Disease Prevention and Control 2020a, 3). The ECDC further recommends to use digital solutions (like apps) to notify people of their test result automatically (European Centre for Disease Prevention and Control 2020a, 3).

While most countries have focused on testing individuals presenting COVID-compatible symptoms and individuals with high exposure (e.g. health workers), some countries and regions have adopted a testing strategy that involves ***population-wide testing of the general population or sub- groups of the population in specific settings.***

The ECDC identified three possible goals of population-wide testing (European Centre for Disease Prevention and Control 2020b, 2):

- Reducing the incidence and preventing or reducing the need for and duration of non-pharmaceutical interventions, for example lockdowns
- Estimating the prevalence and understanding the epidemiological characteristics of infected persons at a given time
- Understanding transmission-drivers in specific high-incidence areas or settings to inform the development of more targeted measures

Population-wide testing efforts that involved so-called ***household testing*** have been conducted in several countries. Iceland for example conducted a random testing of about 6% of its population in April 2020 (Gudbjartsson et al. 2020) while the South Korea analysed 59.073 contacts of 5.706 cases and of 10.592 household contacts between January 2020 and March 2020 (Y. J. Park et al. 2020). ***Population-wide individual testing*** efforts require a high capacity of testing equipment but have been made available in some countries as well. Tests are free of charge and available to all individuals who wish to be tested in Denmark, France, Luxembourg, the Republic of Korea, and other countries (European Centre for Disease Prevention and Control 2020b, 3).

Other countries, such as Germany, Singapore, Luxemburg and many others, focused on testing ***incoming travelers*** (as a means of population-wide testing of this specific sub-population) often combined with temperature checks, especially in the first months of the pandemic, when testing capacities were oftenlimited (European Centre for Disease Prevention and Control 2020b, 3). However, testing incoming travellers requires a high amount of communication (e.g. on testing procedures and quarantine requirements) as well as an adequate number of trained staff and clear case definitions (CDC 2021a). Furthermore, the number and characteristics of the incoming travellers as well as safety considerationshould be taken into account when implementing a traveller-testing approach (European Centre for Disease Prevention and Control 2020b, 4).

Population-wide testing requires a high amount of population compliance, as well as sufficient logistical and material capacities (European Centre for Disease Prevention and Control 2020b, 4–7). Therefore, the ECDC concluded that *"In light of the evidence available at the time of writing, population-wide testing can be considered when:*

- *it is necessary to rapidly decrease disease incidence in a community and thereby reduce thepressure on the healthcare system.*
- *a community is experiencing very low levels of transmission and one of the public health goals is toeliminate the disease (e.g., to resume normal activities or relax non-pharmaceutical interventions).*
- *it is necessary to understand disease prevalence by age, ethnicity, setting, location, etc. in order to target public health measures"* (European Centre for Disease Prevention and Control 2020b, 7).

Detailed technical guidance on the planning and implementation of population-based COVID-19 surveillance is available in several ECDC and WHO surveillance guidance documents (European Centre for Disease Prevention and Control 2020c; 2020d; see for example 2020e).

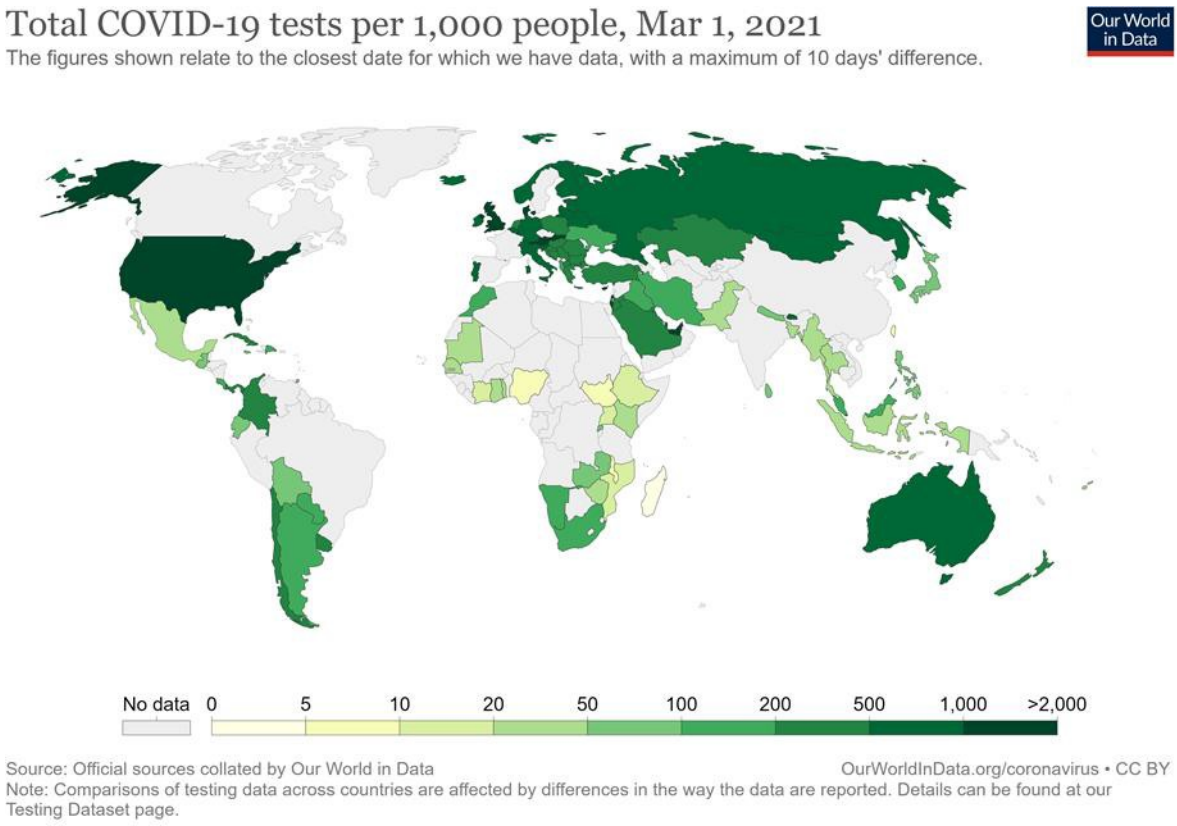

Figure 9 Total number of tests performed relative to the size of population (Our World in Data 2021c)

Many countries have therefore established testing strategies that target high-risk and high exposure individuals in addition to those expressing symptoms of COVID-19. Targeted testing enables health authorities to quickly and precisely estimate infection numbers and thus contributes to a more up-to-date and comprehensive picture of the situation. This is the basis for interrupting chains of infection and protecting health care systems from being overburdened (Robert Koch-Institut 2021b). As one example of those testing strategies, the German model will be described in more detail in the following paragraphs.

In Germany, the national testing strategy has evolved over the course of the pandemic due to new epidemiological insights and newly emerging testing opportunities and technical developments. Germany placed an emphasis on testing in healthcare facilities, as patients and residents in healthcare facilities may be particularly vulnerable to the virus, but also to protect staff and health facilities from outbreaks as much as possible and thereby preserve capacity for patient care in the pandemic. The latest version of the testing strategy from 9 February 2020 advises testing as follows:

Persons exhibiting symptoms consistent with a SARS-CoV-2 infection are tested (preferably via PCR-test) as well as persons with mild symptoms of general upper respiratory tract infections, dependent on their risk profile and exposure (Robert Koch-Institut 2021b). The decision which persons should receive a PCR test is guided by a flow-chart developed and updated by the Robert Koch-Institute (Robert Koch-Institut 2021d).

Asymptomatic persons were to be tested according to the national testing strategy (Robert Koch-Institut 2021b):

- if they were contacts of confirmed COVID-19 cases. Contact persons could also be tested with a PCR test if deemed necessary by a treating physician or public health service.
- in the event of outbreaks or for the detection of outbreaks in institutions, communal facilities, andaccommodation, such as schools, hospitals, refugee accommodation, nursing homes, etc.

The following regulations also applied:

- Staff in medical and care facilities without a COVID-19 case were to be screened regularly via antigentest in areas with a high incidence. It is recommended that staff who look after patients and residents should be tested regularly via antigen test, depending on the respective testing conceptof the facility or company. For regular precautionary serial testing, the Testing Guidance providesfor an entitlement to testing once a week. Each positive antigen test must be confirmed by PCR testing.
- Patients of medical and nursing facilities were preferably to be tested with a PCR test before (re)admission as well as before outpatient surgery due to the higher sensitivity. After admission, these persons should be retested with antigen tests at certain intervals depending on the testing concept of the facility in coordination with the local health authorities, and only in the case of an increased regional incidence (e.g., 7-day incidence >50/100,000).
- Asymptomatic visitors to medical and care facilities without a case of COVID-19 had to be tested by a rapid antigen test immediately before the visit.
- Staff in medical practices, dental practices, practices of other health professionals and emergencyservices without a COVID-19 case were to be tested frequently to prevent the spread of the virus by asymptomatic carriers in practices with high patient turnover. Regular precautionary (serial) testing of staff in areas with increased incidence (e.g., 7-day incidence >50/100,000) is recommended.

4.2.4 Hospital bed capacity

Hospital bed capacity has been an issue of concern for many of the countries affected by COVID-19. Since many COVID-19 patients needed mechanical ventilation due to respiratory failure, the availability of Intensive Care Unit (ICU) beds was a topic particularly widely discussed in national and local news media inmany countries over the course of the pandemic. The availability or lack of hospital beds is certainly one indicator of the strain on a given health system, but it should not serve as a singular measurement ofhealth system capacity utilisatio – especially since the definition (and therefore count) of what is considered "an intensive care bed" is very inconsistent. In some cases, only the existing bed spaces are counted, without taking into account how much additional intensive care capacity can be created, while in others, it is not taken into account that there is an unavailability of staff to run an intensive care bed, which effectively means it cannot be run at full scale. This is a pressing problem in Germany, for example (Karagiannidis et al. 2020).

Iran's health system is immensely strained by the pandemic, and the government's response was often perceived as poor, especially due to not locking down during national holidays to curb the spread of the virus (Bizaer 2020) and relief the strain on the overwhelmed hospitals (Al-Monitor 2020b). At the same time, the Iranian Government in part refused help from abroad. For example, Iran declined an offer by Medecins Sans Frontièrs to support the particularly badly affected region near Isfahan with a COVID-19 treatment field hospital in March 2020 and referred to the capabilities of Iran's own authorities andthe support of its military (Ansari 2020). Since autumn 2020, the situation in the country has worsenedand many hospitals have reached the limit of their admission capacities or have imposed an ***admission freeze***. Since summer 2020, there have been repeated reports in Iranian media about desperate residents who have had to take out loans in order to secure a place for sick family members in private hospitals, while doctors warn that the COVID-19 situation is no longer an issue of waves, but has become an ongoing crisis (von Hein 2020b).

Admission freezes have so far remained the exception in German hospitals. There have been many attempts in Germany to increase bed capacity for the care of COVID-19 patients. Large ***treatment centres*** were set up relatively early in the pandemic, such as a vast, temporary, 500 bed clinic in Berlin. Within weeks, the Senate, clinic operators and many volunteers have implemented a medical concept unprecedented in Germany. The aim of the centre is to guarantee the care of the city's population in an emergency – and thus to relieve the burden on Berlin's existing hospitals. Additional treatment centres are located in other places in the capital and across the country, while personnel recruitment and training are still ongoing in order to be able to rapidly ramp up capacities if needed (Vivantes – Netzwerk für Gesundheit GmbH 2021). Should this need arise, one additional option discussed was to deploy the German Armed Forces to take care of the improvised facilities (Konrad and Kirch 2020), given their high experience with the construction and operation of field hospitals and the associated logistics.

In order to create bed capacity, many hospitals have decided to suspend or ***postpone non-urgent operations and diagnostic procedures*** during the pandemic until local incidence levels decrease (see for example Deutsches Ärzteblatt 2020i; 2020u; 2020x; 2020ab). Overall, however, there were no binding regulations for hospitals and doctors on which procedures should be classified as "non-urgent", and treatment decisions for individual patients were still left to the doctors (Lösch 2020). In total, elective surgery had decreased by 41% during the first shutdown, according to the Professional Association of German Surgeons. A survey of 125 chief surgeons in North Rhine-Westphalia (Meurer et al. 2020) showed that 71% of the chief surgeons thought that the complete suspension of elective surgery in the first wave of the pandemic was the right thing to do, but 30% of the chief surgeons surveyed thought that the postponement of elective surgery had led to unnecessaryhealth risks for patients. The impediment to surgical work was perceived by 22% of respondents as very high and

another 44% as high. 27% rated it as medium and 8% as low. 69% of respondents said that, despite support from the federal and state governments, there would be financial difficulties for their hospital as a result of the pandemic (Deutsches Ärzteblatt 2020l; Meurer et al. 2020). Overall, the postponement approach contributed significantly to the mobilization of resources and the generation of free capacity in the health sector, but there are also critical voices fearing that the postponement of diagnostic and curative interventions could have negative effects on population health in the medium to long term. Moreover, the first lockdown in particular showed that many of the beds that were kept free were not needed to treat COVID-19 patients, so frameworks were being developed for the second wave in Germany to make elective procedures possible to a certain extent (AerzteZeitung.de 2020).

The German Hospital Federation (DKG) also discussed plans to close regular hospital wards in absolute emergencies and to discharge all patients for whom this is justifiable to their homes in order to be able to shift as many staff as possible to the intensive care units (Deutsches Ärzteblatt 2020r). Furthermore, representatives of the German Hospital Federation (DKG) called for the ***suspension of documentation and verification obligations*** that are not absolutely necessary, as well as for the suspension of Minimum staffing regulation ("Personaluntergrenze") for nursing staff (Deutsches Ärzteblatt 2021d). Another measure, implied by many hospitals and nursing homes in times of high incidences, was to impose patient ***visiting bans*** or to at least severely limit visitations (tagesschau.de 2020d)

To counter considerable revenue shortfalls as a result of the measures described above, various so-called "rescue umbrellas" for ***hospital financing*** were initiated. In March 2020, the German government passed the COVID 19 Hospital Relief Act (COVID 19-Krankenhausentlastungsgesetz), to compensate hospitals for the loss of revenue caused by keeping beds available for potential COVID-19 patients (Deutscher Bundestag 2020a). Hospitals received compensation payments for unoccupied beds and subsidies for setting up additional intensive care beds. The Hospital Future Act (Krankenhauszukunftsgesetz), passed in September 2020, stipulates that the health insurance funds must refinance Covid-related revenue losses to hospitals (Deutscher Bundestag 2020c).

To better manage and oversee the available bed capacities for special patient needs, there are local ***referral and competency networks*** in Germany. There are, for instance, several clinics in Germany that specialise in the highly invasive ECMO Therapy (extracorporeal membrane oxygenation) for ADRS patients and are organised in local competence hubs. One is the ARDS Network in Berlin- Brandenburg, under the leadership of Charité University Medicine. For patient transfers and consultations, clinics have 24-hour access to an ARDS telephone hotline. After the call, an interdisciplinary case conference is convened at the network, which advises on the medical and nursing requirements of the individual patient and then call back the referring hospital. In the case of patient transfers, the network organises the transfer with a suitable means of transport or collects the patient from the clinic on-site (Charité – Universitätsmedizin Berlin 2021).

However, a ***nationwide referral system*** was also established to deal with a possible spike in COVID-19 patients in need of ICU treatment. According to the so-called "cloverleaf concept", Germany would be divided into five large regions for this purpose, which would support each other in taking over patients by ambulance or helicopter. In case of a high demand or even an overload in a federal state or a region, the supra-regional transport of patients to regions that are able to treat them is organised via central dispatch offices in the respective regions (Deutsches Ärzteblatt 2020j).

4.2.5 COVID-19 medicines

So far, there are no therapeutic options for COVID-19 disease therapy, albeit that researchers across the world are collaborating closely to identify life-saving treatments with over 400 therapeutic drugs currently at various stages of human clinical trials (bioRender 2021).

In the meantime, existing treatments of viral infections are being trialed and used at an unprecedented scale to treat COVID-19 patients. One of the drugs discussed widely throughout 2020 is the broad spectrum anti-viral ***Remdesivir*** and other similar drugs. Initially, it had raised high hopes to shorten the duration of illness and to lower mortality, but more recent data suggest that its effect had been initially overestimated (Cao, Deng, and Dai 2020; Deutsches Ärzteblatt 2020b; 2020s; Singh et al. 2020). In November 2020, the WHO Guideline Development Group (GDG) consisting of content experts, clinicians, patients, and methodologists from around the world, published its conclusion of research into the effectiveness of the anti-viral drug Remdesivir in the treatment of COVID 19. The group concluded that there was currently no sufficient evidence that Remdesivir improves survival or other important outcome measures. The recommendation goes as far as discouraging the use of Remdesivir because of the remaining possibility of important harm, as well as the relatively high price and resource implications (it has to be administered intravenously) associated with Remdesivir (BMJ 2020).

Dexamethasone, a corticosteroid that has been developed in the late 1950s, is accessible and affordable in most parts of the world and was shown to benefit critically ill patients and significantly improve survival rates in several studies (McFee 2020; Weber 2020; WHO 2020f).

Antibody treatments received a lot of media attention in the summer of 2020, the antibody treatments of Eli Lilly and Regeneron in particular. The antibodies are derived from an elaborate and highly expensive technological process and one of the first therapeutic approaches that seemed to be effective (Deutsches Ärzteblatt 2020e; Eli Lilly and Company 2020b; Meredith 2020; Zhou and Zhao 2020). However, the treatment is expensive, and manufacturers will not be able to scale up the production capacities fast enough to meet the demand. Furthermore, the treatment proved only effective if administered early in the course of the disease, before severe immune system responses kick in (Deutsche Apotheker- Zeitung 2020; Eli Lilly and Company 2020a; Haseltine 2020a; Thomas and Weiland 2020). Another ***monoclonal antibody treatment*** called ***Toczilizumab*****,** that targets the interleukin-6 receptor was recently proven effective in the RECOVERY trial, since it contributed to lower mortality rates and other outcomes in COVID-19 patients with hypoxia and systemic inflammation who were simultaneously treated with steroids (RECOVERY Collaborative Group et al. 2021). However, the drug is in short supply worldwide and thus hard to obtain. In contrast to the steroid dexamethasone, it also is very expensive, which limits its applicability especially in low- resource settings (Deutsches Ärzteblatt 2021i).

The American FDA announced on 23 August, 2020, that they had issued an emergency authorisation for ***convalescent plasma therapy***. The therapy approach is based on the transfusion of blood plasma of recovered COVID-19 patients to those currently suffering from the disease, to provide patients with antibodies from people who have formed them after a natural infection (Cohut 2020). Plasma therapy has been used for more than 100 years and is considered safe (Deutsches Ärzteblatt 2020c) Plasma may particularly help patients in the early stages of the disease (Cohut 2020; Joyner et al. 2020;Nellis 2020; Wu 2021). It has not been proven effective in patients in later stages of the disease (Deutsches Ärzteblatt /; Salazar et al. 2020).

Oxygen is essential in the treatment of COVID-19 and particularly crucial in advanced stages of the disease. Without sufficient oxygen supplies, there is little hope to save patients' lives and prevent further complications and lasting damage to their health. In early 2021 there were several reports about oxygen supply problems in England, the USA, Egypt and Brazil that endangered patients' health (Schulte 2021). This essential is often in short supply in developing countries and vulnerable to supply

chain difficulties (Newey 2020). This is why WHO and several other NGOs initiated the COVID-19 oxygen emergency taskforce (WHO 2021c) mentioned above in order to secure funding and make sure oxygen supply is ensured in low- and middle-income countries as well.

While many LIC had ***difficulties in obtaining COVID-19 medicines*** due to a lack of financial resources, Iran was confronted with a different type of procurement impediment. Although food, health and medical goods are theoretically exempt from US embargoes, de facto many foreign companies and banks refrain from doing business with Iran for fear of US sanctions (Bizaer 2020). This led not only to difficulties in the procurement of medical equipment and vaccines but also to severe difficulties in obtaining essential Covid medicines. Additionally, the Iranian healthcare system does not necessarily cover those medicines, limiting access to appropriate COVID-19 treatment for the poorer section of the population. According to media reports, a flourishing informal market for antiviral drugs such as Remdesivir has developed in Iran (von Hein 2020b).

There are sometimes supply chain issues in the drugs currently used to treat COVID-19 patients and shortages in production capacities when it comes to the manufacturing of new drugs. To counteract this, the EMA developed a monitoring and reporting system for the availability of medicines needed to treat COVID-19 patients. The aim of the system is to provide a better overview throughout Europe of both centrally and nationally authorised medicines. The system will not only cover potential, specific COVID-19 medicines, but also frequently used intensive care medicines such as antibiotics, anaesthetics and resuscitation medicines (Hüttemann 2021) that are needed for most ICU patients. This is because supplies of those essential medicines have also been exacerbated by supply chain problems in the context of the Covid crisis (NDR 2020; Deutsches Ärzteblatt 2020a). In addition, newly developed drugs tend to be quite expensive due to patent issues and the high international demand in a pandemic.

4.2.6 National Vaccination Programmes

Due to the above-mentioned research and production collaborations and the enormous amount of funding available, COVID-19 vaccines were developed at an unprecedented speed. There have been ***accelerated approval procedures*** for vaccines and potentially effective treatments at both, national and international levels. One example of the latter is the rolling review procedure of the European Medicines Agency EMA that is aimed at enabling and supporting fast-track vaccine development in a public health emergency (Glanville 2020; Hrabovzki 2020b). Additionally, EMA offered informal consultation with its ***COVID-19 Task Force*** (ETF) and rapid scientific advice (EMA 2020). The ***EMA COVID-19 Steering Group*** was formed to respond to rapidly evolving scientific developments and resulting regulatory challenges (Hrabovzki 2020a).

Following challenges in the production and fair, global distribution of vaccines, individual countries now face the challenge of administering these vaccine doses. A strategy is required to asses whom to vaccinate first. Apart from or based on the WHO prioritisation framework mentioned in chapter 4.1, many nations and professional associations of various disciplines have developed their own recommendations and guiding documents. In addition to medical or epidemiological issues, ethical factors and social circumstances should also be included in this decision-making process. In Germany, the Standing Committee on Vaccination (STIKO) is responsible for the development of these guidance documents. According to the STIKO's recommendation, the initially limited amounts of available doses should be used to reduce the number of severe courses of the disease and deaths as quickly as possible. This implies, according to the STIKO, to first offer vaccinations to people over 80 years of age and residentsin old people's and nursing homes, as they are particularly at risk. At the same time, the STIKO recommends vaccination for medical staff with high risk of infection and for staff working in geriatric care. The STIKO recommendations are regularly evaluated and adapted, taking into account

vaccination rates, surveys on vaccination acceptance and studies on vaccination effectiveness and safety (Robert Koch-Institut 2021c; 2021a). ***Germany*** started by vaccinating the most vulnerable members of society in December 2020. ***Iran*****,** using a different national vaccination strategy, began its vaccination campaign in February 2021 with the inoculation of health care workers and will extend vaccination to the elderly later on (Deutsche Welle 2021).

The Iranian national ***vaccination strategy*****,** recently published by the Iranian Ministry of Health, envisages that 60 million of the 82 million Iranian population can be vaccinated within a year. To this end, more than 200 ***vaccination centres*** are to be established, which shall administer a total of ten million vaccine doses every month. Iran and Russia have agreed to produce the Sputnik vaccine together, as announced by the Iranian Ministry of Health in January 2021. However, at the time of writing, it is not yet known when production can actually begin in Iran (von Hein 2021). Due to tense diplomatic relations, the country banned vaccines from the US and UK from entering Iran (Wintour 2021). In February however, Iran has now ordered 4.2 million doses of the vaccine from AstraZeneca as part of the international Covax initiative (Reuters 2021). In addition, Iran is developing two vaccines of its own and is collaborating with Cuba in the development of another potential vaccine (von Hein 2021).

The ***performance of the individual countries has so far varied greatly*** regarding the procurement of vaccines and the launch of national vaccination campaigns. ***Israel***, for example, secured considerable amounts of vaccine from BioNTech/Pfizer early on and was one of the first countries to start vaccinating. The Ministry of Health expects 95% of Israelis over 50 to be vaccinated until early March. Vaccinations did not only occur at formal vaccination sites or hospitals, but also at local furniture stores for example that have been converted to vaccination facilities (Salo 2020). Due to this success Israel was able to ease lockdown restrictions in February 2021 (BBC News 2021). However, there is also an ongoing debate on whether Israel is obliged to also vaccinate Palestinians in occupied territory. Most of them have not received a single dose as of early March 2021 (Rasgon 2021).

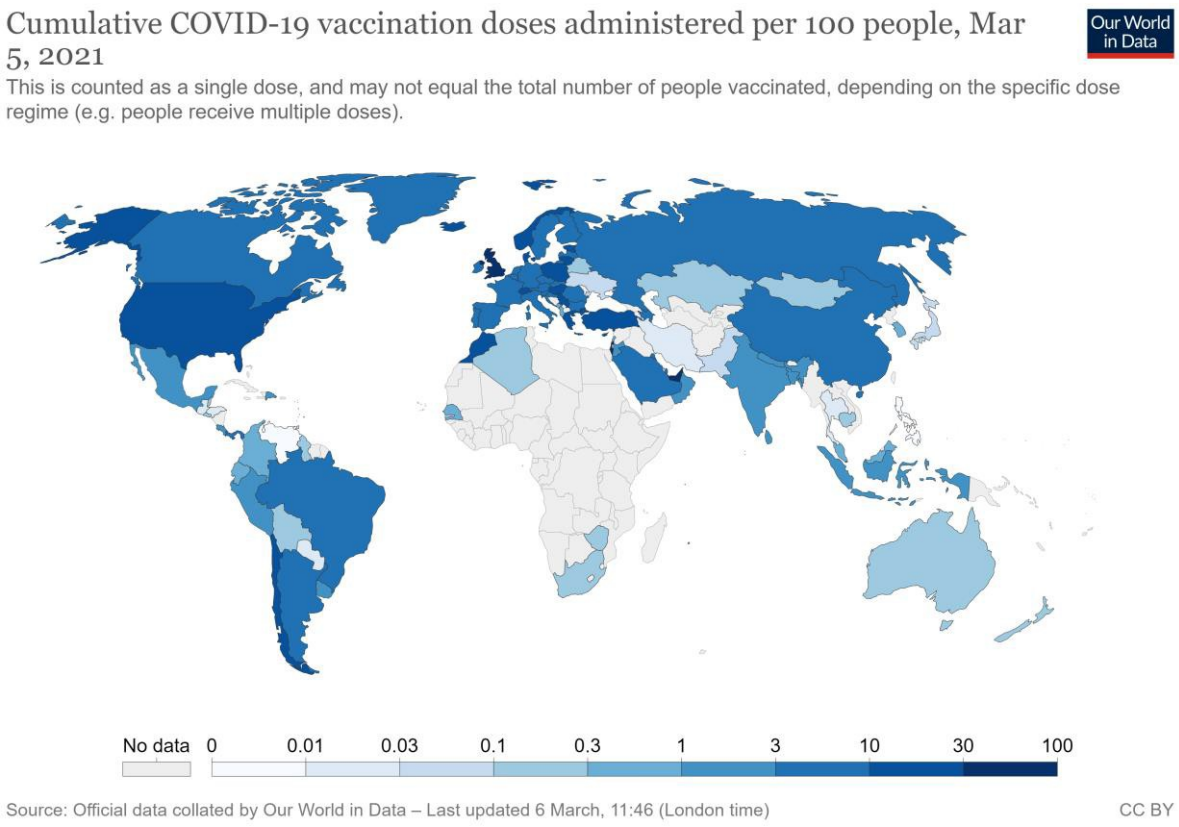

Figure 10 Covid vaccinations administered as of March 6, 2021 (Our World in Data 2021c)

Britain reported high vaccination rates due to early vaccine procurement and a relatively well-functioning vaccination campaign. As of 6 March, 2021, around 18 million people in England have received at least one dose of a COVID vaccine, which accounts for about 38% of the population over 16 years of age (England 2021). The ***US vaccination campaign*** is also taking up speed in spring 2021, although there are still vast regional differences in vaccination speed (Johns Hopkins Coronavirus Resource Center 2021). Both countries, among others, also tested the concept of so-called drive-through vaccinations, where people can drive to vaccination sites and receive the dose inside their car (CDC 2021b; Siddle and Small 2021; van de Kracht and Heragu 2020).

In ***Germany***, vaccination campaigns started in late December 2020, after vaccination centres were set up all around the country in a huge logistical effort. Depending on their size, each site can manage approximately 4.000 vaccinations a day, administered primarily by local doctors but also by other trained staff (Bundesanstalt Technisches Hilfswerk (THW) 2020; Deutsches Ärzteblatt 2020h; 2020q; 2020y). Furthermore, mobile teams went to nursing homes and other care facilities to vaccinate the patients and vaccinated the immobile at home (KVNO 2021). According to the Robert Koch-Institute, an average of close to 700.000 people were vaccinated in May 2021 with a total of 44.343,644 people having received at least one dose of a COVID-19 vaccine (RKI 2021). ***Medical personnel*** received vaccinations as well, mostly at their place of work or in the COVID-19 vaccination centres. However, medical staff is not prioritised equally in the recommendations of the STIKO. A "very high" priority for vaccination is given to staff in medical facilities who have a particularly high risk of exposure. According to the STIKO, this includes staff in emergency rooms, in the medical care of COVID-19 patients, in rescue services and employees in areas where infection-relevant aerosol-generating activities are performed. Staff who are in close contact with vulnerable groups – for example in nursing homes for the elderly, geriatric wards, transplant medicine, haemato-oncology, obstetrics and neonatology – are also assigned to the highest priority level. Other health professionals were then assigned to lower priority levels according to their likelihood of exposure (Deutsches Ärzteblatt 2020aa).

The ***allocation of vaccination appointments*** in Germany is at times problematic, and the actual procedure varies greatly from state to state. Those willing to be vaccinated must first answer some questions on the phone or online. They will then be given an appointment if they belong to a prioritised group (Deutsches Ärzteblatt 2020q). In some cases, people who were entitled to a vaccination were not informed in time; in others, hotlines and online platforms were overloaded or broke down (Express.de 2021; swr.online 2020; Karla 2021). In February 2021, an additional problem emerged. Following media reports on an alleged inferiority of the AstraZeneca vaccine compared to others, some people set to receive the Oxford vaccine in Germany then decided against it, and thus missed or cancelled their vaccination appointments (Westdeutsche Zeitung 2021). From March 2021 onward, vaccination began to take place outside of the vaccination centres as well, allowing General Practitioners to vaccinate in their practices (Deutsches Ärzteblatt 2021j). Vaccination directly at the doctor's office simplifies the process a great deal for vaccinees and vaccinators alike – in particular for the sick and elderly, who are spared the trip to a vaccination centre.

In general, the upscaling of ***production capacities*** for COVID-19 vaccines remains difficult and many vaccine manufacturers were not able to deliver as many doses as they promised so far (Barnes 2021; Ibbetson and Baker 2021; Amaro 2021). To address this matter, pharmaceutical giant Merck & Company has pledged to help manufacture the new coronavirus vaccine developed by its rival, Johnson & Johnson. The ***unusual collaboration*** between the competitors was initiated by US President Biden and could help to massively increase the supply of the new vaccine. Merck will dedicate two of its facilities to the production of the Johnson & Johnson vaccine. However, how quickly Merck will be able to kick off its production is unclear, since the company will need as long as two months or more to convert its facilities (Rowland and McGinley 2021).

4.2.7 Health Workforce

In most countries, the health sector faces ***challenges in recruiting and training medical staff***, which led to a shortage of more than 6 million nurses worldwide even before the pandemic, according to a WHO report (WHO 2020c).

In Germany for example, the so-called *Pflegenotstand* (nursing crisis) was a well-known problem years before the pandemic hit in 2020. In 2017 the country reported a shortage of more than 100.000 nurses in hospitals alone (Bauer 2017). According to a 2019 survey by the Deutsches Krankenhausinstitut (German Hospital Institute), there is a shortage of around 4,700 full-time staff in general hospitals with 100 beds or more in the intensive care sector alone across Germany (Ehrenfeld 2020). Some experts are also concerned that many nurses will quit their job as a result of the coronavirus pandemic (Luckhardt 2021).

The pandemic exacerbated the shortage of doctors and nurses in hospitals, private practices and nursing facilities, and the dire situation eventually caught the attention of the public. German care institutions and private individuals in need of care have often recruited care workers from abroad in the past. In March 2020, the president of the German Hospital Association, Gerald Gaß, called for the rapid formal admission of foreign nurses already residing in Germany to match the rising patient numbers (tagesschau.de 2020c). In order to provide some relief to the tense ***staff situation in the intensive care units*** (Deutsches Ärzteblatt 2020k; 2020g), nursing staff from other departments were allocated to the intensive care units in many hospitals (see for example Deutsches Ärzteblatt 2020p). The shortage of intensive care nurses, which will become even greater as the pandemic progresses, remains a huge problem in Germany: "*Therefore, all inpatient procedures whose postponement is medically justifiable must now be postponed so that staff from other areas of the hospital can come to the aid of the intensive care units*", according to the President of the German Interdisciplinary Association for Intensive and Emergency Medicine (DIVI), Uwe Janssens (Deutsches Ärzteblatt 2020m). However, it must be considered that this cannot replace well-trained and experienced intensive care nurses, who are imperative for the operation of intensive care units.

To incentivise caregivers for their work under the stresses of the coronavirus crisis, ***premium payments*** were promised (and partly already paid) in Germany. The premium was initially allocated to caregivers in elderly care homes before it was extended to caregivers in hospitals (tagesschau.de 2020a). Cleaning staff in ICUs are also eligible for the full bonus payment. The bonuses are to be paid to all entitled persons by June 2021 at the latest. The process will be handled by the hospitals themselves (Antenne Bayern 2021). The actual amount of the premium was to depend on the burden the care workers were under. 100 million Euros were taken from the health fund, which is mainly fed by health insurance contributions; in addition, the federal states are to co-finance the premium. The funds are only to be allocated to hospitals that have treated a certain minimum number of COVID-19 patients by 30 September, 2020 (tagesschau.de 2020a).

In Germany, the Armed Forces (***Bundeswehr***) also conducted a wide variety of tasks in the fight against the pandemic. At the beginning of the pandemic, the Bundeswehr mainly helped to procure medical material, provide camp beds, and stock storage capacities for civilian facilities. For example, the Bundeswehr's procurement office in Koblenz had contracted the delivery of 300,000 pairs of protective goggles and concluded another 36 contracts with a volume of about 241 million euros. The Bundeswehr had also transferred respiratory equipment from the operational hospitals to the five Bundeswehr hospitals in Germany, where it was increasingly also treating civilian patients. Nevertheless, it must be borne in mind that the Bundeswehr medical battalion comprises only about 3,000 doctors and can thus, at best, play a supporting role in medical care (von Hammerstein and Gebauer 2020). As the pandemic progressed, the focus of the Bundeswehr's deployment shifted. Around 10,000 members of the Bundeswehr are currently assisting the civilian authorities in the fight against the pandemic (for example by supporting the contact tracing in the local health offices).

Personnel and logistical support are also being provided to the vaccination centres that have been under construction throughout Germany since December 2020, as well as to testing facilities. In total, up to 20,000 soldiers are available in the Bundeswehr relief contingent, so that as of March 2021, reserves would still be available should the pandemic situation deteriorate (Bundeswehr.de 2021).

In addition, ***volunteers*** have been called upon to provide support in nursing homes and hospitals in the state of Thuringia in Germany for example to relieve the burden on trained staff. People who had previously been employed in healthcare were particularly in demand. The volunteers would be tested for coronavirus by the care institutions during their work, and the institutions would provide them with protective clothing and FFP2 masks (Deutsches Ärzteblatt 2021h). Volunteers were also in high demand for the work in testing and vaccination centres (Deutsches Ärzteblatt 2020v), although there were problems in some cases in coordinating willing volunteers. The Federal Government therefore called for people to register with the Federal Employment Agency (Bundesagentur für Arbeit) via a hotline for volunteering in inpatient care facilities, and to support the testing efforts there. The additional staff are to be used to test staff and visitors in order to enable visits and reduce the likelihood of infections (Arbeitsagentur.de 2021).

Health workers were among those most vulnerable to infection with SARS-CoV-2 due to occupational exposure to infected patients. More than 300,000 health care staff have been infected as of August 2020 (Erdem and Lucey 2021; Haseltine 2020b). An analysis from Amnesty International concluded that more than 7.000 health care workers had died by September 2020, although one has to assume that the figures are actually even higher (Amnesty International 2020a). However, the possibilities and financial means for testing health workers for the virus and protecting them through the material and/or policy measures vary greatly between countries (Chersich et al. 2020; Rivett et al. 2020). However, even developed countries such as the UK struggled to equip their care workers with sufficient PPE and were among the countries with the highest numbers of health worker death from COVID-19 (Amnesty International 2020a). In Iran, the SARS-CoV-2 infections in health care workers have skyrocketed (Al-Monitor 2020a, 10) and many died. In recent weeks, there have been several reports of pregnant nurses who have died as a result of COVID-19 infection (von Hein 2021). To protect medical staff, countries must ensure regular testing and access to sufficient amounts and quality of PPE.

But infection is not the only threat to health workers in the pandemic. In many countries, health staff also suffer from ***increased rates of burn-out and depression*** due to the enormous stress and grief they are forced to endure on a daily basis. Many reports detail the pressure health care workers are experiencing all over the world. The New York Times reported that a growing number of doctors in the United States quit their jobs due to COVID-19-related stress and burn-out (Abelson 2020). Others closed their practices, according to a survey of the U.S. Physicians Foundation (The Physicians Foundation 2020). Several other studies reported stress-related diseases, depression and fatigue among medical frontline staff treating COVID-19 patients (Pappa et al. 2020; Kang et al. 2020; Zhan et al. 2020; Luo et al. 2020). An increasing number of health professionals is dealing with mental health consequences of the pandemic as well. Burn-out and PTSD are only two examples of adverse health outcomes experienced by nurses and doctors and other health workers who have been fighting the pandemic for now over a year (Hoffman 2020; Nelson and Kaminsky 2020; WHO 2020e).

Due to the high infection rates and the difficult situation in healthcare provision, ***Iranian health workers experienced an increase in their stress levels and mental burden***, according to a study conducted by Shoja et. al (2020). Zandifar et al. reported that their study found *"a high prevalence of depression, anxiety and stress among COVID-19-related HCWs in Iran. Nearly half of them had some degree of depression. About half of them suffered from anxiety and one-third experienced stress. Physicians and nurses, especially those in the front line, experienced a greater prevalence of these disorders. In terms of employment relationships, medical residents experienced a higher prevalence of anxiety, stress, and depression than other employment groups"* (Zandifar, Badrfam, et al. 2020).

Nahandi et al. (2020) argue, that the strain on Iranian health personnel is even greater, because of an accumulation of tragic events in the country in recent months as well as the particularly difficult situation (lack of medical equipment and essential medicines) attributed to the economic sanctions. They advocate the use of social networking applications to provide social support for health workers.

All over the world, the situation led to increasing demands for ***mental health protection of doctors and nurses in the wake of the pandemic*** (Tracy et al. 2020; Walton, Murray, and Christian 2020; Abelson 2020). For example, Tracy et al. recommend "*a tiered model of inputs: good induction; building supportive 'buddy' relationships and managerial debriefs; appropriate environmental and 'virtual' well-being supports; and provision of rapidly accessible mental health professionals able to carry out timely 'return to duty'-focused assessments and brief interventions. Unless services take active measures and adopt a proactive 'nip it in the bud' approach, the psychological consequences of the pandemic on healthcare staff could be dramatic*" (Tracy et al. 2020).

Another study recommends E-Learning platforms for educating nurses on case handling and communication, as well as special problem-solving tactics to deal with the mental strain that might come with treating COVID-19 patients (Chidiebere Okechukwu, Tibaldi, and La Torre 2020). Measures to support health workers can be implemented on the organisational as well as on the individual level in order to implement a *"series of coherent measures […] to prevent, screen, and treat mental health disorders of staff who provide services to patients with COVID-19"* (Zandifar, Karim, et al. 2020). But all efforts in this regard will potentially fall short if case numbers remain high and health systems overwhelmed around the world.

A plethora of ***online training and virtual education opportunities*** for health care workers (and the public) became swiftly available, often at no cost, were promoted widely and successfully enrolled millions of individuals in courses ranging from home-based care interventions to ICU level care. The WHO platform OpenWHO alone has enrolled over 5 million people in a wide-ranging multi-lingual set of different training opportunities ('OpenWHO' 2021). There is limited evidence yet on the extent to which virtual education programmes enhance the care of patients. One positive example of providing training and evaluating its impact is provided by the Project ECHO (Extension for Community Healthcare Outcomes) Care of the Elderly/ Long-Term Care (COE-LTC): COVID-19, a virtual education programme, which was conducted and evaluated in Canada in 2020-2021. The outcome of the evaluation is described as follows: "The re*sults demonstrate that ECHO COE-LTC: COVID 19 effectively delivered time-sensitive information and best practices to support LTC teams and residents. It may be a critical platform during this pandemic and in future crises to deliver just-in-time learning during periods of constantly changing information"* (Lingum et al. 2020).

4.2.8 Digital Health Solutions and Telemedicine

COVID-19 has sparked innovations and research in almost every sector and led to the novel or augmented and adapted use of pre-existing solutions. One of the areas that certainly thrived throughout the pandemic was the field of digital health and technological solutions in data management, prevention, detection, and treatment as well as contact tracing and material procurement. ***Technological innovations*** around disease prevention range from assisting people to deal with social distancing via smart-sensor technology (Scott 2020) to disinfecting hospitals, health facilities and public buildings with the help of robots (Blake 2020; Edwards 2020; Murray 2020) while different types of air purifiers aimed at helping to prevent the spread of the virus in public buildings, to name just a few examples.

Another innovation, that was aimed at preventing the spread of the virus and communicating with the populations were the different ***Corona-Apps*** developed and implemented in many countries, such as

Germany (Bundesregierung.de 2020b), Australia (Cartwright 2020) and the United Kingdom (Deutsches Ärzteblatt 2020f). While they differ in certain aspects and features and in their date of release, their common aim is the tracing of contacts of infected people and warning them of their potential exposure to a known or suspected COVID-19 case.

Another successful example of a digital solution to outbreak response and analysis is ***SORMAS*** (Surveillance Outbreak Response Management and Analysis System), a ***pandemic software*** for public health departments, developed in Germany. The software assists health officials in case- and contact person management as well as in the description, visualisation and evaluation of infection chains, to name only a few of the programme's functions (Krause 2020). SORMAS-ÖGD is used in some areas and districts of Germany as well as in Ghana, Fiji and soon in Switzerland, Nepal and Ivory Coast. SORMAS is also suitable for countries with a weak digital infrastructure (Helmholtz-Zentrum für Infektionsforschung 2020) and was implemented in Nigeria with considerable success (Dubich 2021). In the meantime, the system, which works largely automatically, has been modified and matured to such an extent that it can be used to combat 37 infectious diseases, including COVID-19. Switzerland, France and Fiji are already using SORMAS to combat Covid while Burkina Faso, Côte d'Ivoire, Nepal and Afghanistan are also preparing to implement the software (Kinkharz 2021). In Germany however, the software has only been installed in in 295 of almost 400 municipal health offices in Germany as of mid-March 2021 (Helmholtz-Zentrum für Infektionsforschung 2021). But even if the software is installed, some health authorities have been resistant to implement its use in the midst of a pandemic and elected to stick with their current procedures the time being (Stalinski 2021). This is why in 2021, health offices in Germany were in some cases still working with handwritten lists and printed Excel spreadsheets, and data was transmitted by fax and then manually typed into a computer (Kinkharz 2021).

Many laboratories also continued to report infection cases to the local health offices and the Robert Koch-Institute via Email or even fax, since digital solutions had not yet been sufficiently implemented before the pandemic struck. Especially when the information had to be made available to another health office, e.g. in another district, printouts and faxes were used because software programmes of the different administrations were not compatible with each other, and there was no other way to transfer the information in a manner compliant with data protection regulations (Stalinski 2021).

In summer 2020, however, the **DEMIS**-software, an acronym for „Deutsches Elektronisches Melde- und Informationssystem für den Infektionsschutz" or "German Electronic Reporting and Information System for Infection Protection" (gematik 2020) was launced and aimed at upgrading the digital opportunities of public health offices across Germany. The digital connectivity and networking of doctors, hospitals and laboratories with the Robert Koch-Institute has since much improved, with 97% of all health offices in the country now being equipped with DEMIS. The implementation of DEMIS is progressing and Health Minister Spahn has ordered that data concerning notifiable diseases may only be transmitted electronically (Kinkharz 2021). However, at the time of writing, there is still only one version of the software running so far, which does not contain all the features and is still in the testing phase. Only some of the laboratories can already transmit Covid test results electronically. Most of the data ends up electronically (and still also by fax) at the health offices and must be forwarded from there to the Robert Koch-Institute. For this, however, the RKI's own software SURVNET is required (Kinkharz 2021).

In January 2021, the Bundestag decided that all health offices should implement the SORMAS software. This has the additional advantage that, with the current version of Sormas eXchange, data from DEMIS can also be imported and processed. As the decision to use SORMAS is not mandatory, however, each health department can decide if and when this happens. Thus, it will likely be a while before the use of the software is rolled out nationwide (Stalinski 2021).

Even before the pandemic, digital innovations and remote solutions were increasingly promoted and

implemented in many areas of the health sector. These include numerous available health apps, electronic appointment systems and digital applications for health workers and entire electronic patient files that interact with other health solutions, to name just a few of the almost infinite number of opportunities. Of particular importance in the pandemic was the possibility to communicate with the GP via online tools, for example via ***online consultations***. Not only general practitioners and specialists but also psychotherapists made use of these possibilities to be able to support their patients during the pandemic. In Germany, for example, sick leave certificates could be issued via telephone or online appointments instead of the patient having to appear in person (tagesschau.de 2020b). The increase in online appointments has also made it possible to avoid full waiting rooms, as patients with minor complaints or for regular medication prescriptions were not required to visit the doctor's office. Thus, online appointments contributed to relieving the burden on the health system during the pandemic and to preventing further spread of the virus.

Technology, and in particular ***Artificial Intelligence (AI), was used to detect COVID-19 cases and to improve treatment***. During the pandemic, countless programmes and approaches have been developed or augmented to assist in the fight against the pandemic. Like many other countries, Iran used technological devices and methods to screen for COVID-19. For instance, the Iranian Society of Radiology addressed the shortage of on-site radiologists by establishing a teleconsultation system in which clinicians could send in anonymised CT scans of suspected COVID-19 patients via WhatsApp to procure a second opinion on the shared COVID-19 case (Davarpanah et al. 2020). Tunisian engineers have created a web-based platform that scans lung X-rays and evaluates whether patients are likely to be suffering from COVID-19. Once the image is uploaded on the platform, the AI algorithm generates a recognition score for the tested person and delivers a result in approximately 15 seconds. The process is still being optimised in order to detect signs of the virus with even higher reliability, but the technology may be especially helpful for clinicians in remote settings (Paul 2020; BBC News 2020). Another example: researchers from the Massachusetts Institute of Technology have developed an AI model that could diagnose COVID-19 by analysing cough and voice samples (Laguarta, Hueto, and Coventry 2020; J. Chu 2020). In terms of improving treatment, German researchers have developed an app that screens routine data of ICU patients (e.g., PEEP and oxygen settings of the ventilator, oxygenation, Horovitz index, and other variables) for signs of early stages of ARDS. If hints for ARDS are detected, clinicians are alerted via smartphone and diagnostic pathways and therapeutic measures are suggested based on current guidelines (Healthcare in Europe. com 2020). As the pandemic is still ongoing, it remains to be seen which of the technical innovations that have been developed will make an impact and prove efficient in dealing with the pandemic. Some of the digital solutions developed now may even persist beyond the current pandemic and begin to improve healthcare systems as well as diagnostic and therapeutic options in the near future.

5. Conclusion

To adequately address the current pandemic and to meet future (pandemic) challenges, existing health systems must to evolve and adapt according to lessons learned from the pandemic rather than returning to the status ante before COVID-19. Health systems should therefore not only incorporate innovations and digital solutions, but also be intricately linked to research, place greater emphasis on disaster preparedness and planning, and provide incentives for health workers to continue in their profession, to name just a few potential areas for improvement. To do so, however, much research and analysis will be needed to determine which measures worked, both in the short and long term, and which lessons can be derived from the successes and failures in the response to COVID-19 for health systems to be better equipped for future challenges. This report provides a mapping of some of the key innovations and approaches taken globally, regionally, nationally and locally throughout the course of a 12-month real time monitoring of the SARS-CoV-2 pandemic. Mapped against the epidemiological progression of the pandemic, there is potential to attribute the epidemiological trend(s) to some of the measures taken. However, just as international, national and local measures are intrinsically linked in a globalised world, so too are their effects on the epidemiological trend of any disease.

Annex

Horizon Scanning – Innovation Sheets

The ADRU Project "CoronaSys: Addressing the corona pandemic in Armenia through systemic risk management", funded by the German Federal Ministry of Education and Research, produced the following innovation sheets as part of a real-time evaluation of the SARS CoV 2 pandemic (with focus on epidemiological, medical, economical, societal, technical, and cultural developments in Germany and Armenia). Under the leadership of Prof. Dr. Martin Voss, a continuous monitoring of developments and medical, technical, and social innovations concerning Covid-19 was conducted over the course of 6 months in the second half of 2020. Multiple national and international media outlets, research platforms, and scientific and organisational guidelines, briefs, and updates were screened to feed into the outlet. The rationale behind this was to support the project's network partners in Armenia and Germany with short summaries of key developments and promising innovations that were and are shaping the global, German, and Armenian outbreak response and recovery. All innovation sheets were published on the CoronaSys homepage and frequently promoted to the wider network of ADRU stakeholders and network partners. The aim of these short briefs was to give condensed and structured information on selected innovations emerging out of the conducted horizon scanning. This included mainstreambig-ticket items and fringe subjects that are easily overlooked in the global flood of information. Some innovations were followed through their evolution in time while others only appear once. While subjectively selected, the briefs are descriptive in nature and leave analysis and critical interpretation to the reader. Network partners in both countries were invited to provide feedback on their interest areas and suggest particularly relevant topics for the CoronaSys Workshop series. The CoronaSys Innovation Sheet Series has been published by the Academy of the Disaster Research Unit, which is a non-profit limited liability company and a branch of the Disaster Research Unit at the Free University of Berlin.

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8 Corona Traffic Light
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11 LY-CoV555 Antibody Treatment
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13 Regional Corona Prediction Model
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19 European Corona- Map
20 FELUDA Paper Strip Test
21 Humanitarian Action Mapping Tool
22 IKKA Score
23 WHO Digital Implementation Investm. Guide
24 RCCE Toolkit
25 Cough-Analyzing App
26 Follow Up on LY-CoV555 Antibody Treatment
27 Follow-up on BNT162b2-Vaccine
28 Lucira™COVID-19 All-In-One Test Kit
29 COVID-19 Humanitarian
30 AI-Epidemiology-Model
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35 CURIAL AI Screening Test
36 Prioritization Roadmap
37 Ellume Test
38 TV Schooling
39 Octea Test
40 Prognostic Urine Test
41 ICU Training Video
42 SafeZone
43 Project Hazel
44 Viral Escape Modelling
45 Vaccination Communication Handbook

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CoronaSys

CORONASYS INNOVATION SHEET 1

"NEW" ANTIVIRAL FACE MASKS

Background

A study established that people touch their faces 23 times per hour on average[1]. Especially people who are not used to wearing masks tend to touch their faces to adjust the masks very often. Furthermore, the coronavirus that causes Covid-19 remains present and infectious on the outer layer of masks for up to 7 days, according to a study published in *The Lancet Microbe*[2]. Several companies[3] have developed "new" forms of antimicrobial face masks that receive quite a lot of media coverage at the moment.

Features

Some types of "new" masks are coated with various antiviral and anti-microbial substances (e.g. copper oxide, Triiodide), while others work by destroying the negatively charged microbes on contact with the strongly positively charged surface of the textiles. The manufacturers claim that the "new" masks can render 99% of the Corona Virus suspension on the outside surface of the mask harmless[4]. Studies have confirmed the efficacy of the respective products[5]. The masks are reusable and come at a price range from about 6€ to 45€.

State of information: 13/08/2020

Market launch: July 2020

Countries: Canada, Israel, Switzerland

Focus area: Prevention; PPE

Developers:

- i3 BioMedical Inc. (Canada)
- Livingguard (Switzerland)
- Argaman Technologies Ltd (Israel)

Beneficiaries:

- general public, especially essential (health) workers

Potentials

The masks can help limit transmission by preventing the spread of the virus over the mask surface. They also prevent unpleasant smells of the masks. The "new" masks might therefore be an added value especially for health workers or other essential workers who need to wear the masks for longer time periods.

Points to consider

The efficacy under laboratory conditions is undisputed. Still, experts warn against over-expectations and a false sense of security. The "new" masks do not offer 100% protection against infection since other forms of transmission are still far more likely. In addition, it must be noted that only the surface of the masks is largely virus-free but not the other parts of the face that are touched frequently. The products can therefore only be an addition to existing hygiene and social distancing measures in tackling the pandemic[6].

Conclusion

The effect of the "new" masks has been proven but further studies are needed to assess effectiveness and long- term safety of the new products under everyday conditions[7]. Especially for people who must wear the masks for a long time, they might represent an added value. In general, however, existing mask models seem to be sufficient and offer a good price-performance ratio. Various experts consider the everyday masks and medical masks used to date, together with frequent hand washing and compliance with social distancing rules, to be sufficient.

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CoronaSys Innovation sheet 2

"Dyphox" surface coating

Background

The SARS-CoV-2 virus can remain infectious on inanimate surfaces for some time, depending on the environmental conditions[12]. Transmission of SARS CoV-2 through contaminated surfaces can therefore not be ruled out, especially in the immediate vicinity of infectious persons. Surfaces that are touched by many people can pose a particularly high risk of infection. Manual disinfection only works in a temporal context and recontamination between disinfection cycles can hardly be prevented[3]. The permanently effective antimicrobial coating "dyphox" can help to close those hygiene gaps.

State of information: 18/08/2020

Market launch: 2018

Country: Germany

Focus area: Prevention, Disinfection

Developers: TriOptoTec GmbH

Beneficiaries:

- general public
- especially in public areas and in health facilities

Features

Surfaces (e.g. desks and doorknobs in public buildings, grab handles in public transport, and near-patient surfaces in hospitals and nursing homes) can be coated with the clear lacquer[45]. It creates a photodynamic effect to kill bacteria, viruses, and fungi and works on dry and wet surfaces[67]. In addition, the manufacturer[8] offers the disinfecting molecules as an admixture for other coatings[9]. A study[10] showed that the germ colonization on the surface is significantly reduced for about a year. The agent causes a germ reduction of more than 99.99%.[11] The relative risk of high germ loads has been shown to decrease by up to 67% and thus also the risk of spreading germs over surfaces. According to the manufacturer, the one-time treatment of a desk, for example, costs about 30 Euros[12].

Potentials

The varnish could be a valuable addition to other measures. In particular, frequently touched surfaces in public buildings and health facilities could be treated with it to reduce the transmission of coronaviruses and other germs. A major advantage is that the transparent lacquer can be applied to almost all kinds of surfaces. Also, the technology is environmentally friendly[13].

Points to consider

The number of germs is only reduced and other ways of transmission are still far more likely for SARS-CoV-2- infections than smear infection via contaminated surfaces. Therefore, further hygiene measures are of course mandatory and must be obeyed.

Conclusion

In public buildings, public transport, nursing homes, and hospitals the coating can be a good addition to existing pandemic management and prevention measures. However, it is not a substitute for these existing measures.

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CORONASYS INNOVATION SHEET 3

MOVES SLC™ PORTABLE ICU

Background

Covid-19 infections can lead to respiratory distress, and especially patients with pre-existing conditions may need intensive care[12]. However, advanced intensive care units are not always available, particularly in rural areas. Shortages in ICU beds, ventilators, and compressed oxygen can further complicate the challenges in fighting Covid-19[34].

Features

The MOVES® SLC™ addresses these problems by providing ventilation, oxygenation, vital signs monitoring, and suction, without the need for compressed oxygen[5], and while operating on battery power for more than six hours[6]. Its low weight of just 17 Kg makes it easy to handle. It is intended for adults and pediatric patients who weigh between 10 kg and 120 kg. MOVES® SLC™'s circle-circuit ventilator enables a high FiO_2 of up to 85% with low flow O_2 so that no O_2 tanks are required[7]. If a higher FiO_2 is required, the system can operate with 95% less oxygen than the open-circuit ventilators currently in use according to the manufacturer[89].

State of information: 19/08/2020

Market launch: 2017

Implemented in:

- Canada
- Belgium
- Australia
- United States
- Malaysia
- Israel

Focus area: Treatment

Developers: Thornhill Medical

Beneficiaries:

- critically ill patients
- health care providers

Potentials

The system can quickly be set up bedside in any location to ventilate and monitor patients[10]. It can be used for intra- hospital or inter- hospital transport, to set up a temporarily OR or to scale up intensive care and ventilator capacities in hospitals, field hospitals or other locations[11].

Points to consider

Although the MOVES® SLC™ does comply with a wide range of international standards, potential users should check the compatibility with their systems. The system does not have defibrillation capability[12].

Conclusion

The product might be a valuable addition to existing equipment and can be used to temporarily scale up ICU capacities in the wake of the Covid-19 pandemic and in the context of other disasters.

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CORONASYS INNOVATION SHEET 4

PORTABLE TRI- KLEEN 500UV

Background

Droplet infection and infection through aerosols are the main ways of transmission for SARS- CoV-2[12]. Particularly in hospitals where infected persons are being treated the risk of infection in the patients' rooms and examination rooms may be especially high[345]. Many hospitals do not have enough isolation facilities with special air filtering systems (Airborne Infection Isolation Rooms, AIIR) that prevent contaminated air from spilling into other parts of the hospital. In the wake of the COVID- 19 pandemic *Tri-Dim* and *EBM- Pabst* have rapidly developed a portable solution.

State of information: 25/08/2020

Market launch: April 2020 (USA)

Country: USA

Focus area: Prevention, Hospital Hygiene

Developers: *Tri-Dim*, *EBM-Pabst*

Beneficiaries:

- Hospital patients and staff

Features

The portable TRI- KLEEN 500UV is a portable air filtration system that creates a vacuum in closed treatment or examination rooms to prevent the overflow of virus-contaminated air into neighboring rooms[6]. The system includes a MERV 9 pre-filter and a cylindrical HEPA filter[78]. This high-performance filter guarantees the filtering of 99.97 percent of all particles with a size of up to 0.3 microns[9]. The effect of filtration is enhanced by the combination of the HEPA filter with a UV lamp, whose light kills germs, bacteria, and viruses[10].

Potentials

No renovation work is necessary to install the system. The device is mobile and can be set up rapidly and moved according to current needs. It therefore can present a quick solution to provide additional protection for hospital staff and patients.

Points to consider

For now, the product is only available on the American market, but negotiations with other countries are underway and the manufacturers are preparing for the production of 230 Volt-models.

Conclusion

The product might be a valuable addition to other CDC- recommended infection control measures[1112]. Since it is mobile and quick to be installed it can increase the flexibility of healthcare providers in reacting to patient surges.

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CORONASYS INNOVATION SHEET 5

CONVALESCENT PLASMA THERAPY

Background

As of late August 2020, the USA have reported around 5.780.000 Covid- 19 cases and 178.000 deaths related to Covid- 19[1]. This makes the USA to one of the countries that are hit hardest by the pandemic[2]. Since there is no causal therapy and no vaccine available yet, clinicians and researchers have been searching for other solutions to support recovery. One of those possible solutions is convalescent plasma therapy. Together with President Trump, the U.S. Food & Drug Administration (FDA) announced on August 23, 2020, that they issued an emergency authorization for convalescent plasma therapy[3].

Features

The therapy approach is based on the transfusion of blood plasma of recovered Covid-19 patients to patients currently suffering from the disease. Because there is no vaccine yet that stimulates the formation of antibodies against SARS-CoV-2, patients are given antibodies from people who have formed them after a natural infection[4].

Potentials

Plasma therapy has been used for more than 100 years and is considered safe for patients[56]. Plasma may particularly help patients in the early stages of the disease[7]. This is indicated by a study on the efficacy of the treatment conducted by the Mayo Clinic: Out of 35,000 patients treated with plasma, those who were treated earlier benefited more from the treatment. In the group that received the plasma within the first three days of their diagnosis, 8.7 percent died within the following week, while a transfusion after four or more days resulted in a death rate of 11.9 percent[8].

State of information: 27/08/2020

FDA emergency authorization: August 2020

Country: USA

Focus area: Treatment

Beneficiaries:

- Possibly patients in early stages of Covid-19 infections

Points to consider

However, the Mayo Clinic- study is not sufficient proof of the treatment's efficacy for Covid- 19, since there was no comparison group[910]. A Cochrane review also found serious shortcomings in the overall evidence to date, both in terms of the quantity of the studies and their quality[11]. Besides, the emergency authorization does not correspond to a formal authorization with much higher hurdles. And while plasma treatment has been used safely against different diseases over the last 100 plus years, its effectiveness on different diseases is very mixed[12]. Plasma supply is also limited, as it can only be obtained from blood donations. The amount of plasma simply would not be enough for the number of patients who need help in the course of a pandemic wave in the clinics[13]. Plasma therapy is also not the announced breakthrough: approximately 70,000 people have already received plasma under FDA's "expanded access" program[14]. Critics claimed that the FDA and President Trump were pushing the therapy ahead of the republican national convention this week to support Trump´s narrative about the pandemic[15].

Conclusion

There are currently around 50 studies underway worldwide[16], which will examine the topic and are expected to show results by the end of the year. Twenty-two of these studies are Randomized Controlled Trials. Plasma therapy could, therefore, be a supplement if its effectiveness can be proven. However, it is by no means a comprehensive solution.

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CoronaSys Innovation sheet 6

ASIC- App

Background

Covid-19 patients in intensive care units often develop Acute Respiratory Distress Syndrome (ARDS)[12]. Despite all the advances in intensive care medicine, the mortality rate of ARDS and resulting complications is still estimated at 25-50% depending on the severity[34]. Effective therapy is based on the timely detection of impending lung failure, early and appropriate treatment of the underlying disease, and adequate ventilation therapy to prevent further ventilation-associated lung damage[567]. The ASIC- App aims at assisting clinicians in early diagnosis of ARDS and therapeutic decision making in order to improve patients outcomes.

State of information: 01/09/2020

Launch: July 2020

Country: Germany

Focus area: Treatment

Developers:

- RWTH Aachen University clinic
- Healthcare IT solutions GmbH
- Federal Ministry for Education and Research

Beneficiaries:

- Clinicians
- Critically ill patients

Features

The App screens the routine data of ICU patients (e.g. PEEP and oxygen settings of the ventilator, oxygenation, Horovitz- index, and other variables) for signs of early stages of ARDS. If it detects hints for ARDS it alerts the doctors via smartphone- before the patient's clinical condition deteriorates. It then suggests diagnostic pathways and therapeutic measures based on current guidelines[8].

Potentials

The App can be a valuable addition to regular monitoring and diagnostic measures since it can help to detect changes in huge amounts of data. Particularly in times of overburdened health systems and staff shortages, its step by step guidance might be helpful in the early detection of ARDS. The App is free of charge[9].

Points to consider

As of now, the app only operates on Apple- devices and requires iOS 8 or newer[10]. The App is currently only used in Germany and therefore certainly has to be adapted to other countries in terms of software compatibility. Although the developers[11] applied high standards for data protection, the local user has to check for potential security breaches and compliance with the data protection laws of the respective country. The app is relatively new, so some optimization potentials will only become apparent over time.

Conclusion

The App might be an addition to other monitoring and diagnosis tools if it is compatible with local technologies and data protection laws.

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CoronaSys Innovation sheet 7

BinaxNOW antigen test

Background

Testing has posed a major challenge to health systems tackling the novel Coronavirus. Shortages of certain items like swabs and reagents added to the supply chain problems. Overburdening of laboratories and delays in delivering the test results to the patients have been huge problems in the US and elsewhere[1]. The company Abbott claims to have a solution for those difficulties with their BinaxNOW antigen test.

Features

Rapid Antigen tests have been used in the detection of other respiratory infectious diseases before[2]. The BinaxNOW test looks for a specific protein on the virus surface which implies an infection with SARS CoV-2[3]. Antigen tests do not necessarily require specialized labs, certain machines, or highly trained staff.[4] The test result can be read directly from the card. The manufacturer claims that the test can deliver results in 10-15 minutes and will cost around 5 US- Dollars.

State of information: 02/09/2020

Launch: August 2020

Country: USA

Focus area: Testing

Developers: Abbott

Beneficiaries: General population

Potentials

The Food and Drug Administration (FDA) issued an emergency use authorization for the test on August 26, 2020[56]. This could massively scale up testing capacities in the United States[7]. The manufacturer plans to produce and distribute 50 million tests per month[8]. The tests might be especially useful in screening asymptomatic people if they get approved for this usage.

Points to consider

The speed of the test comes with trade-offs. Antigen tests are very specific but are not as sensitive as molecular tests. The tests are more likely to produce false-negative results, meaning there is a higher risk to miss an active coronavirus infection compared to molecular tests. The full FDA Approval process is still ongoing and the test is currently only authorized for people with COVID-19 symptoms within the first 7 days, which is problematic because Covid-19 is asymptomatic in many cases.[9]

Conclusion

The test may rapidly scale up testing capacity. But it remains to be seen whether it can provide accurate and reliable results in large numbers of tests and in asymptomatic patients. A similar test has been developed by the Suisse pharma company Roche and is to be launched on the European Market in September 2020[1011].

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CORONASYS INNOVATION SHEET 8

CORONA TRAFFIC LIGHT

Background

Many European countries have seen surges in Covid- 19 infections after the holiday season[12]. This is also true for Austria.[3] There are many different approaches to evaluate the severity of the situation and to decide which measures should be taken. Austria has now developed a so-called "Corona traffic light" that has gained a lot of media coverage to inform its decision making regarding the pandemic[4]. Similar concepts have already been implemented for example in Berlin[5] and the USA[6].

Features

The Corona situation in Austria is now evaluated weekly with a traffic light system. Four colors from green (low risk) to red (very high risk) correlate with specific measures to apply to the affected region. The Berlin system in comparison does only involve three colors and includes only three parameters (incidence, the R-value, which indicates how many people an infected person infects on average, and the percentage of ICU- beds required for Covid- 19 patients)[7]. Criteria for traffic light colors in Austria are not only the case numbers over seven days but also their traceability, whether sick people became infected in their home town or elsewhere, the capacity of hospitals, the total number of tests, and other factors such as tourism[89]. The traffic light aims to carry out the risk assessment according to objective criteria and to standardize the response to it. For example, in the case of yellow, the requirement to wear masks is to be tightened in shops, restaurants, and during events. Students will also have to wear a mask in schools if the traffic light turns yellow[10].

State of information: 08/09/2020

Launch: September 2020

Country: Austria

Focus area: Monitoring, policy, and public communication

Developers: Austrian government

Beneficiaries: General population, decision makers

Potentials

The traffic light could help officials to make informed decisions, communicate to the public, and provide guidance for the implementation of specific measures according to scientific knowledge, regional differences, and manageability.

Points to consider

However, the traffic light is not excluded from political influence. It is carried out by a commission to which five representatives of the Federal Government and nine representatives of the counties are sent. There will be five experts as well (e.g. virologists) but they are also appointed by the Federal Government.[11] Some cities have already criticized the government's strategy. They claim that the traffic light does not consider the differences between regions and does not paint an adequate picture of the situation[12]. Another point to ponder is whether there should be a green light at all. One could argue that this leads to a false sense of security. The US- System, for example, does not include a green light[13]. Some accuse Austria's government of using the classification to make local officials look bad and enhance the governing parties (ÖVP) chances in the state elections in autumn. Furthermore, some say there is not yet a jurisdictional basis for the traffic light system[14].

Conclusion

In theory, the Austrian Corona traffic light system is a helpful tool to respond to challenges regarding Corona measures. In practice, however, it needs to be improved and a consensus between state and local authorities as well as leading scientists should be reached.

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CoronaSys Innovation sheet 9

A proof-at-home antibody test

Background

People who have been infected with Sars-CoV-2 usually form antibodies against the virus within approximately one to two weeks[1]. These are to be detected by the test developed by Adversis Pharma[2] in collaboration with the Biotechnological Biomedical Center (BBZ) of the University of Leipzig[3]. According to the manufacturer the test can easily be carried out by laymen at home. The test has been heavily advertised in Germany.

Features

People can order the test online and will receive a set, with which they can collect a few drops of blood from the fingertip with a lancet and drip the blood onto a filter card. The blood sample must then be dried and sent to a laboratory in Leipzig[4], where it is tested for antibodies using the standard ELISA method[5]. The result can be retrieved online with the personalized code in the testing kit within 24 to 48 hours. The manufacturer claims that the test has a sensitivity of 100% and a specificity of 99.4%[6]. The test costs 49 euros[7].

State of information: 10/09/2020

Launch: September 2020

Country: Germany

Focus area: Testing

Developers:

- Adversis Pharma
- Biotechnological Biomedical Center (BBZ) of the University of Leipzig

Beneficiaries: General population

Potentials

The user receives information about whether or not he has antibodies against Sars-CoV-2. Since the majority of those infected have mild or no symptoms, the knowledge of an infection acquired retrospectively could affect how individuals assess the situation and deal with the pandemic[8]. Moreover, the test is part of a larger research project aimed, among other things, at obtaining data on the immune status of the population (especially titers of neutralizing antibodies), which could also play a role in the long term in disease monitoring and the development of vaccines[9].

Points to consider

The presence of antibodies is not to be equated with immunity[10][11]. Until now, many researchers had hoped that one would be immune to the virus after infection. But at the end of August, several cases of individuals infected with Sars-CoV-2 a second time became known[12][13]. In addition, the body usually develops better detectable IgG antibodies, for which the test is designed, not until a few weeks after infection. So if one does the test too early, one will not get a reliable test result. But if the test is conducted too late it might not produce a valid result either, as cases are known where the concentration of antibodies dropped again after a short period of time[14][15]. Furthermore, The Federal Association of German Pharmacists' Associations (ABDA) strongly advises pharmacies against offering such tests to their customers due to legal concerns, referring to a passage in the German Medical Devices Act[16]. Initially, Adversis had been counting on pharmacies to sell the product in addition to the online sale.

Conclusion

For patients with symptoms, a PCR test is the means of choice anyway, because it shows an active infection. Antibody testing is more likely to be useful in asymptomatic patients who want to know if they have already survived the infection. The data collected could also contribute to a better understanding of the immune situation of the population.

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CoronaSys Innovation sheet 10

IVAT Hygiene Tower

Background

Aerosols are, in addition to droplet infection, the main way of transmission for SARS CoV-2[12]. These aerosols can float in the air for hours indoors and lead to infection even if the infected person is no longer in the room[34]. The risk of infection is particularly high in public places where many people are in contact with each other. With the end of the summer vacation season, this is for example the case for schools and other public buildings. With the colder season approaching people also spend more time indoors. This requires additional solutions to policies like mask-wearing and social distancing to decrease the risk of infection in public spaces. Air purification devices can contribute to these aims[5].

State of information: 18/09/2020

Launch: 2020

Country: Germany

Focus area: Prevention

Developers: IVAT GmbH

Beneficiaries: Public and health institutions, working spaces etc.

Features

The above-mentioned study by the University of the Bundeswehr Munich recommends the change of the indoor air at least six times per hour to maintain the desired low aerosol concentration.[6]With its four-stage high-performance filter, the Hygiene Air Tower cleans the air of more than 99.995 percent of all viruses at the necessary speed and can thus generate an air quality that meets the requirements for effective air cleaning of rooms. In addition, it can perform many other tasks, such as cooling or heating rooms, filtering odors, and disinfecting hands and objects. The embedded monitor can be used for videoconferencing or to display advertising or other content. The tower is completely quiet and comes at a price range from about 5000 to 30 000 Euros depending on the included features[7].

Potentials

While the tasks of the Hygiene Tower during the day are primarily the cleaning of the air and the monitoring of its quality, it can also serve at night as an alarm and fire alarm center, including video surveillance for protection against burglary[8].

Points to consider

The Hygiene Tower with all its bonus- features might be a little too much for the needs of most customers in need of air purification, such as schools, offices, or public buildings.

Conclusion

The Hygiene Tower can be an addition to other hygiene measures such as mask-wearing and frequent hand washing during the SARS CoV-2 pandemic and afterward, especially if institutions benefit from the towers many additional features.

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CoronaSys Innovation sheet 11

LY-CoV555 Antibody treatment

Background

Neutralizing antibodies are one of the research foci in the search for a possible treatment for COVID-19[1]. Several companies are researching different approaches to antibody treatment for the disease[2]. Eli Lilly and Company published data from an interim analysis of the BLAZE-1 clinical trial[3] on September 16. The data showed reduced hospitalization rates for patients treated with LY-CoV555, a SARS-CoV-2 neutralizing antibody. The randomized, double-blind, placebo-controlled Phase 2 study evaluated LY-CoV555 for the treatment of symptomatic COVID-19 in the outpatient setting. The trial enrolled mild-to-moderate recently diagnosed COVID-19 patients[4].

Features

The antibody LY-CoV555 was originally produced by one of the first COVID-19 patients in America. It is one of about 500 antibodies that the patient's immune system had formed against SARS-CoV-2 after infection. Using a special method, the researchers were able to detect the B cells that produce the antibody, isolate the gene, and produce them in larger quantities using recombinant cells. Treatment consisted of a single intravenous infusion of the antibodies at a dose of 700 mg, 2,800 mg, or 7,000 mg. In a fourth group, patients received an infusion without antibodies[5].

State of information: 18/09/2020

Launch: September 2020

Country: USA, Canada

Focus area: Treatment

Developers:

- Eli Lilly and Company in collaboration with
- AbCellera Biologics Inc.
- Shanghai Junshi Bioscience Co., Ltd.

Beneficiaries: patients with mild to moderate symptoms

Potentials

A significant advantage over placebo in reducing viral load after 11 days was detectable only after the mean dose of 2,800 mg. In the three LY-CoV555 groups, only 1.7% had to be hospitalized or treated by an emergency physician. In the placebo group, this was required for 6% of patients. This corresponds to an absolute risk reduction of 4.3 % and a relative risk reduction of 72%. According to the press release, no patient had to be mechanically ventilated. There were also no deaths[6]. Most hospitalizations occurred for patients with underlying risk factors (age or BMI). The infusion was well tolerated by all patients. Serious side effects have not occurred, according to the manufacturer[7]. Some experts hope that the real benefit of neutralizing antibody treatments will be not only as a treatment of the sick but as a means of infection prevention[8].

Points to consider

One limitation could be that only patients with mild to moderate symptoms were treated, who also remained without complications in the placebo- group. The efficacy in serious cases is therefore not yet proven. It is possible that the antibodies no longer have any effect if the disease is advanced and characterized by an excessive immune response. The manufacturer is still hoping for early approval by the U.S. Food and Drug Administration (FDA). A price has not been mentioned, but antibodies are usually high-priced drugs[9].

Conclusion

The promising results still need to be peer-reviewed by independent researchers and published in a peer-reviewed journal. Further research is needed to determine whether the treatment is effective in patients suffering from advanced and severe clinical manifestations of COVID- 19.

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CoronaSys Innovation sheet 12

4C Mortality score

Background

Hospitals around the world are facing an influx of Covid-19 patients. In order to identify those with the highest risk of death or severe complications timely, there is a need for valid screening tools. Pre-existing scores developed for influenza, pneumonia or sepsis have not been sufficient[12] since Covid- 19 patients often present a clinical picture that leads to different clinical courses than patients with the diseases mentioned above go through[3]. Researchers in the United Kingdom now developed a score that supports clinicians in assessing the severity of Covid-19 in hospital patients by using easily accessible parameters.

Features

The prospective cohort study[45] in which the score was developed included 35.000 adult patients admitted to one of 260 hospitals in England, Scotland, and Wales with Covid-19 in the derivation dataset and a further 22.000 patients in the validation dataset. The researchers identified eight variables available at initial hospital assessment to stratify patients according to their risk of mortality or severe complications: age, sex, number of comorbidities, level of consciousness, respiratory rate, peripheral oxygen saturation, level of C reactive protein, and level of urea. The maximum of the 4C score is 21 points. Patients with a high score (>15) had a 62% mortality while patients with a score of 3 or less had a mortality of 1%[6].

State of information: 24/09/2020

Launch: September 2020

Country: United Kingdom

Focus area: patient assessment**,** Treatment

Developer: ISARIC „Coronavirus Clinical Characterisation Consortium“, involving researchers from

- University of Liverpool
- University of Edinburgh
- University of Glasgow and
- Imperial College London

Beneficiaries: clinicians

Potentials

The score outperformed other risk stratification tools and showed real utility for clinical decision making[7]. The score can help clinicians to assess the severity of disease in Covid-19 patients at hospital admission. Especially in times where less experienced personnel might have to perform the initial assessment due to staff shortages a score with a high predictive value might be helpful in deciding which therapeutic options should be initiated for the individual patient[8]. Patients with a higher score could immediately be treated more aggressively to tackle the disease before the patient's condition deteriorates while patients with a lower score could possibly be sent home for convalescence[9].

Points to consider

The scores´ applicability for other populations has to be further evaluated[10].

Conclusion

The score can be a valuable contribution to the initial assessment of Covid-19 hospital patients and might help clinicians to decide on the clinical pathway.

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CoronaSys

CoronaSys Innovation Sheet 13

Regional Corona Prediction Model

Background

As many countries in Europe are seeing surging case numbers of Covid-19 infections[12] and German authorities are aiming at preventing a second nationwide lockdown[3] and to rely on local measures instead, regional prediction of infections gains ever more importance. Researchers of the University of Osnabrück[4] and the Forschungszentrum Jülich[5] have developed a mathematical model to assess and predict infections for every German district.

Features

The model provides up-to-date estimates for new infections as well as a five-day forecast for each German district. For this purpose, data from the Robert Koch- Institute (RKI) are statistically analyzed on high-performance computers. The model not only considers the most likely development but also estimates the probability for different scenarios that are compatible with the current data[67]. In addition, the spatial-temporal component of the infections with Covid-19 is estimated and presented as a so-called "interaction kernel"[8]. This method has already been used in 2019 to describe the course of infections with rotavirus, Lyme disease, and Campylobacter bacteria[9].

State of information: 25/09/2020

Launch: September 2020

Country: Germany

Focus area: Prediction

Developers:

- Osnabrück University
- Forschungszentrum Jülich
- In Cooperation with Robert Koch- Institute (RKI)

Beneficiaries: general population, local authorities and decision makers

Potentials

The model can help to predict local infection trends and contribute to a comprehensive local risk assessment. The tool is accessible online for everybody[10] and can therefore serve as a source of information for the general public as well as for local authorities.

Points to consider

Since the model has not been used to predict Coronavirus infections before, a comprehensive validation of the results is possible only after analyzing the predictions in the upcoming months. Furthermore, one has to keep in mind, that the prognosis is highly dependent on the data provided by the local health authorities and therefore susceptible to delays[11].

Conclusion

The model can be a helpful tool in assessing and predicting local outbreaks and case numbers but is highly dependent on the underlying data of course.

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CoronaSys Innovation sheet 14

Computer-designed Mini-proteins

Background

The surface of SARS-CoV-2 is covered with spike proteins. These proteins connect to human cells, allowing the virus to enter and infect them. Once inside the cell, the virus can copy itself and reproduce[1]. But the spike proteins are also a weakness of the virus due to their exposed position[2]. Researchers have been testing monoclonal antibody treatments to neutralize the virus by binding the spike protein. But these antibodies are often quite difficult to produce, relatively unstable, and require refrigeration in most cases. Researchers have now generated computer-designed proteins to do the job.

State of information: 10/01/2020

Publication: September 2020

Country: USA

Focus area: possibly treatment

Developers: University of Washington

Beneficiaries: Covid-19 patients

Features

SARS- COV-2 binds to the ACE2 receptor on the surface of human cells[3]. Two approaches were used to create the computer- based proteins. First, a segment of the ACE2 receptor was integrated into a series of little protein scaffolds. In the second method, fully artificial proteins that did not pre-exist in nature were created from scratch. The latter method produced the most potent antiviral proteins, including the most promising LCB1, that outperformed monoclonal antibodies in lab tests[4]. It was then determined how exactly the mini- proteins bound to the receptor and by further testing and correcting the binding mechanisms were improved[5]. The researchers originated more than two million new spike- binding proteins since January 2020 of which more than 100,000 were then tested in the lab[6].

Potentials

The computer-designed proteins are quite easy to produce and can be produced relatively fast in large quantities. They do not necessarily need refrigeration and can be applied locally (e.g. nasal via nebulizer)[78]. With further development researchers might be able to produce the proteins for future viruses within weeks after their genome has been obtained[9].

Points to consider

Although the results seem to be promising so far, clinical testing has to be extended and further research is needed.

Conclusion

The computer-designed antiviral proteins might be a promising innovative method in the fight against future viruses, although much more clinical research is needed to prove their efficacy and effectiveness in human beings under everyday conditions.

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CORONASYS INNOVATION SHEET 15

COVID-19 SIMULATOR

Background

With the start of the cold season people in the northern hemisphere begin to spend more time indoors and case numbers are increasing in many countries[1][2]. At the same time, there are often signs of "corona-fatigue" in many communities, and adhesion to recommended measures and (often non-transparent) hygiene concepts is not always ensured[3]. Austrian researchers have developed a Computer- simulation that aims at protecting people's health while at the same time keeping as much of the economy running as possible[4].

State of information: 10/02/2020

Launch: September 2020

Country: Austria

Focus area: Prevention

Developers:

- pwC in Cooperation with
- Samariterbund
- Austrian Institute of Technology (AIT)

Beneficiaries: people in public buildings

Features

The Covid-19 simulator developed by PwC[5] aims at modeling scenarios for viral spread based on up- to- date medical findings and crowd- simulations and displays them in 3D[6]. By using a digital twin of a specific building (e.g. a school) the simulator calculates the risk of Covid-19 transmission and compares different measures for infection protection. It then calculates the best possible mix of measures to protect people in this specific building[7]. The Simulator is now used in a project in cooperation with the Samariterbund[8], the Austrian Institute of Technology (AIT)[9] , and the Initiative „innovate4vienna" in order to improve infection control in different buildings over the course of the next months.

Potentials

The Simulation might be helpful in deciding which measures should be prioritized or amplified. The simulator might help to communicate the basis for decisions in a transparent and comprehensible way. The graphic display might also help to motivate people to comply with the measures identified as most important[10].

Points to consider

Although the innovation has already been used with some success, only time and use in different contexts will tell if and how much the Simulator can contribute to infection control.

Conclusion

The computer simulation might be a helpful tool in adjusting infection control measures and increasing people's support of those measures.

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CoronaSys Innovation sheet 16

Trimodulin

Background

Since the start of the SARS-CoV-2 pandemic much progress has been made very rapidly in researching possible treatments for Covid-19. Most therapeutics known today, like monoclonal antibody treatment or Remdesivir for example, seem to be most effective when administered in the early stages of the disease[1][2][3]. With Trimodulin the manufacturer Biotest[4] aims at developing a drug that benefits those most severely affected by Covid-19. The company announced that in the ESsCOVID (Escape from severe COVID-19) study the first seriously ill COVID-19 patient was treated with Trimodulin in Spain. In addition, the study was submitted for approval by the authorities in Russia, Brazil, and France.

State of information: 10/08/2020

Public announcement: October 2020

Country: Germany

Focus area: Treatment

Developers: Biotest AG

Beneficiaries: Patients with severe Covid-19

Features

Trimodulin (IgM Concentrate) is an innovative immunoglobulin therapeutic derived from human blood plasma. Compared to pure immunoglobulin G preparations (IVIGs), Trimodulin contains IgM and IgA antibodies in addition to IgG. It is currently being developed by for the treatment of patients with severe community- acquired pneumonia (sCAP) or COVID-19 with severe disease progression. According to previous studies[5][6][7], it works through a variety of mechanisms that could inhibit pathophysiological processes that could otherwise lead to severe respiratory disorders, severe sepsis, multi-organ failure and ultimately the death of the patient[8]. In the ongoing prospective, double-blind, placebo-controlled phase II trial 160 patients with severe Covid-19 are to be enrolled.

Potentials

If it`s efficacy is proven, the drug could contribute to the treatment of critically ill Covid-19 patients in later stages of the disease. The manufacturer expects a significant reduction of mortality and duration of ventilation[9]. Especially the IgM component in Trimodulin could reduce misdirected immune reactions and therefore possibly also help preventing patients from developing exacerbated symptoms of the disease[10].

Points to consider

The study is not finished yet and it remains to be seen whether Trimodulin performs as well in Covid-19 patients as expected. If so, the manufacturer aims at applying for an expedited approval of Trimodulin by the European Medicines Agency (EMA)[11] which already worked together with Biotest by providing “Rapid Scientific Advice” in the planning phase of the study. But although the company`s share price skyrocketed after the announcement that the first patient has been treated[12], the final proof of the drug`s efficacy in critically ill Covid-19 patients is still pending.

Conclusion

The drug could not only contribute to the standard therapy for Covid-19 but might also be helpful in treating community acquired pneumonia which is a significant public health risk beyond and in addition to the current pandemic[13]. But its effectiveness has yet to be proven and further research is needed.

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CoronaSys

CoronaSys Innovation sheet 17

BNT162b2- vaccine

Background

Since the start of the pandemic, researchers have been working hard to develop a vaccine against SARS-CoV-2. Worldwide more than 160 potential vaccines are being tested as of now[1]. One of the promising candidates is the BNT162b2- vaccine developed by BioNTech[2] in cooperation with Pfizer[3].

Features

The European Medical Association EMA just started the rolling review process for the potential vaccine[4]. The Rolling Review process is a regulatory tool that the EMA can use to assess a promising drug during a public health emergency, such as the current pandemic[5].

The potential vaccine belongs to the group of gene-based vaccines – it is a mRNA vaccine. It contains genetic information of the pathogen in order to produce the surface protein (spike protein), with which the virus penetrates cells. The aim of the vaccination is then to encourage the body to form antibodies and T-cells against this protein[6]. In addition, the active substance is supposed to activate other immune system defense mechanisms[7].

State of information: 10/11/2020

Public announcement: October 2020

Country: Germany, USA

Focus area: Vaccination

Developers: BioNTech (Germany) in Cooperation with Pfizer (USA, Germany)

Beneficiaries: General public

Potentials

BioNTech is, after AstraZeneca, the second company to be in the EMA rolling review process[8]. The vaccine is currently being tested in a phase II/III clinical trial[9]. In this phase, the efficacy is further tested, and the appropriate dosage is determined[10]. If successful, the vaccine could help to end the pandemic. One advantage of mRNA vaccines is that they can be produced more rapidly and cheaper than traditional vaccines[11].

Points to consider

If the rolling review process is completed successfully, the company still has to go through a formal application process for marketing authorization[12]. As of now, it is not clear how many doses of the vaccine are needed to induce a sufficient immune response, but experts estimate that it will take as long as summer 2021 to produce the necessary amounts of vaccine to immunize the population[13][14].

Conclusion

The agent might be one of the vaccines against Covid-19 if the trial is completed successfully.

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CORONASYS INNOVATION SHEET 18

SARS-COV-2 RAPIDPLEX

Background

Upscaling testing capacities is one of the major challenges with regard to the pandemic[1]. Overburdened laboratories and health care facilities are still a reality in many parts of the world. Researchers from the California Institute of Technology[2] and the Lundquist Institute for Biomedical Innovation[3] have developed a testing device that they claim can be used by laymen at home, therefore eliminating the need to visit a health facility to get tested and providing several further advantages.

State of information: 10/13/2020

Publication: October 2020

Country: USA

Focus area: Testing

Developers:

- California Institute of Technology
- Lundquist Institute for Biomedical Innovation (USA)

Beneficiaries: General public, clinicians

Features

The SARS-CoV-2 Rapidplex is a portable, wireless electrochemical platform that can identify a patient´s past and present infection status by using blood or saliva samples[4]. The sensors contain a graphene surface with tiny pores. Due to this large surface area, the sensor is sensitive enough to detect substances that are only present in very small amounts with high accuracy[5]. It detects viral antigen nucleocapsid protein, IgM, and IgG antibodies, as well as C-reactive protein (CRP). The sensor also contains antibodies and proteins that enable it to detect the virus itself. It can track the infection progression by diagnosing the stage of the disease, allowing for the clear identification of individuals who are infectious, vulnerable, or immune according to the developers[6]. The test takes less than 10 minutes.

Potentials

Since the platform detects IgM and IgG antibodies and CRP it can not only diagnose the disease but also help to determine how serious the infection might become and how contagious a person is. The parts of the platform are easily available so that the device can be mass-produced at low costs[7]. Since it can be done at home, it can help to treat patients remotely by monitoring them via telemedicine devices.

Points to consider

It remains to be seen if the platform can live up to those high expectations and how it compares to pre-existing tests in broad use. With the pilot study now completed, it is now planned to test how long the sensor lasts and to test its efficacy in Covid- 19 patients. More research is also needed to determine sensitivity and specificity in real-life conditions. After this the device will need to receive regulatory approval so it might still take some time before it is available[8].

Conclusion

The platform might help scale up testing capacities and determine infection status after it´s effectiveness has been proven and it has completed the approval process required.

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CoronaSys Innovation sheet 19

European Corona- map

Background

Covid-19 case numbers are growing all over Europe[1] and some countries are close to reaching their capacity limits in the health sector[2][3][4]. At the same time, rules and regulations concerning the pandemic are inconsistent in Europe[5]. The European Parliament now approved of a European Corona- traffic light to guide states on decisions concerning travelling restrictions in the EU.

Features

Depending on the infection numbers, regions in Europe shall be marked either green, orange, or red. States should not impose travel restrictions on "green" areas with few corona cases. Travel restrictions might be imposed on orange or red areas. The traffic light- map will be produced by the European health agency ECDC and updated weekly[6]. In addition to the EU countries, it will also include Iceland and Norway. Criteria for the corona map will be the 14-day incidence – i.e. the number of corona infections per 100,000 inhabitants within the past two weeks – the rate of positive tests and the rate of tests carried out[7].

State of information: 10/16/2020

Publication: October 2020

Country: European Union

Focus area: Policy

Developers: EU Parliament

Beneficiaries: General public, policy makers

Potentials

The traffic light approach might help to guide informed decision-making regarding travelling restrictions. It might also contribute to transparent information of the public.

Points to consider

The concept does not provide for common rules for travellers from orange or red-marked regions. Nor did the EU countries agree on Europe-wide standards for quarantine and testing rules. Furthermore, the traffic light is not binding but only offers suggestions that Countries might or might not adopt[8].

Conclusion

The traffic light falls short of the expectations since it does not provide binding rules. In a European Union divided not only regarding Covid-19 this might not be enough to ensure adherence to the recommended measures.

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CoronaSys Innovation sheet 20

FELUDA Paper strip test

Background

India is one of the countries most affected by Covid-19[1] and has suffered more than 115,000 deaths since the pandemic hit[2]. India's large population with many people living in crowded spaces or below the poverty line[3] requires a test that is quick, easy to administer, and inexpensive. Indian researchers claim to have found at least one part of the solution to India's testing challenges with the FELUDA-test.

Features

The FELUDA-test is based on the CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) gene-editing technology to identify the genetic components of SARS- CoV-2. The SARS-CoV-2 sequence in the sample (nasal swab) reacts with the barcoded Cas9- protein in the test. The SARS-CoV-2-Cas9-complex is then placed on a paper strip. Similar to a pregnancy test, two lines are used (one test, one control) to determine whether the sample is infected with SARS-CoV-2[4]. According to the CSIR-Institute of Genomics and Integrative Biology (IGIB) the test has a sensitivity of 96% and a specificity of 98%[5]. The manufacturers say that their test is as reliable as a PCR test[6].

State of information: 10/22/2020

Launch: September 2020

Country: India

Focus area: Testing

Developers:

- Council of Scientific and Industrial Research at the Institute of Genomics and Integrative Biology (CSIR-IGIB)
- Tata Group

Beneficiaries: General public

Potentials

The test has been approved by the Indian drug authority. It costs only about 500 Rupees (about 6,70 US$) and delivers results within 15 minutes[7]. Since it is quick and easy to produce, apply, and interpret, it can potentially scale up testing capacities even in challenging environments. Some researchers believe that the Feluda-test could replace antigen tests since it is cheaper and more accurate[8].

Points to consider

Right now the test still has to be done in laboratories (although no extensive equipment is needed[9]) but the company is working on manufacturing it for self-testing[10]as well.

Conclusion

The paper strip test could be helpful in the fight against Covid-19 by making testing more available and accessible at a reasonable price.

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CoronaSys Innovation sheet 21

Humanitarian Action Mapping Tool

Background

Covid-19 adds to the threats faced by people around the world and to the challenges of humanitarian aid providers[1][2]. With the dynamic nature of the pandemic and other humanitarian crisis, as well as travel restrictions that make it difficult, if not impossible, to deploy humanitarian staff, the need for local response strategies and initiatives is stronger than ever. Much can be learned from the efforts others made to address those challenges.

State of information: 10/23/2020

Launch: October 2020

Country: International

Focus area: Humanitarian Aid

Developers: Overseas Development Institute (ODI)

Beneficiaries:

- Humanitarian Aid Providers
- Local and national policy makers

Features

The Humanitarian Policy Group[3] (HPG) at the Overseas Development Institute[4] (ODI) has developed an interactive online-tool to keep track of local and global humanitarian actions regarding Covid-19. The mapping tool monitors local Covid-19 initiatives on different levels and collects evidence. Users can select a country or a certain level of interventions and read examples of local measures and initiatives as well as review the data collected[5]. Possible impacts, as well as enabling factors and barriers of the respective interventions are provided in a short description. ODI will report on key findings regularly.

Potentials

The tool can help to nudge policy makers to a more localized response and to generate more funding and recognition for local efforts[6] not only with regard to Covid-19 but also concerning other humanitarian challenges. It also offers possibilities for mutual learning and inspiration for possibly transferable measures to include in one's own context.

Points to consider

Since the project is quite new, the data sets are relatively small at the moment but growing day by day.

Conclusion

The Covid-19 tracking tool can be a valuable source of information and can help local authorities and initiatives to identify potentially helpful policies or measures.

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CoronaSys Innovation sheet 22

IKKA Score

Background

Covid-19 diagnostics have been developed and improved with unprecedented speed. In addition to diagnostic tests, several scores have also been developed. But so far most of them focused on hospitalized patients or emergency room- patients and aimed at identifying those likely to develop complications or to guide clinical decision making[1234]. The IKKA- score, developed by researchers at the University of Erlangen-Nuremberg[5] and Ludwigs-Maximilians-University Munich[6], aims at detecting those most at risk in everyday workplace settings.

State of information: 10/29/2020

Launch: October 2020

Country: Germany

Focus area: Diagnostics, Occupational medicine

Developers:

- Ludwigs-Maximilians-University Munich
- University of Erlangen-Nuremberg

Beneficiaries:

- (Occupational) physicians

Features

Most previously developed scores take into account comorbidities and sociodemographic information but also rely on clinical parameters such as O2- saturation and laboratory tests to assess the patient's risk for severe Covid-19. Those data are not accessible in a primary prevention setting[7]. The IKKA- score, however, was specially developed for those settings. It consists of 4 categories: **I**mmunosuppression, **K**nown severity of any pre-existing condition, **K**nown risk factors as defined by the Robert Koch Institute (RKI)[8], and **A**ge. Those categories are evaluated according to a point system. In a second step, the employee can then be allocated to one of four occupational groups which determine the possible fields of activity depending on his*her risk[9].

Potentials

The score might be a practical tool in risk assessment for non-clinical settings and can provide helpful and time-efficient guidance for decision-making. Occupational physicians can thus work together with the company to look for risk-adapted fields of work for particularly vulnerable workers. The score could also contribute to a more unified decision-making basis in German companies. The score might be adopted in other countries or areas as well.

Points to consider

The numerical classification and assignment of the point values are mostly based on the authors' assessment due to the very limited evidence on COVID-19 so far. The score considers purely medical information and does not take into account socio-political or ethical considerations that might emerge[10].

Conclusion

The score might provide guidance in alignment with the guidelines of the Federal Ministry of Labour and Social Affairs[11] and might be applicable to other settings as well.

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CORONASYS INNOVATION SHEET 23

WHO DIGITAL IMPLEMENTATION INVESTMENT GUIDE

Background

Digital health solutions can contribute to the health of people worldwide. They can be a major help especially for people with disabilities, people in rural areas where health facilities are scarce, or in times and areas where health care staff are limited[1]. During Covid-19, the importance and potentials of digital health solutions have been further emphasised[23]. Digital health solutions contributed to almost every area of the fight against the pandemic: diagnostics, contact tracing, information, treatment and social support are just a few examples[45]. But the pandemic also emphasised the need for investments in digital health not just to tackle the current crisis but also to "build back better", make health systems more resilient against future crisis and increase availability and inclusiveness of existing technologies and new developments.

State of information: 10/30/2020

Launch: September 2020

Country: International

Focus area: Policy, Digital Health

Author: WHO

Beneficiaries:

- Governments
- Local authorities
- Public health officials
- population

Features

The WHO provides a comprehensive manual for doing just that in its 180-page *Digital Implementation Investment Guide launched in September 2020*[6]. The guide not only provides key principles for digital innovation enhancement but also a step by step guide that is intended to work governments through the process of identifying, designing, financing and implementing needs-adapted digital health interventions[7]. The DIIG is the result of vast international expertise and is an addition to the "WHO guideline: recommendations on digital interventions for health system strengthening"[8] and other related WHO documents[910].

Potentials

The guidelines can be a useful tool for governments in selecting and implementing digital health tools in one or more health programme areas. Due to its needs-based approach and international alignment, it is applicable to low- and middle-income countries (LMIC) as well as high-income countries. The guide might also be helpful for local (health) officials who want to improve their knowledge regarding digital health and possible implementation strategies.

Points to consider

Obviously, the guideline needs to be applied to the local context and the specific needs of the community.

Conclusion

The guide can contribute to informed decision-making and strategic planning of digital health investments. It might contribute to the availability and accessibility of digital health solutions not only for communicable diseases like the SARS-CoV-2 pandemic but for other (public) health needs as well.

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CoronaSys Innovation sheet 24

RCCE Toolkit

Background

Covid-19 has emphasised once more the importance of adequate risk communication and community engagement not only in ensuring adherence to the recommended measures but also in reassuring and supporting people in coping with this extraordinary situation[12]. This might be particularly relevant in humanitarian settings, where Covid-19 is not the only challenge people face but occurs on top of a humanitarian crisis. This not only increases the susceptibility for the virus but makes it harder to treat and protect people and to reach them with communication tools[345]. This is why the *Global Readiness for Major Disease Outbreak Response Initiative*[6] has created a toolkit that assists officials in planning and adapting their Covid-19 messaging in humanitarian contexts.

State of information: 11/05/2020

Launch: 2020

Country: International

Focus area: Policy, Risk Communication and Community Engagement

Developer: READY- Initiative

Beneficiaries:

- Humanitarian actors
- Local authorities
- Public health officials
- Community workers

Features

The *Risk Communication and Community Engagement Toolkit for Humanitarian Actors* is designed to help humanitarian actors or others involved in risk communication and community engagement (RCCE), to plan and implement RCCE in their Covid-19- response. It provides many resources, grouped and structured by topic and linked to key steps and components of effective RCCE. It includes guidelines and suggestions for hiring RCCE- staff as well as sample messages and materials. In addition, resources for the inclusion of several potentially vulnerable groups in messaging strategies are provided[7].

Potentials

The toolkit can be immensely helpful to get a quick overview of the relevant components and basics of a successful RCCE- effort. Since it provides many resources and samples it can contribute to rapid adaption and integration of RCCE in humanitarian contexts. Furthermore, the Initiative offers short courses on several relevant topics free of charge.

Points to consider

The toolkit is not a one-size-fits-all- solution, of course. Although it is well structured and updated regularly, it is crucial for providers to reflect on the situation at hand and adapt the provided guidelines to the local situation.

Conclusion

The toolkit might be a valuable tool to improve RCCE not only in humanitarian settings.

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CoronaSys Innovation sheet 25

Cough-Analysing App

Background

Covid-19 diagnostics have been advanced in unprecedented speed over the last months. Most of them however focused on laboratory testing and virus detection[1]. Researchers of the Massachusetts Institute of Technology[2] have developed an AI model that could diagnose Covid-19 by analysing cough and voice samples.

Features

The researchers built a large database of tens of thousands of cough samples and trained an Artificial Intelligence (AI) algorithm to detect the characteristic features of Covid-19- coughs that stem from the temporary neuromuscular impairment caused by the disease. The model could be used in form of an app: The user can then send a recorded forced- cough sample to the system and will get a result within minutes[3].

The model is said to achieve a sensitivity of 100% and a specificity of 83.2% in asymptomatic patients[4]. Similar tools have been used before to identify patients suffering from pneumonia, asthma and even Alzheimer´s[56].

State of information: 11/08/2020

Publication: September 30, 2020

Country: USA

Focus area: AI, Diagnostics

Developer: Massachusetts Institute of Technology (MIT)

Beneficiaries: General population

Potentials

The technology could provide a free and non- invasive diagnostic tool which could be instantly distributed to screen asymptomatic people[7]. This might scale up tasting capacities and mitigate barriers to get tested.

Points to consider

The app is not yet approved by the Federal Drug Administration (FDA). Researchers at Augsburg in Germany are developing a similar programme at the moment that focuses on voice samples[8].

Conclusion

The app might add to the landscape of diagnostic devices when its effectiveness has been further proven and it has completed the approval process.

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CoronaSys Innovation sheet 26

Follow- Up on LY-CoV555 Antibody treatment

Background

This innovation sheet is a follow up on Innovationsheet No. 11 of this series from September 18th, 2020. Neutralizing antibodies are still one of the research foci in the search for a possible treatment for COVID-19[1]. Several companies are researching different approaches to antibody treatment for the disease[2].Eli Lilly and Company published data from an interim analysis of the BLAZE-1 clinical trial[3] on September 16. The data showed reduced hospitalization rates for patients treated with LY-CoV555, a SARS-CoV-2 neutralizing antibody. After further randomized- controlled trials the Federal Drug Administration (FDA) granted an Emergency Authorization for the antibody treatment now named Bamlanivimab on November 9th, 2020[4].

State of information:

- 18/09/2020
- Updated 11/13/2020

Launch: September 2020

Country: USA, Canada

Focus area: Treatment

Developers:

- Eli Lilly and Company in collaboration with
- AbCellera Biologics Inc.
- Shanghai Junshi Bioscience Co., Ltd.

Beneficiaries: patients with mild to moderate symptoms

Features

The antibody LY-CoV555 is one of about 500 antibodies that the immune system of one of Americas first Covid- patients had formed against SARS-CoV-2 after infection. The researchers were able to detect the B cells that produce the antibody, isolate the gene, and produce them in larger quantities using recombinant cells. The treatment consists of a single intravenous infusion of the antibodies[5]. The research was continued in the BLAZE- 1[6] and BLAZE- 2[7] trial as well as the ACTIV- 2[8] and ACTIV- 3[9] trials over the last months.

Potentials

The initial trials showed significant advantage over placebo in reducing viral load after 11 days after the mean dose of 2,800 mg. Patients with mild to moderate Covid-19 had to be hospitalized or treated by a physician at significantly lower rates than patients in the placebo group. This corresponded to an absolute risk reduction of 4.3 % and a relative risk reduction of 72%. Deaths, need for mechanical ventilation or serious side effects were not reported in the initial studies[10][11]. In the ACTIV- trials the efficacy was tested in different subsets of patients and larger cohorts. With the FDA´s decision Bamlanivimab is now “authorized for the treatment of mild to moderate COVID-19 in adults and paediatric patients 12 years and older with a positive COVID-19 test, who are at high risk for progressing to severe COVID-19 and/or hospitalization”[12].

Points to consider

The drug´s efficacy in serious cases could not be proven which is why the company first paused[13] and then terminated the ACTIV-3 trial with critically ill Covid-patients in October[1415]. It showed that the antibodies no longer have any significant effect once the disease is advanced and characterized by an excessive immune response. This is why the drug is not authorized for patients hospitalized with Covid or requiring oxygen therapy[16]. In order to be as effective as possible the drug should be administered as early as possible after the diagnosis. Right now, the drug is in short supply so that questions have been raised, as to who should be treated with the first doses available[17]. Antibodies are usually high-priced drugs[18]. The U.S. government has already purchased 300.000 doses for about 375. Mio US Dollars[19].

Conclusion

For individual patients treated with Bamlanivimab, the drug could be a factor to save their lives and/ or regain their health. But although the drug proved to be effective in mild to moderate Covid-cases in an outpatient setting, it is in far too short supply to actually curb the virus even if the company can scale up its production and distribution capacities as planned.

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CoronaSys Innovation sheet 27

Follow-Up on BNT162b2-vaccine

Background

This innovation sheet is a follow-up on Innovation sheet No. 17 of this series from October 11th, 2020[1]. Since the start of the pandemic, researchers have been working hard to develop a vaccine against SARS-CoV-2. Worldwide more than 160 potential vaccines are being developed, 10 of them are in the phase 3 trial stage[2]. One of the promising candidates is the BNT162b2-vaccine developed by BioNTech[3] in cooperation with Pfizer[4]. This week the developers announced that an interim analysis showed very promising results[5].

Features

The BioNTech-vaccine is a mRNA-vaccine and belongs to a new group of gene-based vaccines. It stimulates the body to produce antibodies and T-cells by inserting an m-RNA-part responsible for producing the virus´ spike protein[6]. The vaccine is likely to activate other immune system defense mechanisms as well [7]. According to the manufacturer, serious side effects have not yet been registered and vaccination protection is achieved one week after the second vaccination dose and 28 days after the first injection[8].

State of information:

- 10/11/2020
- Updated 11/13/2020

Public announcement: November 2020

Country: Germany, USA

Focus area: Vaccination

Developers:

- BioNTech (Germany) in Cooperation with
- Pfizer (USA, Germany)

Beneficiaries: General public

Potentials

The vaccine is currently being tested in a multicentered phase II/III clinical trial[910] with more than 44.000 patients where efficacy is further tested and the appropriate dosage is determined[11]. BionNTech and Pfizer reported an efficacy of 90% for their vaccine. This would suggest a high protective effect, similar to vaccines for measles or rubella[12]. One advantage of mRNA vaccines is that they can be produced more rapidly and cheaper than traditional vaccines[13]. In terms of tolerability, a positive factor could be that BNT162b2 works without an adjuvant[14].

Points to consider

As of now, the data are not published yet and a comprehensive subgroup-analysis needs to determine whether the vaccine is effective in different subsets of the population (e.g. the elderly and high-risk groups) as well[15]. One major problem regarding vaccine distribution is that the BNT162b2- vaccine needs to be stored at minus 70 degrees so that areas without proper cooling facilities are not eligible for distribution which could be a major disadvantage for poorer countries[16]. (Some of the other potential vaccines, however, can be cooled by a regular fridge and do not need such low temperatures). Furthermore, some companies have already contracted with large and rich states, so that it might be increasingly difficult for Low- and Middle-Income Countries (LMIC) to access the vaccine timely[17].

Conclusion

The vaccine surely raised hope for a nearing end to the pandemic and is a positive sign for the development of other potential vaccines as well. Still, the trial has to be completed, formal approval has to be granted by the various authorities and the vaccine has to be distributed and administered. This process will take well into the next year and it remains to be seen if the COVAX initiative[18] can ensure fair and transparent availability and accessibility to the vaccine for all people in need.

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CoronaSys Innovation sheet 28

Lucira™ COVID-19 All-In-One Test Kit

Background

While testing remains a major challenge around the globe[1], the U.S. Food and Drug Administration (FDA) has granted Emergency Use Authorization[2] to the first molecular at-home test developed by Lucira Health[3].

Features

The test is based on RT-LAMP-Technology (reverse transcription loop-mediated isothermal amplification). As in the polymerase chain reaction (PCR) used in conventional testing, individual genes are reproduced until they are detectable with a chemical reaction. However, unlike PCR, the reaction can be carried out at a constant temperature. This eliminates the need for a laboratory facility to perform the test. The subsequent chemical reaction is also quite simple. It consists of a change in the pH.

State of information: 11/20/2020

Emergency Use Authorization: November 2020

Country: USA

Focus area: Testing

Developers: Lucira Health

Beneficiaries: General Population

The test´s results were compared with an FDA- approved PCR smear assay, the current gold standard, in a "Community Testing" Study. According to the manufacturer, the test achieved a positive percent agreement, i.e. sensitivity, of 94% and a negative percent agreement, i.e. specificity, of 98%. If samples with low viral load (at or below 37.5 Ct) were excluded the test even achieved a 100% positive percent agreement[45].

With the supplied swab, the user takes a sample from the nose, opens the test tube of the detection device, tunes the swab into the reagent and stirs. After the test tube is closed again a slight pressure on the test tube starts the detection reaction. The user waits about 30 minutes for a lamp to signal the end of the reaction. Two more lights indicate whether the test was positive or negative[6].

Potentials

The Lucira™COVID-19 All-In-One Test Kit is the first prescription molecular test for COVID-19. The testing device could help to upscale testing capacities, provide opportunities for at-home testing, and help to ease the pressure on laboratories and primary care physicians.

Points to consider

The product is a single-use device and with a price of $50 quite expensive[7]. But the FDA Emergency Use Authorization might help to accelerate the development of similar but less costly testing devices. Currently, the test is available in the United States only[8] and requires a prescription from a health care provider[9].

Conclusion

The test might be a nice addition in an effort to upgrade testing capacities in the United States. Hopefully, there will soon be similar products at a lower price range in order to make the technology accessible and useful for larger scales of the population.

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CORONASYS INNOVATION SHEET 29

COVID-19 HUMANITARIAN

Background

While COVID-19 is certainly challenging for every country affected, those who are suffering from humanitarian crisis are particularly vulnerable to its impact[1234]. This is why researchers from the Johns Hopkins Center for Humanitarian Health[5], the London School of Hygiene & Tropical Medicine[6] and the Geneva Centre of Humanitarian Studies[7] developed an online platform where humanitarians can share their experiences.

Features

Humanitarians can send their programs and field experiences to the online platform where they are reviewed by the three universities together with various guidance documents. After that, the examples are uploaded to the website using an operational framework[8]. At the moment, more than 130 guidance documents and 65 field experiences are accessible on the website[9].

State of information: 11/23/2020

Publication: November 2020

Country: International

Focus area: Humanitarian Aid

Developers:

- Johns Hopkins Center for Humanitarian Health
- London School of Hygiene & Tropical Medicine
- Geneva Centre of Humanitarian Studies

Beneficiaries:

- Humanitarian Assistance
- Local, regional and global policy makers

Potentials

The openly accessible platform allows humanitarians to share their experiences with colleagues and initiate a dialogue on local, regional and global levels. The platform also provides an academic perspective on local solutions and can generate a process of mutual learning to benefit the recipients of all the projects. The platform might even serve as an example for expert exchange in future global health emergencies[10].

Points to consider

The researchers initially hoped for an advanced feedback loop, meaning that field experiences could serve as a basis for improved COVID-19 humanitarian guidance iterations. As of now, this did not occur sufficiently[11], probably due to the still very acute development of the pandemic.

Conclusion

The online platform can be a very useful tool for humanitarians and might provide valuable insights into COVID-19 response for all stakeholders involved in tackling the pandemic.

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CORONASYS INNOVATION SHEET 30

AI- EPIDEMIOLOGY- MODEL

Background

Covid- 19 cases are still surging across the globe while governments are trying to figure out which measures are most effective in curbing the spread of the disease[1]. Researchers of the Massachusetts Institute of Technology[2] (MIT) have developed a tool that combines machine learning and epidemiology and could help in assessing the effectiveness of nationwide lockdowns.

Features

The researchers developed a novel model that analyses and compares the role of quarantine control policies globally and across continents. While other models rely heavily on data derived from the past SARS and MERS outbreaks, this one uses machine-learning optimized algorithms on publicly available COVID-19 data based on an augmented SIR-model[3]. The SIR-model is a standard epidemiological tool for outbreak analysis[4]. Among other adaptions, the model was enhanced by training a neural network to include the number of infected people under quarantine, who are therefore no longer spreading the infection to others[5]. The researchers found that there was "generally strong correlation between strengthening of the quarantine controls as learnt by the model and actions taken by the regions' respective governments"[6].

State of information: 11/20/2020

Publication: November 17, 2020

Country: USA/ International

Focus area: Evaluation

Developers: Massachusetts Institute of Technology

- Raj Dandekar
- Chris Rackauckas
- George Barbastathis

Beneficiaries:

- Researchers
- Governmental policy makers
- Local authorities

Potentials

The model is globally applicable and can help to assess the impact of certain policies aimed at slowing down the spread of SARS- CoV-2. The data are accessible online via a public platform that shows the results for the 70 most-affected countries[7]. According to the researchers, the model could also be extended to include even more and more complex data (e.g. hospitalization rates, distinctions between symptomatic and asymptomatic carriers, …) so that it could be adapted to any province, state, or country globally. This could be a useful tool for policymakers[8].

Points to consider

The model does not (yet) have predictive elements. To do so, it would need real-time data on social distancing and other parameters that are currently under development. [9]

Conclusion

The model might be a helpful addition to other tools in assessing the impact of certain measures to curb the spread of SARS-CoV-2.

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ADRU
Academy of the Disaster Research Unit

CoronaSys

CoronaSys Innovation sheet 31

Solar- powered Steam Generator

Background

Covid- 19 highlighted the challenges Low- and Middle-Income Countries (LMIC) face in ensuring the provision of health care to their citizens. Not only limited financial resources but also shortages in certain materials and frequent power cuts can limit their ability to do so. This applies not only to direct patient care (e.g. ventilators, medical devices) but also to necessary services such as sterilisation of medical products and invasive medical equipment. Additionally, LMIC suffer from a particularly high burden of healthcare-associated infections, partly due to the use of materials not properly sterilized[1,2]. Researchers from the Massachusetts Institute of Technology[3] have developed a Steam Generator that can keep up with challenging environments.

Features

The researchers developed a solar-powered and portable device. The steam generator can power an autoclave to sterilize medical equipment. The built-in solar component heats water to produce steam. The steam is then transferred to a pressure chamber. To avoid heat loss to the environment a so-called aerogel (a foam-like but solid material) made from silicia is used as an insulator[4].

Potentials

The device was tested under realistic weather conditions and can be used on cloudy or hazy days as well. It is built mostly from off-the-shelf components and the prototype did only cost $38. The same principle could be used to power other devices as well[5].

State of information: 11/27/2020

Publication: November 18, 2020

Country: USA/ International

Focus area: Prevention

Developers: Massachusetts Institute of Technology

- Zhao et al.

Beneficiaries:

- Clinics and physicians in remote areas

Points to consider

Even if it can be manufactured very quickly from commonly available materials, the Steam Generator is just a prototype so far[6]. The generated 240 watts are not sufficient to power the large autoclaves used in big operation theatres, so one would have to combine several of the Steam Generators to power those[7].

Conclusion

The Steam Generator (or similar products) could help to relieve healthcare-related infection burden in challenging environments. Particularly in situations like the current pandemic, the device can add to a cost-effective, accessible, and applicable solution for remote settings.

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CORONASYS INNOVATION SHEET 32

GRADIAN CCV

Background

Many Covid- 19 patients need mechanical ventilation[12]. This can be a major challenge especially in rural areas where ICU beds and oxygen- supply are scarce and power cuts frequent. Gradian Health Systems[3] has developed a ventilator designed especially for those environments.

Features

The Gradian CCV is a portable ventilator designed for challenging environments. It can be operated for 21 hours on battery and has a built-in oxygen compressor that allows to mix in room air or use an external oxygen source. Some commonly used ventilation modes are pre-programmed allowing clinicians less experienced in ventilation therapy to optimize patient ventilation. The product comprises of generic components, that are locally available at low costs. The ventilator can be used for adults and children > 5 Kg[456].

State of information: 12/02/2020

Broader Implementation: 2020

Countries: USA, Rwanda, Nigeria, Nepal, Zambia, Uganda, Tanzania, Sierra Leone and Kenya

Focus area: Treatment

Developers: Gradian Health Systems

Beneficiaries: Clinics and physicians in remote areas

Potentials

Gradian Health Systems is a Nonprofit Medical Technology company that targets low- resource settings. The company also offers comprehensive customer support via Email, Whatsapp, Phone and in-person as well as locally contextualized training for medical teams[7]. Gradian Health Systems also developed the Universal Anaesthesia Machine, “the first internationally-certified anaesthesia machine that can generate its own medical oxygen and work without electricity”[8].

Points to consider

As of now, the company is not yet present in the near and middle east and Europe[9], so its additional services like local customers support and training might not be available in these areas.

Conclusion

The CCV ventilator might be an affordable and valuable asset in low- resource settings and challenging environments.

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CORONASYS INNOVATION SHEET 33

RAPID HOSPITAL READINESS CHECKLIST

Background

Hospitals all around the world are still struggling to keep up with the high influx of COVID-19 patients. With the cumulative number of cases worldwide now topping 66 Million and more than 1.5 million people dead[1] the burden COVID-19 poses for healthcare systems worldwide is evident. Some argue that Europe neglected its chance to enhance health system preparation and response in summer when case numbers were relatively low[2]. Even with promising vaccines on the horizon, COVID-19 will continue to challenge health systems and societies for the foreseeable future[3]. Preparedness and response remain crucial to mitigate the devastating consequences of the virus and its effects on society.

State of information: 12/06/2020

Publication: 11/25/2020

Countries: International

Focus area: Hospital Preparedness and Response

Developers: WHO

Beneficiaries:

- Hospital leaders, managers, and administrators
- managers and administrators of long-term care facilities
- Ministries of Health

Features

WHO has developed and updated the "Rapid hospital readiness checklist"[4]. It can be used to inform decision- making and (contingency) planning before, after and amid the pandemic. The checklist can help to determine current capacities and identify relevant gaps along 12 key components: Leadership and Incident management, Coordination and Communication, Surveillance and information management, Risk communication and community engagement, Administration, finance and business continuity, Human resources, Surge capacity, Continuity of essential support services, Patient management, Occupational health, mental health and psychosocial support, Rapid identification and diagnosis, Infection prevention and control[5]. The Checklist comes with an Excel file to quantify and analyse a hospital´s readiness[6].

Potentials

The checklist can help to determine whether facilities have the necessary arrangements in place and the functioning capacity to respond to COVID-19 surges. It can identify potentials and priority actions to enhance the facilities response. The tool can also help to monitor the development of hospital emergency readiness over time[7].

Points to consider

All recommendations have to be checked for their feasibility for the individual context. Due to the fact, that the guidance derives its recommendations through real-time analysis it has to be regularly updated to include new information on best practises in the field.

Conclusion

The WHO Rapid hospital readiness checklist can be a useful tool for local health officials in assessing and enhancing hospital capacity for COVID-19.

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CoronaSys Innovation sheet 34

School Reopening Checklist

Background

Since the beginning of the pandemic, school closures have occurred again and again in many parts of the world, some of which have been of significant duration[1]. As a result, children's educational opportunities have been reduced worldwide and children from vulnerable backgrounds were affected particularly hard[23]. Schools were faced with the challenge of making classroom teaching safe and offering effective remote learning services that reach as many children as possible[4].

Features

WHO has developed the "Checklist to support schools re-opening and preparation for COVID-19 resurgences or similar public health crises". The document distinguishes several phases and three levels (national, subnational and individual school level) of coordination for school responses. In addition, the checklist identifies 38 essential actions for the different levels and phases of the response and offers many links to relevant guidance documents[5].

State of information: 12/12/2020

Publication: 12/11/2020

Countries: International

Focus area: Education

Developers: WHO

Beneficiaries:

- Policy makers in Health and Education
- National and regional school management boards
- Individual schools

Potentials

The checklist can help to determine whether facilities have the necessary arrangements in place and to augment the schools capacity to respond to the needs in different phases of reopening and responding to case surges. Furthermore, the document helps to divide responsibilities among the different stakeholders involved and provides concrete measures to implement[6].

Points to consider

All recommendations have to be checked for their feasibility for the individual context. Due to the fact, that the guidance derives its recommendations through real-time analysis it has to be regularly updated to include new information on epidemiological considerations and best practises in the field. For example, the checklist was published just before the data of a new study examining the spread of Covid-19 in Austrian schoolchildren which stated that children play a more significant role in the spread of COVID-19 than initially assumed [7].

Conclusion

The WHO checklist can be a useful tool for local health and education officials in assessing and enhancing the capabilities of schools in different phases of the pandemic.

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CORONASYS INNOVATION SHEET 35

CURIAL AI SCREENING TEST

Background

Although the good news of an effective vaccine on the horizon largely dominated the news over the last weeks, testing remains a major issue in the fight against SARS-CoV-2 as well. With the new and large surges currently seen in many countries, laboratory capacities remain strained and PCR testing requires some time even without overburdened testing sites and labs. Researchers at the University of Oxford[1] may have found a way to distinguish non- COVID-19 patients from those infected with SARS-CoV-2 with an Artificial Intelligence testing model.

State of information: 12/12/2020

Publication: 12/11/2020

Country: United Kingdom

Focus area: Testing

Developers: University of Oxford

Beneficiaries:

- Clinicians in high- and- middle-Income countries

Features

The CURIAL AI screening test was derived in a study involving data of more than 150.000 patients – "the largest dataset of any laboratory artificial intelligence study on COVID-19 to date"[2]. It uses routine hospital data like blood tests, blood gas testing, vital signs, and results of PCR testing for respiratory viruses. The AI model was further trained with different levels of prevalence of Covid-19 in the population to simulate real-life conditions during a pandemic. The AI model derived from the study has a sensitivity of 77.4% and a specificity of 95.7% which means the test can efficiently identify Non-Covid patients. Test results are available after one hour.[3]

Potentials

The AI- model can help to provide rapid triage for COVID-19 based on routine hospital data. It fits into routine procedures and clinical pathways and can therefore speed up the patient flow. It can be conducted with existing equipment in high- and middle-income countries. This means the test could be implemented quite quickly and inexpensively. The model can also be rapidly adapted to various scenarios[4] and might be a helpful pretest for PCR testing where availability is limited[5].

Points to consider

A possible limitation of the study is a quite limited ethnic diversity of the patients included[6], although ethnic disparities might be influential in the clinical course of patients[789]. Also, patients under the age of 18 were excluded, so that the AI model might not perform as well in different subsets of the population and further research is needed in this area[10] . The test is primarily designed for infrastructures available in high and middle-income countries. Its applicability for other contexts has to be further assessed.

Conclusion

The AI test might be a helpful to rule- out non-COVID patients in facilities that already have the necessary equipment.

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CORONASYS INNOVATION SHEET 36

PRIORITIZATION ROADMAP

Background

Over the past few weeks, much attention has been paid to COVID-19 vaccines and the start of vaccination campaigns in some countries[1234]. Since the vaccine will initially only be available in limited quantities, it has also become clear that countries are taking different approaches in distributing the vaccine and deciding who gets the first doses[5]. A WHO document assists in the development of the prioritisation policy.

Features

Based on the WHO "SAGE Values Framework for the Allocation and Prioritization of COVID-19 Vaccination"[6] the "Roadmap for prioritizing uses of Covid-19 vaccines" (Prioritization Roadmap) was developed to assist countries in the development of public health strategies regarding vaccination planning and identifying and targeting priority groups for different levels of vaccine availability and epidemiological requirements.

The Prioritization Roadmap offers three examples for rationales for prioritisation a) Health workers at high to very high risk of becoming infected and transmitting SARS-CoV-2 in the community b) Sociodemographic groups at significantly higher risk of severe disease or death, e.g. elderly people c) Social/employment groups at elevated risk of acquiring and transmitting infection because they are unable to effectively physically distance[7].

State of information: 21/12/2020

Publication: 13/11/2020

Country: International

Focus area: Policy

Developer: WHO

Beneficiaries:

- Policy makers
- Health officials

Potentials

The document also offers epidemiological setting and vaccine supply scenarios as well as recommendations for prioritization in the context of limited supply[8].

Points to consider

As of now, the roadmap does not include special recommendations for specific vaccines. The roadmap will be updated regularly and followed-up by recommendations for specific vaccines, as soon as there is enough scientific evidence to derive such recommendations. Due to the dynamic nature of the pandemic, it is likely that refinements of the Roadmap will be needed.[9]

Conclusion

The Roadmap can assist policymakers and health officials in identifying and targeting priority groups for COVID-19 vaccination while taking into account epidemiological developments and availability issues.

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CoronaSys

CoronaSys Innovation sheet 37

Ellume Test

Background

Although vaccination campaigns have started in many countries testing will remain an issue for the foreseeable future. The US Food and Drug Administration (FDA) has now authorized the first over the counter COVID-19 test[12] produced by the Australian manufacturer Ellume[3].

Features

The test uses a patented detection method that combines several known procedures for antigen detection. Contrary to other at-home tests, the swabs do not have to be sent to a laboratory per mail but can be analysed on-site. The test can be used for adults and children older than 24 months with and without symptoms of COVID-19. It costs about 30 US$[45]. The manufacturers reported a specificity of 97% and a sensitivity of 95% compared to an emergency use-authorized RT-PCR laboratory test. The Ellume test delivers results within 15 minutes[6].

State of information: 22/12/2020

FDA Authorization: 12/15/2020

Country: Australia

Focus area: Detection and Diagnostics

Developers: Ellume

Beneficiaries: General population

Potentials

The test could help to scale up testing capacities. It saves the user a trip to a clinic or testing site and therefore helps to minimize contacts. One major advantage is that the test requires the user to download an app that transmits the result to a cloud where local health officials can access the data which means that the test result can be included in the official epidemiological statistics.[7]

Points to consider

Like other antigen tests, there is a probability of false-negative results, since these tests perform best in cases with high viral load[89]. Some experts also argue that a negative test result might lead to a false sense of security and more reckless behaviour in people who do not realize that the test can be negative the one day and they can acquire the virus the next day. Another issue is that the manufacturer will need some time to produce a sufficient quantity of the assays although production capacities have already been scaled up. Additionally, the test has to be authorized by each country separately to give people access to this form of testing[10].

Conclusion

The test might be a valuable addition to existing tests as soon as it is available and accessible for the respective population.

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CoronaSys Innovation Sheet 38

TV Schooling

Background

Homeschooling has been a challenge for parents and caretakers all over the world since the SARS-CoV-2 pandemic interrupted education systems in an unprecedented manner[12]. Against the background of high infection rates and the virus mutant recently discovered, the United Kingdom imposed a new strict lock-down on its citizens[3]. After opening the schools again in summer and autumn they are now forced to close again posing renewed challenges to education[45].

Features

Because not all pupils in the United Kingdom have access to the internet and online learning tools, BBC and some other television networks will broadcast educational programs for several hours per day during the lockdown. Since Monday, January 4, 2021, three hours of primary school lessons will be broadcasted every day, plus at least two hours for secondary school pupils[67]. Mexico had adopted a similar approach early in the pandemic to support students without internet access. The Mexican government cooperated with several networks to produce a comprehensive set of lessons for all grade levels and broadcast those lessons via TV and radio[8].

State of information: 01/07/2021

Launch: 01/04/2021

Country: United Kingdom

Focus area: Education

Developers: BBC

Beneficiaries: Pupils in the UK

Potentials

TV-based education could help to reach students who do not have sufficient access to online learning tools.

Points to consider

Since television does not really allow for interactive and participatory learning, online tools will remain an important part of remote learning. This is why some experts are demanding a cut of internet fees and the distribution of laptops and other devices to help low-income families in the UK to enable their children to take part in remote learning[9]. Obviously, none of the remote learning techniques can fully replace the face-to-face teaching in schools were pupils can also socially engage with their classmates.

Conclusion

The TV education might be an addition to existing remote learning techniques and devices but it certainly cannot fully substitute online tools or even face-to-face teaching in schools.

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CORONASYS INNOVATION SHEET 39

OCTEA TEST

Background

PCR tests are still the gold standard for detecting a SarsCoV-2 infection. However, especially against the background of the testing strategy recommended by the EU Commission[1], novel and reliable rapid tests are increasingly coming into focus. Rapid antigen tests show within a few minutes whether infection with the coronavirus is present, but they are generally considered somewhat less reliable than PCR tests[2]. The German Startup GNA Biolsolutions[3] has now developed a promising new technology.

Features

Unlike the antigen rapid tests commonly used so far, the new rapid test is a PCR test that directly detects the genetic material of the COVID-19 pathogen but unlike the PCR tests used so far, it can deliver results within an hour. The testing device is portable and can process eight samples simultaneously.[4] The technology, called Pulse Controlled Amplification (PCA®), combines sample preparation and nucleic acid amplification processes, reducing time and material requirements for the test[5].

State of information: 01/07/2021

Authorization in Germany: 12/29/2020

Country: Germany

Focus area: Detection and Diagnostics

Developers: GNA Biosolutions

Beneficiaries: General population

Potentials

The test could help to scale up testing capacities. GNA Biosolutions plans to apply for EU-wide approval in March. Due to its speed and its relatively low price (around 20 Euros), it might be particularly valuable for testing at hospitals, nursing homes and airports, for example.[6]

Points to consider

The German state of Bavaria has already secured the purchasing privilege for 1000 testing devices and one million tests[7]. It remains to be seen how fast the manufacturer can scale up their production capacities to serve other countries as well.

Conclusion

The test could help to increase testing capacities after approval in the respective country. Especially in busy places like airports, care facilities and hospitals, it could contribute to a much anticipated "return to normality".

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CORONASYS INNOVATION SHEET 40

PROGNOSTIC URINE TEST

Background

While covid cases continue to rise or are stable at high levels in many regions of the world[1], hospital capacity is strained in a lot of countries[2345]. This makes it all the more important to identify from the many infected people those who are most likely to experience a severe course or even require treatment in the intensive care unit. A urine test developed by Mosaiques[6] and DiaPat GmbH[7] aims to help clinicians identify patients at risk.

Features

The DiaPat-CoV-50 test uses Proteomanalyse- technique to identify patients with a higher risk for complications. Per urine sample, a special device analyses up to 14,000 proteins and detects changes[8]. The test has already been in use for early detection of chronic kidney disease, heart failure and diabetes mellitus[9]. It was adapted to the requirements of Covid-testing and has received a special use authorization by the German Federal Institute for Drugs and Medical Devices[10] in December 2020 after the results of a study[11] conducted in summer 2020 were confirmed.

State of information: 01/12/2021

Authorization in Germany: December 2020

Country: Germany

Focus area: Detection and Diagnostics

Developers:

- DiaPat GmbH
- Mosaiques
- St. Georg Hospital Leipzig

Beneficiaries:

- Covid-19 patients
- Clinicians

Potentials

The test has a specificity and a sensitivity of 83%. Compared to a purely clinical prognosis of the expected course of the disease, the test provides an increase in predictive accuracy of 20 %, according to the study leader[12]. Early identification would enable adequate early treatment.

Points to consider

The test is only possible in seven German cities[13] and with 850 Euros per sample, it is quite expensive. The German Ministry of Health is currently negotiating with the manufacturer about future pricing[14].

Conclusion

The test could help to identify patients who might suffer a severe course of the disease. But the local possibilities for implementation would have to be expanded so that there is enough capacity to test the patients in need. Especially with regard to implementation in countries with fewer resources, the price of the test still seems quite high.

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CORONASYS INNOVATION SHEET 41

ICU TRAINING VIDEO

Background

Although significant progress has been made in the treatment of Covid-19 over the last year, it continues to pose significant challenges for ICU teams. A team of researchers from the University of Tübingen[1] has now developed a training video that gives medical students and the interested public a comprehensive insight into the care of a Covid-19 patient.

Features

The video[2] was developed by doctors and medical students. Together with intensive care nurses, the developers realistically recreated the treatment of a Covid- 19 patient in a replica of a fully equipped intensive care unit.

The video accompanies a (fictive) young Covid patient from hospital admission, through intubation to artificial oxygenation of the blood with the help of ECMO (Extracorporeal Membrane Oxygenation[3]) therapy and the subsequent recovery process. In between, insertions provide detailed information on the background of the individual treatment steps (like for example proning[4], ventilation modes[5] [6]and ECMO-Therapy[7][8]) and medical devices used[9].

State of information: 01/12/2021

Launch : November 2020

Country: Germany

Focus area: Treatment

Developers: Uniersity of Tübingen

Beneficiaries:

- General population
- Medical students
- ICU staff

Potentials

The video is to be used in medical teaching. It can also give medical laypeople an insight into how the care of a Covid patient actually unfolds and therefore help to generate awareness[10]. The video could also be helpful for staff assigned to ICU from other parts of the hospital to treat covid patients or for relatively inexperienced ICU staff.

Points to consider

As of now, the video is available in German and English only. It is also tailored to the context of very high-capacity intensive care medicine in highly developed and resource-rich countries.

Conclusion

Even apart from the particularly advanced treatment equipment and methods, the video can provide valuable insights into the actual treatment of Covid-19 patients. This can generate awareness of the severity of the disease and the care required, especially among medical laypeople.

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CORONASYS INNOVATION SHEET 42

SAFEZONE

Background

Over the course of the pandemic, several approaches have been discussed with regard to infection prevention. Social distancing is one of the measures that are provenly effective in containing the spread of SARS-CoV-2[12]. But particularly in the work environment where ones mind is occupied with other things, people tend to forget to keep the distance required to effectively prevent transmission. The SafeZone is one example of proximity detectors invented or augmented in the last months to meet the requirements of the pandemic.

State of information: 01/13/2021

Launch : 2020

Country: Germany

Focus area: Prevention

Developers: Kinexon

Beneficiaries: Employees at offices or factories

Features

The German start-up Kinexon[3] has developed a sensor system called SafeZone. The sensors are smart and can be integrated into wristbands. The technology tracks distance using ultra-broadband signals and gives an acoustic and visual alarm when the set distance of 1.5m is not maintained[4]

Potentials

The technology is helpful to encourage employees to maintain the appropriate distance and currently used by more than 200 companies worldwide[5]. The system could also have a behavioural aspect: through the acoustic warning tones, the sensors "punish" violations of social distancing, which could change people's behaviour in the long run.

Points to consider

As often with movement tracking devices, there are some concerns regarding data safety and privacy issues[6]. Not only do the sensors track who engages with whom but they theoretically enable the managements to constantly keep tabs on their employees' movements[7].

Conclusion

The sensors might be helpful in ensuring adherence to social distancing guidelines, but companies should make sure to consider the privacy rights of their employees with regard to the data used.

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CoronaSys Innovation sheet 43

Project Hazel

Background

Mask wearing (if done right) belongs to the prevention approaches that are scientifically proven to be effective[12] . But some people claim that the masks make them uncomfortable and that they have difficulty speaking and breathing. The computer and gaming hardware manufacturer Razer[3] has now developed a mask that aims at solving these issues.

Features

The mask developed under the catchy name Project Hazel[4] uses an N95 medical-grade respirator as well as detachable and re-chargeable ventilators and air flow regulators. The ventilators can be disinfected and recharged by using a UV-sanitization device that comes with the mask. Inbuilt microphones amplify muffled speech. The mask is transparent so that the face is visible and lip-reading possible. Also, it is made of recyclable plastics[5].

State of information: 01/13/2021

Launch: not yet determined

Country: USA, Singapore

Focus area: Prevention

Developers: Razer

Beneficiaries: General population

Potentials

The reusable mask might be an addition to existing community masks, especially for those who appreciate an added aesthetic value. The company also has distributed free face masks earlier in the pandemic and converted one of its production sites for mask production[6].

Points to consider

At the moment, the mask is still in development and not for sale. Moreover, it is to be expected that such a technologically and aesthetically sophisticated design will not come all too cheap.

Conclusion

The masks might be a nice addition for fashionable mask users who also appreciate environmental friend-liness and sustainability. But they are certainly not a game changer in the fight against the pandemic.

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CORONASYS INNOVATION SHEET 44

VIRAL ESCAPE MODELLING

Background

Newly emerged mutations of the coronavirus are causing great concern. Not only do they seem to be more infectious[1][2] and therefore put even more strain on already heavily burdened health systems. Some researchers are also concerned that the new variants (and other mutations of SARS-CoV-2 that may emerge in the future) could temporarily or permanently compromise the effectiveness of some vaccines.

Features

Some viruses, like for example SARS-CoV-2 but also influenza and HIV, can mutate quite quickly, which makes it very difficult to produce effective vaccines against them. The mutation allows them to bypass the antibodies produced by a particular vaccine, through a process known as "viral escape". Researchers from the Massachusetts Institute of Technology[3] have developed an AI (Artificial Intelligence) model that aims at predicting which parts of the viral surface are likely to mutate and which are not[4]. The model is based on models that were originally designed to analyse language[5]. It "identified escape mutations as those that preserve viral infectivity but cause a virus to look different to the immune system, akin to word changes that preserve a sentence's grammaticality but change its meaning" (Hie et al., 2021)[6].

State of information: 01/15/2021

Publication: 01/14/2021

Country: USA

Focus areas: AI, Research, Prediction

Developers: Massachusetts Institute of Technology (MIT)

Beneficiaries:

- Scientists
- Vaccine developers

Potentials

The identification of viral surface structures that are not likely to mutate could help vaccine developers to identify possible targets for new vaccines. The researchers aim to apply their model not only on SARS-CoV-2, HIV, and Influenza but also on the production of the so-called cancer vaccines[7]. The technique also lays the foundation for even more complex modelling[8].

Points to consider

The researchers have also applied their model to the new variants of SARS-CoV-2 that have recently emerged in the UK and South Africa after their paper was accepted for publication. Those results have not been published yet[9].

Conclusion

The model might contribute to future efforts to control viral spread and provide effective vaccines against a variety of different pathogens.

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CoronaSys Innovation sheet 45

Vaccination Communication Handbook

Background

Since December 2020, vaccination campaigns are underway in many countries[1]. But apart from logistical and medical challenges[23] that need to be overcome, the authorities also have to convince people to get the shot. This is complicated by a large amount of misinformation, fake news and outright conspiracy theories circulating among the population. A team of scientists and volunteers from different academic disciplines[4] has produced a handbook to help educate people about the Covid-19 vaccine.

Features

The 16-page manual draws on information from the World Health Organization (WHO), UNICEF, the U.S. Food and Drug Administration (FDA), the Royal Society and other agencies and scientific organisations. It provides information on vaccination in general and Covid-19 vaccination in particular, as well as factors that promote vaccination readiness within the population. In addition, it devotes several sections to the topic of communication, providing basic information on risk communication as well as practical advice on how to deal with or prevent misinformation[56].

State of information: 01/15/2021

Publication: January 2021

Country: International

Focus areas: Prevention, Communication

Developers: SciBeh Research collaboration

Beneficiaries: Doctors, journalists, nurses, policy makers, local and national health officials, researchers, teachers, students and parents,…

Potentials

The Handbook might be a valuable help for everybody who deals with informing people about vaccination. Many of the sections in the manual contain links to a wiki with more in-depth information. This wiki is continuously updated by the team of authors[7].

Points to consider

The handbook can only provide assistance in conducting informational interviews and must be adapted to the respective situation. Continuous updating is crucial to ensure that the information is up to date.

Conclusion

The handbook might be helpful for professionals who conduct talks on the topic of vaccination and educate the public. It can also help laypeople who want to take action against fake news and lack of vaccination hesitancy in their environment.

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