

Analysis of the Virus SARS-CoV-2 as a Potential Bioweapon in Light of International Literature

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ABSTRACT

Introduction:

As of early 2022, the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic still represents a world-wide medical emergency situation. The ongoing vaccination programs can slow down the spread of the virus; however, from time to time, the newly emerging variants of concern and antivaccination movements carry the possibility for the disease to remain in our daily lives. After the appearance of SARS-CoV-2, there was scholarly debate whether the virus was of natural origin, or it emerged from a laboratory, some even thinking the agent's potential biological weapon properties suggest the latter scenario. Later, the bioweapon theory was dismissed by the majority of experts, but the question remains that despite its natural origin, how potent a biological weapon the SARS-CoV-2 virus can become over time.

Materials and Methods:

Based on 12 bioweapon threat assessment criteria already published in 2018, we performed a literature search and review, focusing on relevant potential bioweapon properties of the virus SARS-CoV-2. Instead of utilizing a survey among experts, we tried to qualify and quantify characteristics according to the available data found in peer-reviewed papers. We also identified other key elements not mentioned in the original 12 bioweapon criteria, which can play an important role in assessing future biological weapons.

Results:

According to the international literature we analyzed, SARS-CoV-2 is a moderately infectious agent (ID₅₀ estimated between 100 and 1,000), with high infection-to-disease ratio (35%–45% rate of asymptomatic infected) and medium incubation period (1–34 days, mean 6–7 days). Its morbidity and mortality rate can be categorized as medium (high morbidity rate with significant mortality rate). It can be easily produced in large quantities, has high aerosol stability, and has moderate environmental stability. Based on laboratory experiments and statistical model analysis, it can form and is contagious with droplet nuclei, and with spray technique utilization, it could be weaponized effectively. Several prophylactic countermeasures are available in the form of vaccines; however, specific therapeutic options are much more limited. In connection with the original assessment criteria, the SARS-CoV-2 only achieved a “0” score on the ease of detection because of readily available, relatively sensitive, and specific rapid antigen tests. Based on the pandemic experience, we also propose three new assessment categories: one that establishes a mean to measure the necessary quarantine restrictions related to a biological agent, another one that can represent the personal protective equipment required to work safely with a particular agent, and a third one that quantifies the overall disruptive capability, based on previous real-life experiences. These factors could further specify the threat level related to potential biological weapons.

Conclusions:

Our results show that the virus can become a potent bioweapon candidate in the future, achieving a total score of 24 out of 36 on the original 12 criteria. The SARS-CoV-2 has already proven its pandemic generating potential and, despite worldwide efforts, still remains an imminent threat. In order to be prepared for the future possibility of the virus arising as a bioweapon, we must remain cautious and take the necessary countermeasures.

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INTRODUCTION

As weapons of mass destruction, agents classified as biological weapons are under strict international regulations. One of the main nonproliferation efforts is the Biological and Toxin Weapons Convention (BTWC), which entered into force in 1975, having 183 member parties as of late 2021.¹ This criminalized the development, production, and storage of bioweapons, declaring the mentioned procedures as war crimes. However, there are states that did not sign the treaty, nongovernmental actors who are not bound by international regulations (e.g., individual perpetrators and terrorist groups), and, in some cases, even states that ratified the BTWC that did not follow the restrictions.² These examples carry the

possibility that a newly emerging infectious agent, which is not well known but is readily available to be collected from natural cases, can become a bioweapon candidate, particularly if its properties make it ideal for biological warfare utilization.

The virus SARS-CoV-2 emerged in late 2019, and after several months, the World Health Organization declared the epidemic caused by the mentioned agent a pandemic.³ Almost 2 years have passed since this declaration; our lives inevitably changed in light of travel and movement restrictions and internal lockdowns.

The virus, despite the efforts, showed a rapid spreading pattern, combined with a significant case fatality ratio. Eventually, the seemingly ideal properties of the SARS-CoV-2 raised the question if it was an engineered biological weapon, intentionally released, or an agent that unintentionally escaped in a laboratory leakage event.^{4,5} These theories were later dismissed by studies, concluding that the virus most probably has natural origins, which is strengthened by the lack of signs of genetic engineering.^{6,7}

SARS-CoV-2 is a member of the Coronaviridae family and Betacoronavirus genus.⁸ It contains a positive-sense, single-stranded RNA genome, which codes structural proteins (such as S, E, M, and N genes) and non-structural proteins as well.^{8,9} As an RNA virus, it has significant mutation capability, a factor that is important in the microbe's ability to escape host immune response and to adapt to different selection challenges.¹⁰

As of May 31, 2021, the World Health Organization "proposed labels for global SARS-CoV-2 variants of concern (VOCs) and variants of interest (VOIs) to be used alongside the scientific nomenclature in communications about variants to the public."¹¹ While in the case of VOCs, clear evidence is available indicating a significant impact on transmissibility, severity, and/or immunity that is likely to have an impact on the epidemiological situation, this evidence is still preliminary or is associated with major uncertainty among VOIs.¹¹ Some other variants of SARS-CoV-2 have been de-escalated based on at least one of the following criteria: "(1) the variant is no longer circulating, (2) the variant has been circulating for a long time without any impact on the overall epidemiological situation, (3) scientific evidence demonstrates that the variant is not associated with any concerning properties."¹¹ Since no SARS-CoV-2 variants are designated as VOIs currently, [Figure 1](#) shows the main characteristics of VOCs as well as de-escalated variants.

Understanding the genetic and structural characteristics of the virus is an important factor in the evaluation of how large a threat the SARS-CoV-2 represents ([Figure 2](#)). It is also already known that more than 70% of zoonotic emerging infectious diseases in humans are caused by pathogens that have a wildlife origin.¹⁵ Many characteristics of coronaviruses, e.g., large genomes, predisposition to mutation, and frequent recombination events have led to a diversity of strains

and species that are capable of rapid adaptation to new hosts and ecologic environments.¹⁵

Valencak et al. have pointed out that genome sequencing showed 96% concordance between human SARS-CoV-2 virus and SARS-CoV-like strains isolated from bats strongly confirming that SARS-CoV-2 originates from bats as primary hosts.¹⁶ Moreover, the authors draw attention that infected (companion) animals are also potentially able to spread new strains of SARS-CoV-2 to other people and pets in the household. However, several species of companion animals, farmed animals, and captive wild animals got infected with SARS-CoV-2 after having contact with asymptomatic or symptomatic humans.

In line with the above statements, a recent—not yet peer-reviewed—Hong Kong study found genetic evidence that Syrian hamsters (*Mesocricetus auratus*) kept in a local pet shop were responsible for a coronavirus disease 2019 (COVID-19) outbreak, which has so far infected at least five people.¹⁷

Hamsters are only the second animal proved to be able to infect humans so far. In late 2020, small outbreaks of COVID-19 among farmers in Denmark and the Netherlands were linked to farmed mink (*Neovision vision*).^{18,19} In these outbreaks, hamsters and mink were initially infected by other, COVID-19–positive employees triggering a vicious circle of zoonosis and reverse zoonosis.¹⁷⁻²⁰

Summarizing the characteristics of SARS-CoV-2 presented above, and if we accept the natural origin of the virus, these questions still remain: can SARS-CoV-2 become a potent biological weapon? Which properties determine its potential? What scenarios can represent a real-life possibility of SARS-CoV-2 weaponization?

MATERIALS AND METHODS

In order to adequately evaluate the threat SARS-CoV-2 represents as a biological weapon, we utilized the bioweapon risk assessment tool (BRAT) proposed by Theodore J. Cieslak et al. in an article published in 2018.²¹ In the original article, the authors performed a survey among bioweapon experts, ranking the analyzed bioweapon agents based on 12 different criteria. As SARS-CoV-2 is a relatively newly identified virus, some of its main attributes are not well known, or at least are still under intensive research. Because of this, we decided that instead of creating a questionnaire, we will perform a focused literature search, trying to collect the most recent data we can rely on to complete the scoring. We utilized the PubMed search engine to identify relevant publications, using "SARS-CoV-2" and "COVID-19" keywords, combined with keywords related to the 12 bioweapon criteria (infectivity; infection-to-disease ratio; predictability and incubation period; morbidity and mortality; ease of large-scale production, storage; aerosol stability; environmental stability; ease of dispersal; communicability; prophylactic countermeasure availability; therapeutic countermeasure availability; and ease

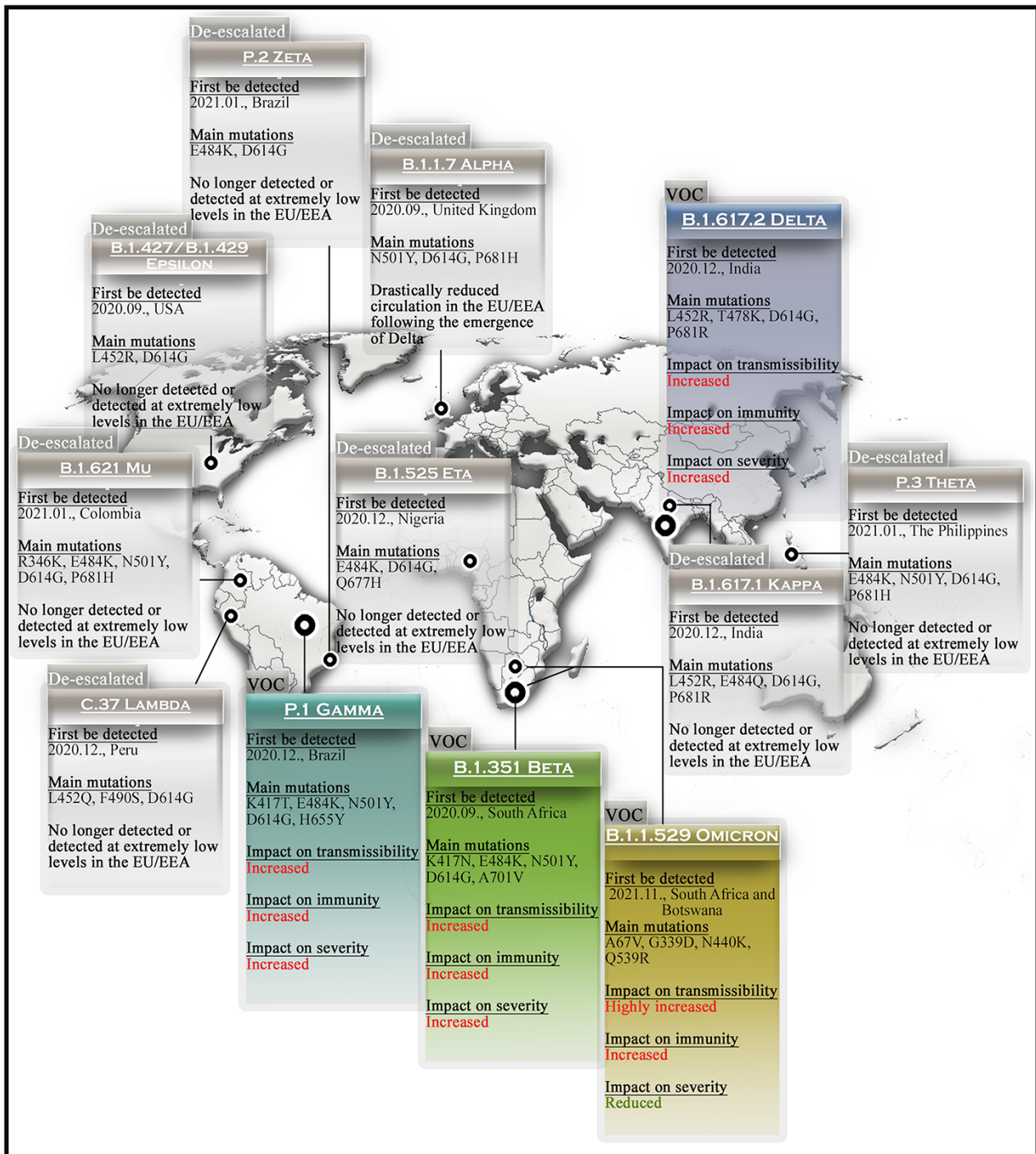


FIGURE 1. Variants of concern and de-escalated variants of SARS-CoV-2; note that VOCs according to the U.S. government SARS-CoV-2 Interagency Group classification are Delta (B.1.617.2 and AY lineages) and Omicron (B.1.1.529 and BA lineages), while Beta (B.1.351), Gamma (P.1), Delta (B.1.617.2 and AY lineages), and Omicron (B.1.1.529 and BA lineages) in the European Union/European Economic Area.^{11,12} (Figure based on the modified world map originally created by Petr Dlouhý; original work available at: https://commons.wikimedia.org/wiki/File:A_large_blank_world_map_with_oceans_marked_in_blue.svg.)

of detection). In light of the strength level of evidence, where available, we looked for reviews and meta-analyses. Based on the collected information, the SARS-CoV-2 properties were quantified on a 0–3 Likert scale, where 0 represented the lowest, 3 the highest related to bioweapon potential.

RESULTS

Infectivity

To this date, the infectivity of the SARS-CoV-2 virus has not been measured in humans within validated experimental

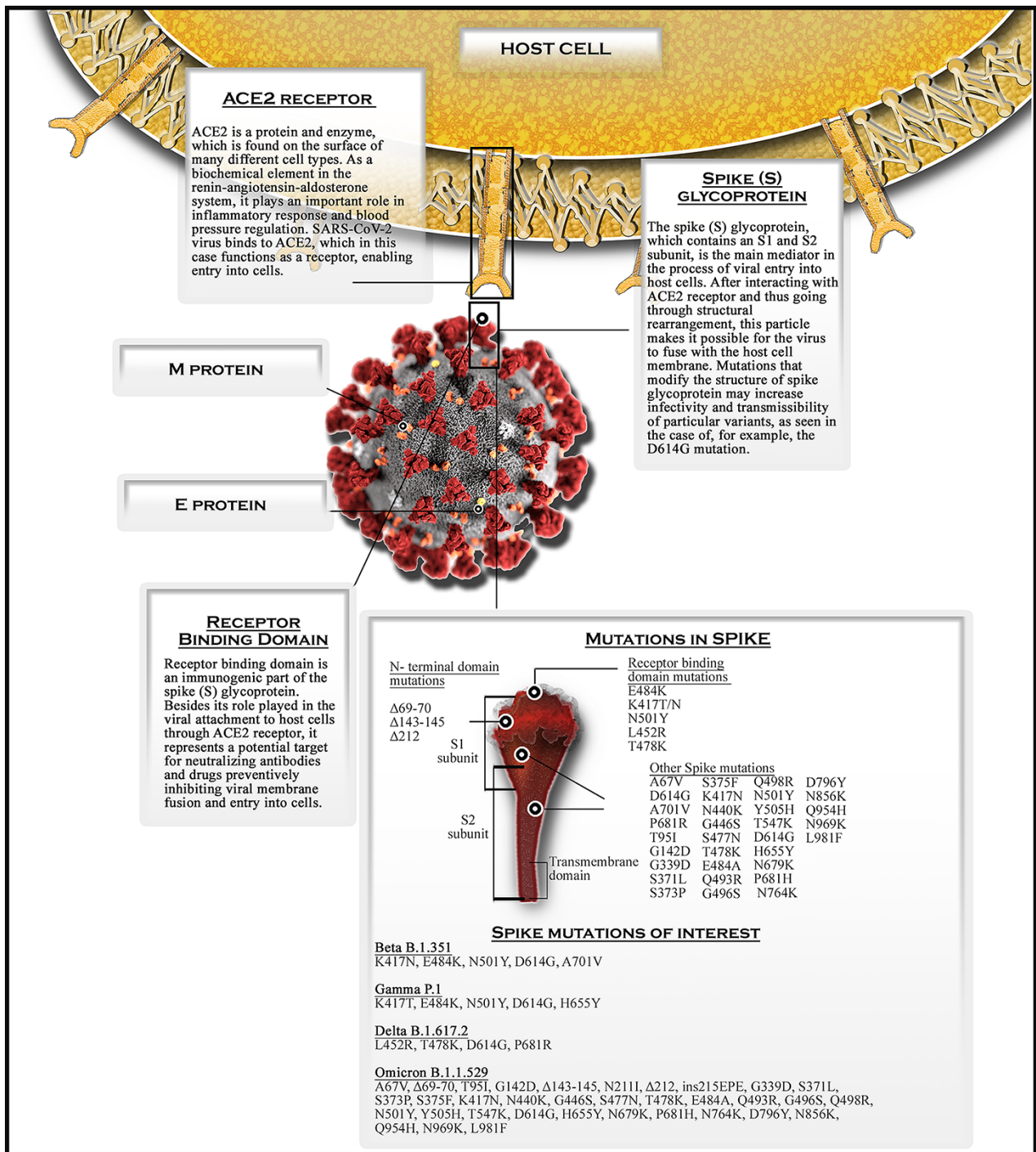


FIGURE 2. Illustrates highly mutable structural elements that facilitate the penetration into host cells. While these mutations are found in relatively low numbers in variants Beta, Gamma, and Delta, variant Omicron carries much more of them, contributing to a significant increase in infectivity, transmissibility, and immune escape.^{11,13,14} (Figure based on the modified model originally created by Alissa Eckert, MSMI and Dan Higgins, MAMS; original work available at: <https://phil.cdc.gov/Details.aspx?pid=23313>.)

conditions. Available literature data are based upon statistical analyses, animal study models, and estimations connected to similar, previously measured (or estimated) pathogens. To quantify infectivity, the original scoring system in the bioweapon assessment tool uses the ID50 number.²¹ This

represents the number of pathogens that are needed to infect 50% of a given susceptible population.²² Infectivity is influenced not just by the properties of the pathogen, and the target host, but also by the route of transmission as well: this means that, for example, intranasal inoculation will not

produce the same ID50 result as an aerosol-based infection.²³ If we accept the possible similarity between human influenza viruses, the SARS-CoV-1, Middle East respiratory syndrome virus, and SARS-CoV-2, the estimated ID50 value can be quantified somewhere between 100 and 1,000 particles.^{22,23} This means that the SARS-CoV-2 is a moderately infectious agent, achieving a bioweapon risk assessment tool (BRAT) score of 2.

Infection-to-Disease Ratio

In BRAT, the reliability of a potential bioweapon is based on its infection-to-disease ratio. Related to SARS-CoV-2, international literature provides wide-scale data on this topic, which is not surprising in light of that more than 300 million laboratory-confirmed infected cases occurred worldwide. However, it is not easy to assign a single number to the infection-to-disease ratio, as it is highly variable among different subpopulations, for example multimorbidity, or even age can significantly influence the course of the infection. Another limiting factor is that even if common signs and symptoms are missing, the manifestation of subclinical tissue or organ damage is still a possibility.²⁴

During the outbreak on the aircraft carrier U.S.S. Theodore Roosevelt, 43% of laboratory-confirmed patients never developed any sign of infection during the clinical course.²⁵ A meta-analysis published in the summer of 2021 estimated the asymptomatic percentage as 35.1%–36.9%.²⁶ These numbers put the SARS-CoV-2 virus in the high category of the infection-to-disease ratio, as much more than 1 individual out of 10 will show signs and symptoms of the COVID-19 disease, achieving a score of 2 on the relevant BRAT criterion.

Predictability and Incubation Period

The predictability or incubation period criterion in the original BRAT scoring system does not provide a well-quantified guideline and only establishes the following categories: very low (“0 score, incubation period very lengthy, and/or variable”); low (1 score); medium (2 score); high (“3 score, incubation period short, and/or very predictable”).²¹ If perpetrators want to deploy a biological weapon, it is understandable that in most scenarios, shorter or more predictable incubation period will be more beneficial in achieving desired goals (e.g., inducing public panic, and overflowing health care providers in a shorter time), and also planning the operation can be easier. But it should also be considered that in some cases, where the main goal is to infect as many people as possible, meanwhile also avoiding detection, a longer, supposedly asymptomatic incubation period could perform better. The incubation period will also determine the necessary quarantine and restriction of movement-type precautions.

However, terms like “lengthy and variable” without any further specific definition can be interpreted variously. SARS-CoV-2, according to a meta-analysis published by Cheng et al., has an average incubation period of 6–7 days (data ranging from 1 to 34 days).²⁷ If we consider that toxins like ricin

can cause symptoms (depending on the route of transmission) a few hours after exposure, and for example anthrax can have an incubation period of 1 day up to 2 months, we can safely assume that SARS-CoV-2 has a medium predictability and incubation period, achieving a score of 2 on BRAT.

Morbidity and Mortality

In the case of morbidity and mortality, the relevant BRAT criterion provides a relatively straightforward guideline. However, it is important to note that morbidity and mortality are variable among available studies, and different definitions and assessment methods can lead to the overall confusion. We can relatively safely state that SARS-CoV-2 has significant virulence, as it can cause serious illness in a significant proportion of patients, mainly by affecting the respiratory system.²⁸ The virus’ morbidity and mortality are influenced by its mutations, as variants can have different properties; for example, variant of concern 202012/1 (Alpha variant) is highly probable to have an increased mortality risk compared to wild-type SARS-CoV-2.²⁹ It is also important to mention that performing an autopsy, combined with adequate postmortem microbiological and histological sampling, is the most reliable method to determine the correlation between virus infection and the cause of death. In a study published recently from Hungary, based on 100 full-scale autopsy cases in the first and second wave of the pandemic, the cause of death showed strong association with SARS-CoV-2 infection in 57% of the cases, in 27% SARS-CoV-2 infection contributed to the course of death, and in 16% of the cases, only weak association was found.³⁰ This finding can be translated as not every SARS-CoV-2 infected patient will die directly because of the infection. To complicate things even further, we can also assume that a number of strongly associated COVID-19 death cases remain undetected because the infection is not explored or autopsy is not performed. Overall, various reviews and meta-analyses estimate the case fatality rate of the virus between 1% and 10%.^{31–33} These numbers are arguable, but even the lower end of 1% represents a significant potential bioweapon attribute. In our opinion, summarizing the aforementioned, the virus deserves two points on BRAT.

Ease of Large-Scale Production and Storage

In this category, again, it is somewhat hard to objectively assess the risk SARS-CoV-2 represents. What quantity does count as “large-scale”? A few grams of most bioweapon microbes, with an effective dispersal method, could be enough to infect hundreds or even thousands of people. To induce public panic, or reach better defined operational goals, most terrorists would not need to have access to tons of bioweapon agents. Of course, we should not forget that without adequate safety precautions, it is very hard to cultivate a pathogen agent. Working with isolated, living SARS-CoV-2 requires biosafety level 3 criteria according to most recommendations.³⁴

As a virus, SARS-CoV-2 needs cell lines to be cultivated effectively. Some of the available cell lines are of human origin, and others are of animal origin.³⁴ For example, Vero E6 is an easily accessible solution, with well-detailed descriptions regarding maintenance and growing.³⁵⁻³⁷ Logically, another indirect fact that can strengthen the possibility of large-scale production is that there are ongoing live attenuated virus vaccine projects, which could be unimaginable without effective cultivation methods.^{38,39} The aforementioned circumstances, in our opinion, are enough to give a 3 score on the relevant BRAT criterion.

Aerosol Stability, Environmental Stability, and Communicability

The BRAT criteria related to aerosol stability, environmental stability, and communicability are correlating closely in the case of SARS-CoV-2, making it easier to evaluate the three categories together. According to available literature, it is suggested that the virus can form viable aerosols, at least under experimental conditions, with a half-life of 1 h, and living aerosolized viral particles detectable up to a day.^{40,41} This also creates the possibility for the virus to infect people via droplet nuclei, a theory not yet confirmed in an undebatable way. However, evidence suggests that besides infections occurring after contacting with infectious droplets, aerosols can also have an important role in the transmission of the disease.^{40,42} Of course, environmental conditions largely influence the viability of aerosols: temperature, humidity, and UV light can play an important role in the survival of the virus.⁴³ Overall, if we calculate with the “worst-case scenario” in the category of aerosol stability and communicability, we can give a score of 3 in both to the virus.

Environmental stability also determines the bioweapon potential of SARS-CoV-2. Naturally, not only aerosol stability is defined by environmental factors, but also viable virus quantity in droplets. Based on one of the early publications about SARS-CoV-2 environmental resilience and survivability, the virus can survive on different inanimate surfaces, like plastic or stainless steel up to 72 h.⁴⁴ A more recent systematic review on the topic found that SARS-CoV-2 can survive up to 28 days under laboratory conditions and room temperature, on glass, steel, and both polymer and paper banknotes.⁴⁵ Comparing these findings to the infamously resilient anthrax spores, which can remain contagious for years, we can safely give a score of 2 on the relevant BRAT criterion, meaning a moderate, but not extreme environmental stability.

Ease of Dispersal

This is again an attribute which cannot be evaluated easily. No direct public data are available on dispersal weaponization efforts related to SARS-CoV-2. The BRAT criterion proposes the following categories: “0 – Virtually impossible to disperse in quantity; 1 – Low (requires sophisticated stabilization, aerobiology, and dispersal techniques); 2 – Moderate (requires

spray techniques); 3 – High (can survive dissemination via ballistic weaponry).”²¹ Considering the data mentioned under the previous section and accepting theories regarding the aerosol transmission potential of the virus, we can assume that with adequate spraying technique utilization, it could be dispersed in large quantities. We cannot be sure, if viral particles could survive a trauma like dissemination via ballistic weaponry; however, evidence suggests that the virus has significant mechanical resilience, a property which could make less “traumatizing” means of dispersal possible.⁴⁶ According to these findings, SARS-CoV-2 reaches a 2 score on the BRAT criterion.

Prophylactic Countermeasure Availability

When the first vaccines appeared in late 2020, there was hope that the pandemic could come to an end in the foreseeable future. This hope, however, has since faded, as antivaccination movements and breakthrough infections, mainly related to newer and newer VOCs, emerged. Antivaccination movements are also recognized as a factor increasing vulnerability to biological warfare events, according to a recent publication.⁴⁷ Nevertheless, in an increasing number of countries, and for increasing number of subpopulation (e.g., health care workers and armed forces personnel), vaccination becomes obligatory as time passes. With the widening selection of available vaccines, and more and more strict internal and international regulations, the hope of prophylactic countermeasures solving the pandemic is again on the horizon.⁴⁸ But we should not forget that VOCs can arise anywhere and can undermine vaccination efforts with causing breakthrough infections.⁴⁹ Another aspect worth mentioning is that relatively slowly progressing vaccination programs, not reaching goals like herd immunity fast enough, place a significant selection pressure on the virus, creating a possibility of resistance mechanisms like mutations to appear more frequently.

Summarizing, prophylactic countermeasures are readily available in most countries but, because of the aforementioned difficulties, are not a universal and solely working solution for the pandemic, giving a score of 1 on the BRAT criterion to the SARS-CoV-2 virus.

Therapeutic Countermeasure Availability

Opposite to prophylactic countermeasures, in the field of adequate therapy, our options are much more limited. From time to time, randomized controlled trials dismissed the efficacy of majority of agents. Most of the antiviral, immunomodulatory, and anti-inflammatory agents (with the notable exception of corticosteroids) could not live up to the long-term expectations.⁵⁰ Despite of anticoagulant therapy, in postmortem specimens, micro- and macrothrombi still represent a frequent finding.³⁰ While the lack of efficient therapeutic agents could somewhat undermine weaponization efforts in the eyes of potential perpetrators, in order to avoid unintended losses, fanatic bioterrorists truly determined to a cause would not be

TABLE I. The Bioweapon Risk Assessment Tool Categories and SARS-CoV-2²¹

Score Category	0	1	2	3	SARS-CoV-2
Infectivity	Noninfectious	Mildly infectious (ID50 > 1,000 organisms)	Moderately infectious (ID50 10–1,000 organisms)	Highly infectious (ID50 1–10 organisms)	2
Infection-to-disease ratio (reliability)	Low (fewer than one case of clinically relevant disease for every 100 infected individuals)	Moderate (1 case in 10 to 1 case in 100 infected individuals)	High (greater than 1 case in 10 infected individuals)	Certain (nearly all infected individuals develop clinically relevant disease)	2
Predictability (and incubation period)	Very low (incubation period very lengthy and/or variable)	Low	Medium	High (incubation period short and/or very predictable)	2
Morbidity and mortality (virulence)	Minimal	Low (incapacitating agents)	Medium (high morbidity and/or some degree of mortality)	High (lethal agents)	2
Ease of large-scale production and storage	Nearly impossible to cultivate in quantity	Difficult (requires embryos or other living systems for cultivation)	Moderate (can be produced in cells via genetic techniques)	Easy (can be propagated efficiently in artificial media)	3
Aerosol stability	Very low (impossible to formulate in a homogenous aerosol)	Low	Moderate	High (can be formulated in a homogenous aerosol of 2–3-µm particles)	3
Environmental stability	Very low (decay rates of unstabilized organism in the environment >3%/min)	Low	Moderate	High (relatively impervious to decay under normal atmospheric conditions)	2
Ease of dispersal	Virtually impossible to disperse in quantity	Low (requires sophisticated stabilization, aerobiology, and dispersal techniques)	Moderate (requires spray techniques)	High (can survive dissemination via ballistic weaponry)	2
Communicability	Noncontagious	Contagious via contact only	Contagious via respiratory droplets	Contagious via droplet nuclei	3
Prophylactic countermeasure availability	Countermeasures readily available or unnecessary	Antibiotics and/or vaccines readily acquired (most bacteria)	Vaccines may be producible given adequate time; antibiotics ineffective (most viruses)	No known countermeasures available (e.g., filoviruses)	1
Therapeutic countermeasure availability	Countermeasures readily available or unnecessary	Antibiotics readily acquired (most bacteria)	Antibiotics ineffective or generally unavailable (most viruses)	No known countermeasures available (e.g., filoviruses)	2
Ease of detection	Point-of-care assays available	Laboratory assays available	Special laboratory capabilities required	No assays available for detection	0
Total score					24/36

frightened off by this. Because we only have some promising new drugs, but no proven specific therapeutic countermeasure, in this category, SARS-CoV-2 deserves a score of 2 on BRAT.

Ease of Detection

Maybe this is the only field, where breakthrough has relatively been achieved during the battle against the pandemic. With the wide-scale availability of rapid antigen tests, the increasing speed and capacity of polymerase chain reaction examinations, detecting the presence of the virus is challenging only in a minority of cases.⁵¹ But we must not forget about

the possibility that emerging VOCs may show different antigens, decreasing the value of rapid antigen tests not optimized for new variants. Furthermore, rapid tests should only come from a reliable manufacturer in order to avoid false results. Overall, in this category, SARS-CoV-2 does not represent a significant threat, achieving a 0 score on BRAT.

DISCUSSION

According to our analysis, SARS-CoV-2 could become a bioweapon candidate in the future. It achieved a total score of 24 out of 36 on the bioweapon risk assessment criteria (Table I). Because of the method used to qualify and quantify

the attributes of the virus, our results are not directly comparable to the original BRAT validation study; nevertheless, the awareness of experts and decision makers should be raised toward the possibility of the COVID-19 disease arising as a bioweapon agent.

Because of newly emerging variants of SARS-CoV-2, the scoring we hereby presented can change over time. Bioterrorists most probably could get interested in variants that have increased transmissibility and severity; trying to further augment these characteristics through genetic engineering is also a possibility. If made available, asymptomatic carriage, combined with occult tissue damage, could also serve bioterrorism purposes. The above-mentioned issues further justify why monitoring of variants, particularly with unusual symptoms, should be thoroughly carried out.

With the increasing number of vaccinated people, the selection pressure is increasing on the virus. However, we also should not forget about that SARS-CoV-2, as mentioned in the introduction, can also survive in animal hosts, making zoonosis and even reverse zoonosis possible. This could present opportunity for new variants to show up even after achieving herd immunity in local human populations, and also an unconventional way for bioterrorists to “hide and preserve” collected viral strains. Keeping these in mind, regular monitoring of animal reservoirs potentially harboring SARS-CoV-2, especially rodents and other species with high reproductive rates, in highly urbanized territories could be necessary in the future.

The pandemic showed that besides antivaccination movements, other factors can also undermine the battle against the virus. One of the identified vulnerabilities is personal protective equipment shortage, which was a main problem mostly in the early phase of the pandemic.⁴⁷ This finding, in our opinion, should also be under consideration to complement the BRAT. The quality and quantity of personal protective equipment required to work safely under the threat of a particular biological agent is an essential question in many aspects. From the aspect of economy, personal protective equipments (PPEs) can be expensive, and not always readily available in large quantities. Another aspect is that if not enough PPEs are available, the most important service members (e.g., health care providers, first responders like ambulance servicemen, armed forces personnel) will be at increased risk of infection, which can lead to the escalation of the situation rapidly. It is also important to note that higher-level PPE usage requires training, again an attribute which can influence the potential of a bioweapon: a pathogen that requires higher level, more expensive PPE limits the options of first responders and other servicemen in a greater way, ergo represents greater burden. We suggest a scale where 0 represents minimal PPE requirement (e.g., surgical mask, with latex gloves), 1 represents PPE that requires minimal training or fit test to use (e.g., FFP3 half masks), 2 represents medium PPE requirement (e.g., higher-level respiration protection combined with more expensive overalls and gloves), and 3 represents higher-level

PPE requirement (e.g., PPE that is expensive and requires intensive training to be able to work with).

The SARS-CoV-2 pandemic also showed that, besides economic consequences, public order and morale are largely influenced by quarantine regulations, restriction of movement, and public lockdowns. A possible goal of future bioterrorist attacks could be to incite “revolts” against government-issued lockdowns, a threat that could put pressure on decision makers during long-term negotiations. In our opinion, this category should also be considered to be a part of the BRAT. Agents that do not require large-scale quarantine regulations should be considered a moderate threat, compared to microbes that more probably require significant lockdowns. This category could also include the epidemic or pandemic generating potential of the virus, an important driver of restrictions. In this new scale, 0 score represents no quarantine requirement, 1 represents local or short-term restrictions (e.g., restrictions limited to a few buildings or for just a few days), 2 represents moderate restrictions (e.g., regional restrictions of movement or quarantine longer than a week, but shorter than a month), and 3 represents serious quarantine and lockdown regulations (e.g., whole country lockdown needed or international regulations in effect).

As a final addition to BRAT, a criterion that measures overall disruptive potential that is based on previous experiences with a particular agent should be considered for inclusion: 0—no previous experience with agent, only theoretical threat; 1—minor disruptive potential (e.g., outbreak contained in short time, with local resources); 2—significant disruptive potential (e.g., control of outbreak required national resources and caused significant organizational/economic losses); 3—high disruptive potential (e.g., international efforts required for containing the situation).

CONCLUSION

To our knowledge, this is the first time a systematic analysis was carried out related to the SARS-CoV-2 virus as a potential bioweapon. In light of the still ongoing pandemic, the possibility of SARS-CoV-2 getting into wrong hands is unfortunately real. We hope that our work contributed to better understanding the threat of this virus. Only time will tell whether SARS-CoV-2 will become a newcomer in the toolbox of bioterrorists or not. However, in our opinion, raising awareness and preparing for worst-case scenarios are always worth investments.

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CONFLICT OF INTEREST STATEMENT

None declared.

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