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A risk science perspective on the COVID-19 risk handling

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ABSTRACT

This paper provides some reflections on the risk handling of the COVID-19 pandemic worldwide: What went wrong, and what worked well? On many issues – for example the origin of the coronavirus, societal lockdowns, and the effectiveness and safety of the vaccines – there are still considerable uncertainties and discussion. The paper aims to provide a new perspective on the risk handling, by studying such issues through the lens of risk science. This perspective stimulates considerations of the dilemmas the authorities faced because of the uncertainties about the development of the disease and the effectiveness of measures to meet the risks, by looking into the role of science, the appropriateness of the precautionary principle, the need to establish some official narratives, and the use of misinformation/disinformation. The main conclusion of the paper is that the COVID-19 risk handling failed in many critical ways, many of which are due to the authorities' failure to adequately provide information about the dilemmas and convey relevant risks and uncertainties.

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1. Introduction

Science is very much about searching for improved understanding of the 'world', about what happened or could happen, why and what the consequences could be. This paper addresses such understanding in relation to the coronavirus and COVID-19. Many perspectives and sciences can be used for this search: virology, microbiology, health science, social science, economics, etc. The present paper adopts a risk science perspective. This science covers the most updated knowledge on concepts, principles, theories, models, approaches and methods on how to understand, assess, characterize, communicate and handle risk (SRA. 2015, 2017a, 2017b; Aven and Zio 2014; Hansson and Aven 2014; Aven 2018a). Risk science plays a central role in the understanding, as there are uncertainties about the 'world'; at any specific point in time, we commonly cannot predict with accuracy what events could occur and what the consequences will be. There are uncertainties and hence risks. To be able to understand and evaluate the COVID-19 disease and its handling, it is necessary to take into account all relevant uncertainties and risks.

To illustrate, think about the situation in March 2020. At this point in time, there were considerable uncertainties about what the consequences of the coronavirus would be, and most countries implemented some type of societal shut down (lockdown) to reduce the risks. Using risk science terminology, weight was given to the precautionary principle. Today, questions are

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raised as to whether these lockdowns were appropriate. Reference is made to Sweden, which to a large extent kept society open during this period (Ludvigsson 2023) – recommendations were given about, for example, washing hands and social distancing, but public life was largely normal.

The present paper discusses the extent to which weight given to the precautionary principle was a prudent strategy dealing with the risks then faced in March 2020. Now, we can compare statistics on deaths from different countries up to and including 2023. It is interesting to observe that, although Sweden had considerably higher relative excess mortality figures in 2020 than the other Scandinavian and Nordic countries, the total numbers for the period 2020–2023 show that the differences have basically evened out (OECD 2024; Ioannidis, Zonta, and Levitt 2023). Can we then conclude that the Swedish policy was the best? Weight given to the precautionary principle in March 2020 can be seen as a sensible strategy, given the threat then faced and the scientific uncertainties present. In 2020, thousands of residents of nursing homes died in Sweden, not in the other Nordic countries.

This is the type of issue discussed in this paper. We question: What went wrong, and what worked well when it comes to the risk handling of the coronavirus and COVID-19? The paper provides reflections on an overall level, with a focus on risk aspects and using risk science knowledge. It is acknowledged that the paper provides a specific perspective on this discussion, in line with the basic ideas of how to conduct conceptual risk research (Aven 2018b). What are highlighted are the reasoning and arguments used. Readers may disagree on some of the conclusions made, but to do so, they need to point to weaknesses or errors in the argumentation used. This in turn stimulates discussions on key issues of importance for risk science and its application to COVID-19.

There are many potential topics that could be considered when evaluating the risk handling in relation to COVID-19. The present paper has selected some, including the origin of the coronavirus, societal lockdowns, and the effectiveness and safety of the vaccines. Both issues linked to the occurrence of the coronavirus and issues associated with the handling of the virus given its existence and spread are discussed. If A represents the occurrence of the virus, C its consequences, and U associated uncertainties (will A occur, and what will C be?), risk in its broadest sense can be viewed as comprising both (A,U) and (C,U|A), where '| A' is to be read as 'given the occurrence of A' (SRA. 2015; Aven 2016). The latter risk component (C,U|A) reflects the vulnerabilities when faced with the existence and spread of the coronavirus. The former risk component (A,U) is about the risk of occurrence of the coronavirus or another type of virus and is critical in understanding and assessing risk. In the risk field, one of the most important activities is hazard/threat identification and causal analysis. The questions raised are: What events and type of events can occur, and how? In the aftermath of serious events, investigations are conducted with the objective of explaining what has happened and identifying weaknesses and shortcomings in the risk handling, in order to make improvements. The main focus is on understanding, to be able to identify the best measures and decisions to be taken. If there is one serious event that requires scrutiny, it is the coronavirus (Aven 2023).

The paper specifically looks into the dilemmas the authorities faced when implementing risk policies, including the strategy of basing the risk handling on vaccines. To ensure that the policies could be effectively implemented, it was difficult to be fully transparent, open and honest on key information and risks. As such, basic principles of high-quality risk communication were ignored or overruled, the result being a massive distrust of authorities, as the truth is being revealed. The paper questions whether suitable policies could have been implemented without conflicting basic ethical standards and risk science principles.

The paper is organized as follows. Section 2 looks into issues concerning the origin of the coronavirus, Section 3 addresses issues concerning the consequences, given the existence of the coronavirus and its spread. Section 4 discusses some key topics addressed in Sections 2 and 3, and, finally, Section 5 provides some conclusions.

2. The occurrence of the coronavirus

This section will discuss the following two claims:

- The COVID-19 pandemic was a result of unacceptable risky research (gain of function research) (2.1)
- The origin of the coronavirus issue has been mishandled by central actors (2.2)

2.1. Unacceptable risky research

Gain-of-function research is research that involves changing naturally occurring viruses to make them more infectious – to improve the ability of a pathogen to cause disease – so that one can study its potential effects on humans and, in the next step, develop vaccines and, more generally, strategies for medical countermeasures, to be able to handle possible viruses that may occur in nature (e.g. Fauci 2012; Selgelid 2016; CRS. 2022). The research involves risk – concerning both biosafety and biosecurity – a potential for serious negative consequences for people's lives and health. Many scenarios are conceivable, for example that a scientist accidentally becomes infected with the virus, which leads to an outbreak and ultimately triggers a pandemic. Bioterrorism is clearly also a risk factor. Consequently, scientists and authorities face a dilemma. There is the potential for the research to have considerable benefits, and not allowing such research means a potential loss of valuable knowledge, which could be critical for the handling of future epidemics. But there is also a potential for considerable undesirable consequences of the research. The issue and dilemma have been thoroughly discussed in the literature (e.g. Fauci 2012; Selgelid 2016; CRS. 2022).

In 2014, President Barak Obama announced a 'pause' in gain-of-function research, to address key questions about the risks and benefits of this type of research. A white paper was developed, commissioned by the US National Institute of Health (NIH). This paper includes a framework for decision-and policy-making (especially regarding funding) regarding gain-of-function research (GOFR). It covers principles related to (1) *Research imperative*, (2) *Proportionality*, (3) *Minimization of Risks*, (4) *Manageability of Risks*, (5) *Justice*, (6) *Good Governance*, (7) *Evidence,* and (8) *International Outlook and Engagement*. These principles address key topics of risk management and governance (Renn 2008), linked to acceptability of risk, the balance of risks and benefits, the use of risk-benefit analysis, and community engagement/consultation. The GOFR 'pause' was lifted in 2017, but the degree to which GOFR has been conducted in recent years is a debated topic. There is evidence pointing to such research being conducted at Wuhan Institute of Virology, supported by the EcoHealth Alliance and National Institute of Allergy and Infectious Diseases (NIAID) (NR. 2021; COA 2023). In a paper in 2012, Dr. Fauci, the director of NIAID from 1984–2022, stated that the benefits of GOFR outweigh the risks (Fauci 2012). Making such a conclusion clearly involves judgments covering both scientific issues and values.

Today, we cannot state with certainty that the coronavirus was a result of GOFR. Yet, we can discuss the issue of whether such research should be conducted. Selgelid (2016) provides an excellent starting point for such discussions. In the following, some related reflections based on risk science knowledge are provided.

Can risk-benefit (cost-benefit) analysis help us decide whether GOFR should be conducted or not? The question has been addressed by several authors, using both qualitative and quantitative approaches. Although such analysis in many cases can provide useful decision support, it is not very helpful in this case – the uncertainties are too large. It can be argued that any analytical approach aiming at integrating risks, costs and benefits to guide the decision-making in a case like this would fail. The knowledge supporting the judgments would be too weak. Such analyses need, for example, to make explicit characterizations of the relevant risks, to be able to compare them with the benefits. Such characterizations can in theory be produced, but the basis for them would be very poor.

To support the decision-making, risk needs to be assessed and characterized. Risk science provides guidance. Consider the following examples to illustrate how the risk could be described:

> For GOFR conducted in line with the established guidelines, it is unlikely that it leads to a person (accidentally or as a result of a malicious act) becoming infected by the virus which leads to an outbreak and ultimately triggers a pandemic. The knowledge supporting this judgment is considered strong for the following reasons (need to be provided). (2.3)

Then the risk needs to be evaluated: Is it too large or acceptable? The answer depends on the argumentation provided – the scientific message as presented in (2.3) – but it goes beyond this, as it comprises claims and judgment which could be more or less representing or expressing the truth. There is also the potential for surprises, as key aspects (for example, risk sources) could have been overlooked. And it is also a critical point; at some time, guidelines may not be followed. The uncertainties are considerable. To make conclusions about risk acceptability, the experts judgments are important, but these are subject to uncertainties, and the weight to be given to these uncertainties is mainly about values and, hence, equally as much about ethics and politics as science. Risk science does not give recommendations on what is an acceptable risk. What it does is to give guidance on how to think in relation to risk: what concepts, principles and methods are applicable and can help us improve our understanding about the issue and support the decision-making.

If one asks people today, it is to be expected that many would find GOFR unacceptable or intolerable – they consider the risk too high. They may or may not relate the COVID-19 pandemic directly to the GOFR; the decisive point made is that there are considerable risks and uncertainties involved in this type of research. As the potential consequences are so extreme, this research should be banned, as errors occur in nearly all types of systems. The argumentation gives strong weight to the precautionary principle, which states that, if the consequences of an activity could be serious and are subject to scientific uncertainties, then precautionary measures should be taken, or the activity should not be carried out (SRA. 2015).

Others may argue differently, stating that the benefits of the research are so important for saving lives in the future that the GOFR needs to continue. The safety of the research needs to be further strengthened, but we cannot let one event and the uncertainties eternally block activities that could produce critical knowledge for meeting potential pandemics in the future.

2.2. Mishandling of the origin of the coronavirus issue

It is February 2024, and we still do not know the origin of the coronavirus (Komesaroff and Dwyer 2023; Quammen 2023; Vogt, del Valle, and Fimia 2023). How is this possible? The virus has affected us all, millions of people have died, many have lost their jobs, and most of us have experienced a reduced quality of life. The world has been in a state of emergency for several years. We want to know what has happened; it is about understanding the world we live in but also about learning to avoid something similar happening again. In risk and safety science, hazard and threat identification and analysis is one of the key tasks: What events and types of events can occur, and how? In the aftermath of serious events, investigations are conducted with the objective of explaining what has happened and enhancing our understanding, so that the correct measures and decisions can be taken.

Unfortunately, it has proved very difficult to carry out such studies. The origin of the coronavirus quickly became a highly political issue. It is difficult not to conclude that the process of finding out the origin of the coronavirus represents a serious failure of the global health risk handling process. The problems had already started in early 2020. In February 2020, the renowned medical journal *The Lancet* published a letter signed by 27 scientists, strongly condemning the idea that COVID-19 did not have a natural origin (Calisher et al. 2020). The letter referred to the ideas as conspiracy theories, and the authors declared that they had no conflicts of interest.

One of the signatories and a key person in drafting the letter was head of the EcoHealth Alliance. This organization was heavily involved in research in Wuhan, also in GOFR research. How then could he say there were no conflicts of interest (Thacker 2021)?

Many researchers, politicians and others have criticized the article in *the Lancet*. It can be seen more as political activism than a contribution to science. That the journal accepted the letter can be seen as alarming, as the letter in many ways violates basic principles of scientific work and communication. Using a term such as 'conspiracy theory' in such a context is a form of ruling technique, which obviously has the intention of smearing those having different perspectives and arguments than the authors of the letter. The knowledge was not strong enough to make a clear conclusion at that time. Several experts pointed this out and stressed the need to keep the possibilities open and let the research reveal the truth. They pointed to the lab theory as a plausible explanation, but these scientists were largely portrayed by the media as controversial and untrustworthy. With the label 'conspiracy theory', interest in following up the lab explanation disappeared quite quickly in the media and among journalists (van Helden et al. 2021). The 'truth' was found. The media platform shut down accounts that questioned the 'official view'. People should not have access to information that questioned this view; it was referred to as misinformation. Material referring to the lab explanation was removed. It was based on a conspiracy theory that people had to be shielded from. The many fact-checkers also strongly emphasized how unlikely the laboratory explanation was.

In the early summer of 2021, the picture suddenly changed. Intelligence sources indicated that the laboratory explanation was not so unlikely after all. The media began to write about the laboratory explanation in a new way. The lab theory was no longer a conspiracy theory. One can speculate as to what led to this change.

There are still uncertainties about the origin of the coronavirus. Efforts are made to find out what happened, but there is also considerable resistance. This fact is just depressing. The world seems unable to perform the work needed to sort things out and obtain clarity on the issue of what caused the COVID-19 pandemic. Key actors on the world stage have shown the opposite of what we learn in risk science classes: To communicate risk, openness and honesty (transparency) must come first, and therein also lies recognition of uncertainty and risks. Conveyed in the right way, such acknowledgments do not weaken the authority of the message that is being attempted to be conveyed – quite the opposite. If, however, central actors have an agenda and need to hide key knowledge and information, the risk communication ideals no longer prevail. It is all about hindering the truth from being revealed.

A few health experts have had dominant positions and roles in communicating the risks to the decision makers and the people in general. They use science to back their stances and recommendations, while at the same time seeking authority and power. In relation to the origin of the coronavirus, some of these health experts have strongly influenced the work – or lack of work – on finding the origin of the coronavirus. Their roles in the process have been scrutinized, and more will certainly come. Looking back on what has happened on this issue since early 2020 – and even earlier than that – there are good reasons to question all aspects of the process. We need to understand what caused the coronavirus, and that cannot be done without also digging into key actors' roles in the process.

3. Handling the consequences of the virus

3.1. Did lay people or the experts misjudge the risk in February 2020?

In February 2020, we could read in the *New York Times* about a discussion at a university in the US concerning the risk related to COVID-19 (NYT 2020). Many were concerned about the risk, but one student became exasperated. She referred to the fact that the coronavirus had

killed about 1000 people worldwide and infected around a dozen in the US, whereas the common illness, influenza, kills about 400,000 people every year and more than 30,000 in the US. So why this extreme disparity in public reactions? Experts on risk perception provide the answers: The coronavirus 'hits all the hot buttons' for how we misjudge risk. Due to factors such as lack of control, disaster potential, delayed effects, new and unknown risks, people are strongly influenced by feelings and tend to increase risk estimates and overreact (NYT 2020; Slovic 1987; Kahneman 2011).

However, care must be shown when interpreting this research. When facing uncertainties, there is no basis for concluding that people overestimate the risk and overreact. The truth and the objective reference for this do not exist. In this case, many people will argue that people's concerns were justified and that the indications of misjudgments of the risk and overreaction were unfounded. Of course, this example does not prove that people's concerns are always right and that the experts are wrong. The point is that we should be careful about concluding that people misjudge the risk and overreact when the situation being assessed is subject to uncertainties.

Risk research also explains that people's risk perception is not only about feelings. It can also capture conscious judgments of uncertainties (Aven and Bouder 2020; Aven and Thekdi 2022a). History has shown many examples of this, where highly relevant uncertainties were ignored by the professional risk judgments but included in lay people's risk judgments (for example, in relation to nuclear risk, Aven and Thekdi 2022a).

3.2. Containment of the hazard/threat

A basic principle of safety and risk management is confinement of the hazard/threat (Khan and Amyotte 2020) – here, the virus. A natural question to ask is whether greater adherence to this principle in the early stage of development could have prevented the pandemic and saved millions of people and the world from an economic meltdown. Unfortunately, a clear answer is not easy to give (e.g. HFACMS. 2020; TIP. 2021; Wu et al. 2021; Chen et al. 2021; Leung et al. 2022; Wang et al. 2022). Some sources strongly criticize the early risk handling and argue that the pandemic could have been prevented. The World Health Organization (WHO)-commissioned report, TIP. (2021), concluded that the pandemic was due to a myriad of failures, gaps and delays in preparedness and response. A key point made was that the early responses to the outbreak detected in Wuhan, China, in December 2019 'lacked urgency', with February 2020 a costly 'lost month', as countries failed to heed the alarm. The WHO waited too long to declare a public health emergency of international concern, the report stated. Governments in different countries did not sufficiently acknowledge the threat and know how to respond, and because of the uncertainties concerning the seriousness of the pathogen, 'wait and see' seemed a less consequential and costly choice than concerted public health action (TIP. 2021). It was a failure not to highlight the risk due to human-to-human transmission, the report also concluded. The WHO Director-General did declare that the outbreak constituted a PHEIC (A Public Health Emergency of International Concern) on January 30; however, the outbreak was not defined as a pandemic until March 11, 2020, and no travel restrictions were recommended. For an event to be defined as a PHEIC, at least two of four conditions must be met: it must (1) have serious public health impact; (2) be an unusual or unexpected event; (3) have significant risk of international spread; and (4) carry significant risk of travel or trade restrictions. The TIP. (2021) report concluded that the precautionary principle was not applied to the early alert evidence when it should have been.

Today, there is considerable discussion about the adequacy of the measures introduced to meet the COVID-19 risk, in particular the use of societal lockdowns. From a risk and safety science perspective, it can be argued that it is essential to distinguish between the early and later stages of the pandemic, as the former are characterized by urgent action in the case of

considerable uncertainties, in contrast to the latter, where science provides critical knowledge and there is not the same pressure on time. Also, it is essential to evaluate the decisions made based on the point of the decision-making and knowledge available at that time. Of course, it is always interesting to reflect on what would have been the best decision with hindsight, but the main reference for any evaluation of risk handling should always be based on the judgments made at the decision point.

The coronavirus outbreak can be viewed as meeting the conditions of the precautionary principle, in both early January and March 2020. However, the principle does not in general specify which measures to implement. It is a guiding principle that needs to be viewed in a policy and political context, balancing different concerns and particularly how much weight should be given to risks and uncertainties (Löfstedt 2014; Aven 2020). There were strong arguments for giving weight to the precautionary principle in early 2020, to meet a potential serious threat. With hindsight, it is easy to conclude, as TIP. (2021), that more should have been done in January-February 2020. TIP. (2021) recommends that 'the world' should improve its information and governance systems, to improve the early-stage handling of potential future outbreaks, and there is a strong rationale for doing this, given the experience with COVID-19. The issue is, however, not straightforward. It is difficult to know when to declare PHEIC and urge countries to take action that has serious implications for social and economic life. A too strict application of the precautionary principle could lead to false alarms, which could have serious effects on the reputation of world and national health institutions. There are also many issues linked to the development of surveillance and information systems, including aspects like privacy and individual freedom (Leclercq-Vandelannoitte and Aroles 2020; O'Connor, Hopkins, and Johnston 2021). Nonetheless, it is difficult to argue against measures that can improve the world's handling of potential new epidemics. How to obtain such improvements is, however, challenging, as the issue is not only about health management but also about politics. When to declare a PHEIC is about health but also politics, as it requires the balancing of different concerns, including health issues, costs and uncertainties. Not all countries have been fully open and transparent about what has happened – key information has not been shared. How can we then obtain the desired effectiveness and decisiveness at the critical early stages of a potential new virus outbreak?

The precautionary principle was applicable in the first months of 2020 – but not later, as the uncertainties were reduced, and they cannot be considered fundamental or scientific. Yet most governments also introduced societal shutdown at later stages but to varying degrees in different countries. From a risk science perspective, the situation can be seen as one characterized by potentially severe consequences and moderate levels of uncertainties. Various risk handling strategies are commonly adopted for such situations, balancing different concerns and giving different weights to (i) risk assessment knowledge, (ii) robustness/resilience (to a large extent founded on the cautionary and precautionary principles), and (iii) discursive policies (Renn 2008; Aven and Renn 2018). In general, we can say that proponents of societal shutdowns give stronger weight to ii) than those who would like to keep society open, who focus more on the results from risk assessment i). A considerable volume of research has supported the policy of keeping preschools and schools (for children up to age 15) open (e.g. Axelsson 2021; Ludvigsson et al. 2021; Stebbings et al. 2022); yet, we have seen many communities in different countries rejecting the policy. Weight is given to the cautionary principle; faced with the potential for severe consequences, which are subject to uncertainties, cautionary measures should be implemented (Aven and Renn 2018). The COVID-19 risk for school children was very small; hence, the main justification for school closure was to protect the staff and parents. The issue of closing school is basically about balancing the risk for teachers and parents against the negative consequences for the children of having schools closed. This risk and these consequences are difficult to measure, refer to discussions in Axelsson (2021), Ludvigsson et al. (2021) and Stebbings et al. (2022); yet decisions are required. Depending on values and priorities,

different conclusions were made. The policy of keeping schools open was combined with mitigation measures like testing, contact tracing, social distancing and masking. It seems fair to say that the policy worked well (Axelsson 2021; Ludvigsson et al. 2021; Stebbings et al. 2022).

The handling of a virus pandemic requires measures to minimize transmission as much as possible, using well-established communicable disease-prevention measures such as quarantine, minimizing contacts among people, physical distancing, hygiene routines, and personal protective equipment, in combination with testing and contact tracing (Collins, Florin, and Renn 2020; Tegnell 2021). The level of implementation of such measures varied between countries. There has been and remains discussion about the justification and effectiveness of this type of measures. In a recent comprehensive study conducted by the UK Royal Society it was concluded that clear evidence exists showing that stringent implementation of packages of such measures was effective in some countries in reducing the transmission of COVID-19 (The Royal Society 2023; Walport 2023). If we compare, for example, data from Sweden from mid-2020 to today, the numbers of deaths are comparable or lower than those of most other countries, even though Sweden implemented less restrictive measures (using voluntary measures, rather than mandatory measures and lockdowns) (OWID. 2023; Björkman et al. 2023; Ludvigsson 2023). Looking back to some of the mandatory measures implemented in some countries, there is good reason to question the effects. An example from Traveller (2020): You could be fined for not wearing a face mask when you are walking down the street, regardless of how many other people are around or how close they are to you.

The efficiency of masks is still a controversial issue. Many research studies show that such masks are effective, whereas other studies do not (Pepples 2020; Hajmohammadi, Malehi, and Maraghi 2023; Jefferson et al. 2023). We remember how health officials in the early phase of the COVID-19 pandemic did not recommend masks – there was clearly a shortage of these, and the authorities wanted to prioritize the healthcare systems, but this rationale was not openly and honestly communicated. Later, the arguments were made that the masks were very effective and important. Now, the overall assessment is more balanced, showing the positive and negative effects. As commented by Dr. Fauci, 'masks work at the margins – may be 10%' (NYT 2023). In The Royal Society (2023) report it was concluded that 'The weight of evidence from all studies suggests that wearing masks, particularly higher quality masks (respirators), supported by mask mandates, generally reduced the transmission of SARS-CoV-2 infection. Studies consistently, though not universally, reported that mask wearing and mask mandates were an effective approach to reduce infection'.

During the COVID-19 pandemic, considerable data and statistics have been produced presenting the number of deaths, number of intensive care unit patients, etc. These data and statistics say something about the future and risk, but risk is more – also reflecting changes that may occur over time, as well as potential surprises. Many studies have been conducted that also address such issues, but the number of such studies has been rather limited, and the quality of many of them can also be questioned – the risks have been poorly characterized and communicated (Glette-Iversen, Seif, and Aven 2023). As an illustration, consider the following example from Norway in late 2021.

The concern was the risk related to the omicron variant, and the Norwegian Institute of Public Health (FHI 2021) carried out a scenario analysis that laid an important foundation for the Government's COVID-19 handling in early 2022. The study presented four scenarios for the number of hospital admissions in Norway in the coming months, as a result of the coronavirus. The numbers were all high, and, for two of the scenarios, the figures were alarming. If these numbers were to prove correct, it was clear that strong measures would be needed.

It turned out that scenarios were too pessimistic – the two rather extreme scenarios were nowhere near the actual number hospitalized. From a risk science stand, the study was problematic because it outlined four scenarios, without relating these to risk, likelihood, knowledge (strength of knowledge) and assumptions. From a reader's perspective, the four scenarios could

be seen as being of the same importance. The considerable uncertainties were stressed in the study reports, but, focusing on the key results and message, the FHI (2021) report showed a risk description, in which two out of four scenarios were extremely worrying. Differences in likelihood and related knowledge support were not adequately reported and communicated. The study was based on a key assumption: that the effects of the omicron disease were almost as severe as those of the delta variant. This was, however, a very pessimistic assumption. Assessments in South Africa showed that omicron was much milder in effect than the delta variant.

A study based on risk science knowledge would have been different – far more nuanced, with characterization of risk using likelihood and knowledge strength judgment, where the risk related to deviations in assumptions is also addressed (Glette-Iversen, Seif, and Aven 2023). Now, we can speculate as to whether this would have changed the government's and people's decisions – it can be argued that there are good reasons to believe so. The government was giving strong weight to the most serious scenarios. Many people, including the young, chose to take a vaccine booster as a result of the clear recommendations from the authorities at this time. It is in place to ask whether these recommendations came as a result of the mischaracterization and miscommunication of the risks that we faced at the time.

In most countries, the health agencies and many health experts had a prominent role at the government's press conferences on COVID-19 during the pandemic. Risk was a central theme, but not many – if any – explained what risk is, how the understanding of risk is connected to probability and knowledge, and what the difference is between professional risk assessments and people's risk perception. It was a lost opportunity. The press conferences were a perfect arena for informing people about key themes of great importance to people's lives. It can be argued that the absence of such discussions is connected to a lack of competence in risk science. The responsibility for this situation rests mainly on the health institutions and these experts – but also on the risk science community, which has not been sufficiently active in preparing and communicating relevant knowledge.

3.3. Vaccination

Vaccines are commonly considered one of the greatest successes in modern medicine. The degree to which the COVID-19 vaccine has been a success is, however, open to discussion. Normally, it takes many years (5–10 typically) to develop a vaccine, but in the case of COVID-19 the vaccines were created, evaluated and authorized for use in under a year. There are strict procedures for the approval of vaccines, regarding demonstrations of effectiveness and safety, and strong concerns have been raised regarding the degree to which the COVID-19 vaccines were/are in fact effective and safe. Several important risk science issues are associated with the COVID-19 vaccines. In the following, these statements will be discussed:

- A successful vaccination strategy requires that there is i) sufficient evidence that the vaccine is effective and safe, and the ii) vaccination process is honest, open and transparent
- Both i) and ii) failed in relation to COVID-19.

3.3.1. Sufficient evidence that the vaccine is effective and safe

When the mass vaccination rollout began in early 2021, the public were reassured by governments and authorities that the vaccines had been tested and judged to be effective and safe. Numbers were presented for their effectiveness (efficacy) and safety, and most people accepted the vaccines. Vaccine efficacy refers to effectiveness in controlled clinical trials, whereas vaccine efficiency refers to the effectiveness of the vaccine in the real world (WHO 2021). The efficacy

is measured by comparing the fraction of people who had the vaccine and developed the 'outcome of interest' (usually disease) with the fraction of people who had the placebo (dummy vaccine) and developed the same outcome.

In December 2020, the vaccine manufacturers reported high efficacy of essentially any severity (FDA 2020a, 2020b):

- Reduction in the risk of confirmed COVID-19 occurring at least 14 days after the second dose of vaccine
- Reduction in the risk of confirmed severe COVID-19 occurring at least 14 days after the second dose of vaccine.

Research concluded that most of the COVID-19 vaccines appeared to be effective and safe (Xing et al. 2021).

However, the health agency reports and research also pointed to important uncertainties (unknowns). These related to coronavirus infection, severe COVID-19 and the durability of effectiveness. More research was needed to investigate the long-term effectiveness and safety of the vaccines and the influence of factors such as dose, age, and production process (Xing et al. 2021). The vaccine authorizations were conditional, reflecting that, at the time of authorization, less evidence than traditionally required for full approval was available (Prugger et al. 2021). Groups of particular interest, such as older, chronically ill, or immunocompromised people, were under-represented in or excluded from trials. Data on uncommon adverse events, as well as risks related to medium- or long-term harms of the vaccines, were necessarily limited at the time of mass vaccine rollout.

Reviewing the risk characterizations available in early 2021 concerning both the effectiveness and safety of the vaccines, it seems balanced to state that the common understanding among health experts and politicians was that, by using the vaccines, the total effects and risks related to the COVID-19 disease could be considerably reduced. The safety risks related to side effects of the vaccines were not considered large, although the knowledge supporting the safety assessments was rather weak at this stage. The uncertainties were acknowledged and to be further studied in the coming years. An example of such work addressing concerns about the safety of the vaccines includes the issue of possible association between immunization with the AstraZeneca vaccine and cases of blood clots (Petersen, Jørgensen, and Lindholt 2022). Studies confirmed a causal link, and the conditions have been included as potential side effects in the product safety information for these vaccines (EMA. 2021); see Glette-Iversen, Seif, and Aven (2023) for other examples.

The health agencies and the vast majority of scientific research supported the judgments that the COVID-19 vaccines were effective and safe. Yet there were many concerns, as discussed above; see also Barbari (2021). Having a future perspective, the risk concerning the COVID-19 disease was difficult to characterize, but the overall assessment was that the risk was large for older age groups and for people with underlying health problems, but low for younger healthy persons (Adam 2020; Bauer et al. 2021; Biggs and Littlejohn 2021). With the vaccines, the disease risk was assessed to be reduced, especially with respect to severe effects, but the uncertainties made it unclear to what degree. There were considerable uncertainty issues concerning the safety of the vaccines. As uncertainty is an aspect of risk (refer to Section 1), the risks related to the effectiveness and safety of the vaccines cannot be judged as small and negligible.

With the different coronavirus variants, the risk characterizations needed updating. In late 2021, the omicron variant indicated lower COVID-19 severe disease risk, but the uncertainties were considerable; refer to the discussion in Section 3.2. Yet the overall assessment was that the omicron variant was milder than the delta variant. As a result, the risk related to the COVID-19 disease was reduced, even though the variant was significantly more transmissible.

Today the knowledge concerning the effectiveness and safety of the vaccines is much stronger than it was in 2021. There is strong evidence that the vaccines are not very effective in preventing infection (Hui 2022). It is difficult, however, to find comprehensive risk characterizations from health agencies, beyond statements that the vaccines are effective and safe. The vaccinations' effectiveness regarding severe COVID-19 illness and their safety remain topics subject to considerable discussion (e.g. Chirico et al. 2022; Graña et al. 2022; Atanasov et al. 2023; Aarstad and Kvitastein 2023; Gøtzsche and Demasi 2023; Halma, Rose, and Lawrie 2023; Lytras et al. 2023; Sy 2023; Beladiya et al. 2024).

Reading the scientific literature, it is difficult to draw a conclusion about the observed high excess death numbers in 2022 and 2023 (EU. 2023). Health agencies' argumentation is that a main factor contributing to the high numbers is that the virus waves expose the most vulnerable people, the old and those with underlying conditions. With societies opened up again, many of them will die from the infection, leading to higher death numbers than expected when this disease did not exist. On the other hand, studies also indicate that vaccination can be an influencing factor for the high excess numbers. Care has to be shown in drawing conclusions on causality from observed correlation, but the issue is certainly of importance and requires further research. Many people have questioned the safety of the vaccines. There are uncertainties about the safety; there are risks. A main reason for this concern can be traced back to the way the vaccination process has been handled.

3.3.2. The vaccination process is honest, open and transparent

When health authorities faced the coronavirus risk, various strategies were discussed. Early, it became clear that the development and distribution of vaccines against the COVID-19 disease would be the cornerstone strategy for meeting the pandemic. There is clearly a rationale in that, if an effective and safe vaccine could be developed. Unfortunately, it takes many years (5–10) to develop such a vaccine; yet decisions were made worldwide to pursue this strategy. The potential losses and risks without a vaccine were considered higher than the potential losses and risks of implementing a strategy using fast developed vaccines. It was a dilemma; the strategy required vaccines, but they had to be used even without strong knowledge of their effectiveness and safety. The vaccination strategy requires that most people get vaccinated, to obtain herd immunity (WHO. 2020a). Again, the authorities faced a dilemma. If they highlighted issues concerning the effectiveness and safety of the vaccine, people could be less prone to take it. If, however, the communication highlighted the importance of the vaccination and that it works well and is safe, the strategy could be successful, in the sense that most people would take the vaccines. In many countries, this was exactly what happened. It was up to the individual to make a decision to take the vaccine or not, to weigh up and balance the various considerations and risks. For example, the Norwegian Institute of Public Health (FHI) writes on its website: 'We will inform about the effect of the approved vaccines and their side effects, so that everyone can make an informed choice. The goal is that everyone who is recommended vaccination chooses to take advantage of the offer'. However, in other countries, mandatory policies were implemented to ensure that most people took the vaccines. This policy raises difficult issues concerning the individual's freedom to choose for themselves versus what is best for society as a whole. FHI's strategy stresses the arguments, and especially the risks, that should convince people to choose to take the vaccine. The choice must be risk-informed. However, even when not mandatory, there was considerable social pressure to take the vaccines.

Given that the vaccination policy is implemented, we can discuss the extent to which all means are acceptable to get most people vaccinated. Is it acceptable for health officials and authorities to lie, to ensure that the overall goal is achieved? Many examples of such lies can be given. We all remember what President Biden's adviser on COVID-19 said in December 2021, and which Biden himself repeated in a speech to the people: 'For unvaccinated, we are looking

at a winter of severe illness and death – if you're unvaccinated – for themselves, their families, and the hospitals they'll soon overwhelm'.

These are strong words, and it is obvious that the intention was to scare people into getting vaccinated. But the statement is highly misleading – it is an almost deterministic conclusion – death and disease are coming with certainty. The consequences are given; uncertainty and probability are not addressed – it is a risk characterization that violates the basic principles of risk science and risk communication.

People are unlikely to be convinced by such a speech. The result is that trust in the authorities is further weakened. Instead, it could have been said that the likelihood of serious disease is significantly reduced if you take the vaccine, and the evidence and knowledge supporting this assessment is strong (and, here, reference must be made to relevant data and scientific work, and to the population groups to which the statement applies). This would be a risk science response.

This criticism concerning this COVID-19 statement is not politically motivated towards Biden and his administration. There is misinformation from most, if not all, authorities. Here, misinformation is used in the sense of false, incorrect, inaccurate or misleading information, whether there is an underlying intention to harm or not. The authorities' underlying intention is hopefully not to harm, but the result can quickly become harmful if there is only one correct narrative and it is the authorities who own it. Risk science can help the politicians and health authorities to improve the understanding and communication of risk, but will they listen? The issues are also about ideology and politics – and, for many, that is far more important than the risk aspects.

Another example was the statement that the vaccines prevent you from becoming infected and getting COVID-19 – again serious misinformation – stated by both health officials and politicians. The authorities not only cooperated with the technology platforms; now, we know that the authorities in some countries also exerted strong pressure to censor material that they believed represented misinformation. The technology platforms and the media in general largely supported the authorities' efforts – professionals who asked questions that challenged the official view were removed from these platforms and their arguments largely ignored in the media. The official view was presented as being in line with science, but the fight against misinformation was in reality a threat to both freedom of speech and science. As we know, science is about challenging the existing, prevailing ideas and beliefs. Without an exchange of opinions and criticism of what exists, science does not work.

Openness and honesty are the cornerstones of good risk communication. In many countries, like the Nordic countries, trust in the authorities has been high, in contrast to, for example, the USA, where large proportions of the population are skeptical of everything that comes from the authorities. But in the Nordic countries also, it is a challenge to find the right balance between combating misinformation by means of censorship and other measures and ensuring freedom of speech and science's need for dialogue and criticism of the prevailing 'truths'. In nearly all countries in the West, the media are largely supporters of the official view. There have not been many newspapers that have expressed concern that the technology platforms engaged in a large degree of censorship of people who had divergent assessments of the risks associated with the COVID-19 disease and the COVID-19 vaccines. Many of these people are also leading scientists. Instead, we see that questions are now being asked on Elon Musk's Twitter because he wants more voices and less censorship. From a freedom of speech and scientific point of view, it can be argued that the changes we are now seeing on Twitter are for the good. Why is the media not cheering it? Are they not champions of freedom of speech and scientific dialogue?

The authorities are concerned about misinformation. It is seen as a serious threat to people's safety and health. And it is not difficult to find illustrations of information that is obviously misinformation; see, for example, Hansson et al. (2021) and the EU's websites related to the

COVID-19 disease and the COVID-19 vaccines (EU. 2024). Misinformation was early an issue in relation to COVID-19. WHO wrote in February 2020 that the outbreak and response of the virus 'has been accompanied by a massive "infodemic"– an over-abundance of information – some accurate and some not – that makes it hard for people to find trustworthy sources and reliable guidance when they need it' (WHO 2020b). Today WHO explains infodemic in this way:

> An infodemic is too much information including false or misleading information in digital and physical environments during a disease outbreak. It causes confusion and risk-taking behaviours that can harm health. It also leads to mistrust in health authorities and undermines the public health response. An infodemic can intensify or lengthen outbreaks when people are unsure about what they need to do to protect their health and the health of people around them. With growing digitization – an expansion of social media and internet use – information can spread more rapidly. This can help to more quickly fill information voids but can also amplify harmful messages (WHO. 2024).

The authorities' advice to deal with this problem is to refer to reliable sources and information that has been fact-checked. The authorities also work closely with the technology platforms to get them to promote the reliable sources and remove or make less available and visible material classified as misinformation. But what are reliable sources, and who does the fact-checking? One is naive if one thinks that the problem of misinformation is only about removing/censoring all sources that are not in line with the authorities' view, as discussed above. See WHO. (2024), EU. (2024), Aven and Thekdi (2022b), Chiou et al. (2022), Ries (2022), Simon and Camargo (2023), Sundelson et al. (2023) for further discussions, in particular on how to fight the infodemics.

It can be argued that health organizations and national agencies failed in establishing adequate risk characterization related to COVID-19 – and particularly in relation to vaccination – and in communicating the risks to the public. There are many reasons for this. One is related to weak risk science knowledge among health experts and officials on how to conduct the risk characterizations and communicate the risks, another is a lack of willingness to perform such characterization and communication. The point is that, if the focus is on getting people vaccinated, issues about the effectiveness and safety of the vaccines would necessarily hamper this goal. Public health agencies face a dilemma, to release or not contentious information, for example on reports of adverse events, as this information is easily misinterpreted as causal when there is no basis for concluding this. If they do not present the information, they can be seen to be hiding something, which is also problematic (Demasi 2022).

Doshi, Godlee, and Abbasi (2022) argue that serious and severe harms of the COVID-19 vaccines have been ignored or downplayed – and sometimes deliberately excluded by the study sponsors in high impact medical journals. There are good reasons to ask whether there are underlying agendas influencing the analysis and communication of the vaccine risks. More research on this is needed, but will it be supported by the health agencies and governments? Authorities have recommended that virtually everyone should get vaccinated, but, for low-risk groups, the vaccine risks could clearly outweigh their benefits (Doshi, Godlee, and Abbasi 2022). Are the authorities really interested in scrutiny and full disclosure of the risks related to side effects?

Health agencies justify the use of compulsory COVID-19 vaccination following the same type of logic: it is necessary to get people vaccinated. An individual could view the risk of side effects as too high in relation to the disease risk, but, with vaccination mandates, the societal concerns are seen as more important that the individual judgments. There is strong evidence that the compulsory COVID-19 vaccination did little to persuade the already reluctant – rather, it increased levels of anger, especially in those who were already mistrustful of authorities (Bardosh et al. 2022). Research also indicates that the COVID-19 vaccine mandate energized anti-vaccination activism, reduced compliance with other public health measures, and decreased acceptance of future voluntary vaccines (Bardosh et al. 2022).

Now, there is considerable proof that important evidence concerning the effectiveness and safety of the COVID-19 vaccines was held back and not made available to the public (Demasi

2022). There is no scientific reason as to why the raw data should not be made fully and immediately available for public scrutiny (Doshi, Godlee, and Abbasi 2022). Instead, we have seen all kinds of attempts to keep relevant data away from inspection and analysis. If there is nothing to hide, openness and transparency are welcomed by all parties.

4. Discussion

Science is the practice that gives us the best knowledge – the most justified statements and beliefs – that are produced by the relevant scientific disciplines at a specific point in time (Hansson 2013; Hansson and Aven 2014). During the COVID-19 pandemic, we have seen this practice in action in many ways. We have seen how it has been misused, for example in relation to the issue of the origin of the coronavirus, refer to Section 2, when researchers and a scientific journal used ruling techniques to hamper scientific analysis and discussion. We have seen health officials referring to science to strengthen their recommendations and decisions, when, in fact, science could also be used to argue for the opposite conclusions. Science can help us make better decisions, but science is not one voice, one answer. Knowledge develops all the time, and there are always discussions and different views within and across scientific environments. Far too seldom did we see this acknowledged when governments and health agencies referred to science and used science to support their evaluations and decision-making. The COVID-19 pandemic has been characterized by some official views about key issues, for example that the vaccines are effective and safe, and these views should not be challenged. Perspectives and people challenging these views have been ignored, cancelled and even condemned. Highly recognized scientists were banned from social platforms, often as a result of pressure from the authorities, for questioning some aspects of these views. The media is supposed to challenge the authorities and the official views, but what we have seen is that the media to a large extent has acted as activists supporting the official views. The scientific process has been strongly hampered by the lack of support for research challenging the official views and by the media blocking debate about relevant uncertainties and risks.

Can all this be justified for the sake of good intentions, to obtain the best outcomes for the world and the nations' populations? No, is the clear answer, if we believe in science, democracy and human rights. Science is a powerful tool, but it has limitations in guiding us to what the best decisions are. Risk science tells us much about that. In the case of uncertainties, science cannot provide conclusive answers. The decision-making can be strongly influenced by how one judges the benefits relative to the risks, but the issue is also about values. Even in the case of rather strong knowledge, there can be disagreement about what decisions to make, as people have different values and priorities. That is, for example, why we have different political parties.

Science could not provide clear answer what to do in mid-March 2020 to meet the coronavirus outbreak, regarding, for example, the need for lockdowns and the use of face masks. We gradually obtained more knowledge, but there were uncertainties, and different conclusions were made in different countries and states, as discussed in Section 3.

A scientific attitude to research and science is to have a sound skepticism regarding insights and results obtained (Poortinga and Pidgeon 2003). Science does not produce the truth but claims about the truth. The knowledge obtained has limitations. When the economic incentives are as big as in this case, there is a special need to be concerned about actors having dubious motives. It could, however, be difficult to have such a skeptical perspective when quickly being threatened by proponents of the official view, who use derogatory terms like 'anti-vaxxer' and 'conspiracy theorist' to label you and weaken your authority. Healthy skepticism and due scientific processes are required, challenging the official view. Such skepticism also means to question the rationale and motivation behind claims about misinformation. Too often, we see that it is those raising concerns about misinformation that actually convey misinformation.

5. Conclusions

Many aspects of the COVID-19 pandemic failed. We do not for sure today know what the origin of the coronavirus was, but evidence suggests it could have been non-natural causes. Independent of this issue, we can make conclusions about the gain-of-function research that potentially led to this outbreak. The potential consequences of this type of research are extreme, and there are considerable related uncertainties. Hence, there is a serious risk involved in this type of research. It is difficult to see that potential benefits can outweigh this risk, a risk that could kill the human race. Arguing along these lines, there is no dilemma: not doing such research can potentially save lives, but the risk of the research is too high.

The pandemic is to a large extent about risks, in relation to the disease and the effect of the measure implemented to fight the disease. However, risk has not been adequately assessed, characterized and communicated in relation to COVID-19. The paper argues that this is due to a lack of access to and use of contemporary risk science knowledge but also to a lack of willingness to conduct open and honest risk analyses. The consequences of the poor assessments, characterizations and communications are that the decision makers have been poorly informed in many cases and potentially made the wrong decisions.

Efficient risk handling is not in conflict with policies of open and honest risk analyses and communication. The tendencies observed in this period, trying to control people's thinking by promoting only one official view, are a threat to science and the fundamental values that our democratic societies are built on. Debate and acknowledgment of different views are needed if we are to obtain new insights and have trust in the societal institutions.

Risk handling is about balancing different concerns, and science provides essential input. However, science has limitations, as we have all seen in relation to the COVID-19 pandemic. In mid-March 2020, science could not provide clear guidance on how to deal with the coronavirus outbreak, but urgent decisions were needed. The authorities gave weight to the precautionary principle. The paper argues that, given the uncertainties and the values at stake, this had a rationale. However, at later stages of the pandemic, such justification was difficult to make. Then, science could provide more insights and arguments, for example about keeping schools open. It was possible to provide arguments for the school closures, but, given the clear findings in some countries, it is difficult not to conclude that schools then should, as a rule, have been kept open.

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