Science, Policy and Resilience: Reflections on the Role of Scientific Advice to Government during Pandemic Crisis Response

Abstract

Purpose

The SARS epidemic in 2002 - 2004 and the COVID-19 pandemic had a disruptive impact on countries around the world and highlight the importance of using scientific evidence to inform policy decisions and priorities during crises. The purpose of this article is to reflect upon the term "following the science" and examines the differences between SARS in 2002 - 2004 and COVID-19.

Design/methodology/approach

This study is exploratory, adopts a qualitative approach and reflects on the synthesis of scientific evidence into advice informing government decisions on health interventions. Random sampling of the literature was used to avoid bias and was guided by the key words.

Findings

It considers preparedness activities and the need for these to be integral in the design of future planning and take a whole system approach. It argues that simulation exercises be intrinsically linked to all aspects of crisis management and provide the opportunity to use the scientific evidence base as part of preparedness planning. The article concludes that more transparency in the use of scientific advice in strategic decision making would support building more resilience into health emergency preparedness through an integrated systems approach.

Originality

This article contributes to the literature on the evaluation of the "following the science" approach and its implementation. It also contributes to the limited literature on simulation exercising to deal with health crises, like pandemics and identifies potential areas for further research or work on developing an integrated systems approach to pandemic preparedness.

Keywords : Science, Policy, Scientific Advice, Pandemic, Crisis Response

Article Classification : Conceptual paper

1. Introduction

In the past two decades, a succession of diverse emergencies have led to threats to public health and have challenged preparedness and response capacities of government agencies, the health service, public health agencies, and academic researchers, in the United Kingdom and globally. These crises include disasters resulting from natural hazards such as Hurricane Katrina, the earthquake in Haiti, and the tsunami that led to the Fukushima Daiichi nuclear reactor emergency (Lurie et al 2013). In addition, infectious disease emergencies present huge challenges as illustrated in the Severe Acute Respiratory Syndrome (SARS) epidemic in 2002 - 2004 and the Ebola epidemic in 2014-16. More recently, the COVID-19 pandemic dramatically illustrates the disruptive impact of crises on countries around the world as well as the profound importance of sound evidence-based policies for disaster risk reduction (DRR) to mitigate hazard losses, build disaster resilience, and contribute to sustainable development (Carabine 2015). Action toward strengthened DRR ideally builds from evidence-based policymaking to inform decisions and priorities (Nohrstedt et al 2021). The knowledge that is generated through well-designed, effectively executed research in anticipation of, in the midst of, and after an emergency is critical to our future capacity to better achieve the overarching goals of preparedness and response; which are, preventing injury, illness, disability, and death and supporting recovery (Lurie et al 2013).

Clinical and scientific research are vitally important in developing the evidence base when a range of potential policies and interventions need to be considered to aid effective crisis decision making and inform policy development (Molloy 2020; Lancaster et al. 2020). This process is used to address and reduce uncertainty which can be triggered by a new public health problem or crisis. Ideally, the process is multi-disciplinary, includes all relevant expertise and perspectives from relevant stakeholders and must recognise that advice may change as new evidence is uncovered. Therefore, it should also be regarded as a dynamic process facilitating adaptation to a rapidly changing situation during crises. There are two main aspects to this; the nature of the evidence that has been synthesised into advice and how that advice is used, or not used (Alexander 2021). In the UK case of COVID-19, the clinical and scientific research was regularly reviewed by the Scientific Advisory Group for Emergencies (SAGE). Published minutes of their meeting on 21st April 2020 revealed that the Group felt it necessary to clarify the roles of SAGE attendees. It stated that there are three categories of attendee; (i) scientific experts providing evidence and advice as part of the SAGE process; (ii) Her Majesty's Government (HMG) attendees listening to the discussion, to help inform policy work, and are able to provide the scientific experts with context on the work of government where appropriate and (iii) the members of the secretariat that attends in an organisational capacity (GOV.UK 2022).

During crises, the UK government uses the outputs from SAGE to inform policy which, during the COVID-19 crises, led to the use of the term "following the science" by the UK government. This article reflects upon the issues and themes associated with the term "following the science" and focuses on the use of this terminology during the COVID-19 pandemic and provides a comparison with the 2002 - 2004 SARS global epidemic. It examines the relationship between scientific advice and policy and considers whether this is an active or passive relationship; for example, is the term "following the science" an over-simplification of what is in practice a complicated process of synthesising scientific evidence into advice and subsequently into policy? Or, in the case of COVID-19, was it used as a mantra by the UK government to deflect responsibility to the clinical and scientific experts?

It is now commonly accepted that the synthesis of clinical and scientific evidence into scientific advice is of great importance during health emergencies, such as pandemics, and can inform the evidence-based decision making of government (Donovan 2021). It is also important to acknowledge the ongoing challenges and how experiences drawn from the current COVID-19 pandemic can input into planning for future crises. In any crisis, there will always be a requirement for rapid decision making even when information and data is uncertain, incomplete or absent. Scientific advice can inform strategic decision making; yet it remains only one part of a plethora of advice that may be required to help build a complete picture on which decisions can be based and, especially in the early stages of a crisis, the amount and nature of available information and data on which to base decisions will change rapidly over time. Therefore, effective situational awareness is essential to provide as complete a spectrum of available information from as many informed sources as possible that can aid governmental considerations on policy and its implementation, any specific impacts (such as on the economy), the implications of the decisions on society as a whole and, most importantly, clear communication by government to the public so that protective behaviours will be adopted (WHO 2004; Lewandowsky et al 2013).

Significantly, the public are less likely to be receptive to government advice on changing their behaviour if they perceive that any government is using "following the science" merely as a sound bite and this may contribute to confused and inconsistent public perceptions that may lead to and perpetuate a false sense of security. Furthermore, it can lead to difficulties in the public accepting that evidence-based decisions may require changes in direction as the respective situation changes and more information and data becomes available. Enhancing public understanding remains essential to avoid mixed messaging and confusion, reduce any potential erosion of public trust at a time when long-term public engagement remains critical as well as ensure public acceptance that following decisions from government will protect them and keep them safe from harm.

The ramifications of the both the SARS epidemic 2002 – 2004 and the COVID-19 pandemic illustrate how outbreaks of transmissible diseases give rise to substantial political, economic, and social challenges as societies do their utmost to stop, or at least hinder, the spread of the disease. This will inevitably involve the application of medical, microbiological, behavioural and social sciences, with advice from the relevant experts to inform government policy (Larson 2021). However, this article argues that COVID-19 has demonstrated that the provision of expertise to inform decision making may need to be expanded further to include emergency planners, economists and business leaders in order to consider fully the health, scientific and socio-economic challenges that a global pandemic presents (Guardian 2020, 05 05).

At any point during an emergency, scientists can synthesise the currently available scientific evidence into advice; but ultimately, it is for government to use or ignore the evidence. Governments make decisions and scientific advice is invariably only one of the elements that they need to consider. Therefore, considering the scientific advice and synthesising this into government decisions is more complex than simply "following the science", and transparency and clarity around this process is essential.

The focus of this study was to examine the clinical and scientific advice on non-pharmaceutical interventions (NPIs) and the synthesis of this advice into government policy within the context of the UK government mantra of "following the science" during the COVID-19 pandemic and comparing this with actions taken by other countries during the SARS epidemic in 2002 - 2004. This study adopted an exploratory approach using qualitative methodology. Random sampling of the literature was used to avoid bias and was guided by the key words; science, policy, scientific advice, pandemic, crisis response. Peer reviewed publications and grey literature were searched using websites and databases, including PubMed, Scopus, EMBASE, ScienceDirect, Wiley Online Library, BMJ Journals, WHO publications and government publications, including a comprehensive search of SAGE and SAGE sub-group proceedings. A total of 92 publications were retrieved that were relevant to the study and a total of 43 with the most relevance to this article were examined in detail.

2. What can we learn from past and present health emergencies on the role of scientific advice?

The term "following the science" is a very broad term and is often based on two principles. First, it often represents an assessment based on presently available data and trends. Second, 'the science' is usually a majoritarian affair. When scientists consider the evidence and formulate advice, it is reasonable to expect that not all scientists will agree on all of the issues and on the interpretation of the evidence. Nevertheless, the government still has to base their decisions on the evidence presented and will often seek to emphasise the solidity and cohesiveness of the science on which decisions are based. This can lead to tensions between the policy makers and scientists, policy makers like to present their decisions and policies as the unanimous view, however, the reality is often different. It is the role of science to interpret the evidence and provide advice, and there may be different interpretations to be considered by policy makers, inevitably it is for the policy makers to consider the advice provided by scientists and make accountable decisions based on the advice; it is not simply "following the science".

Several examples are presented here that demonstrate how clinical and scientific evidence has been considered and used in crises, with a focus on NPIs which highlights the complexity of the synthesis of scientific evidence into advice especially when acknowledging the psycho-social acceptance and impacts of these types of intervention. Public perceptions should be considered to best tailor and communicate policy approaches that need public support. Also, consideration needs to be given as to how perceptions change over the course of a pandemic/epidemic to help inform policy and sequencing of policy. SteelFisher et al (2012) provided evidence from the H1N1 influenza pandemic that indicated that some behaviours are likely to be more widely adopted than others, since certain behaviours were adopted by a majority of the public in different countries during the H1N1 influenza pandemic. Their research indicates that public perception of factors such as prevalence of illness, government responses, availability and cost of interventions and the media's portrayal of these factors are grounded in each affected country's culture, values and practices.

This article presents a comparison between the SARS epidemic 2002 - 2004 and the current situation with respect to the use of scientific advice during the COVID-19 pandemic. The SARS epidemic 2002 – 2004 reached 29 countries across the world including major outbreaks in Canada (Artbuthnott and Calvert 2021) and a number of UK scientists were involved in the international response to SARS in 2002 - 2004 (WHO 2004). The UK had 4 suspected cases; this, plus the global reach of SARS prompted public health action in the UK to prepare for a potential increase in confirmed cases (Chow et al. 2003). Subsequent to this, the focus was primarily on influenza as the next potential pandemic threat. The UK felt it had world-leading pandemic plans which may have been why between 2017 – 2019 it chose to focus on Brexit as the next potential national emergency, especially in preparing for a no deal Brexit. The approach was very different in countries who had experience of a greater number of cases and deaths in the SARS epidemic in 2002 - 2004 (Arbuthnott and Calvert 2021).

The widespread SARS epidemic in 2002 - 2004 was contained in human populations largely by the aggressive use of traditional public health interventions (Bell 2004). However, there was a key difference between the SARS virus in 2002 - 2004 (SARS-CoV1) and the SARS-CoV2 virus (the causative agent of the disease COVID-19) that emerged in late 2019 in that pre-symptomatic transmission was not observed in the SARS-CoV1 outbreak. The SARS-CoV2 virus replicates in the upper respiratory tract in contrast to SARS-CoV1 which is a less contagious lower respiratory tract virus (van Doremalen et al. 2020, Wölfel et al. 2020, WHO; 2020). In the case of SARS-CoV1 in 2002 – 2004, infectivity in most patients was low at onset of illness and seemed to peak during week 2 of illness in association with maximal respiratory symptoms, when patients were often in isolation in hospital. Virus transmission was primarily by respiratory droplets, with little natural airborne dissemination but some environmental spread. Cases among children were uncommon, and children did not seem to be involved in transmission (Bell 2004). The spread of SARS-CoV1 bears some similarities to the mode of transmission of other respiratory viruses such as influenza. This may be one of the reasons why pandemic influenza planning was followed in the early stages of the COVID-19 pandemic in the UK (Guardian 2020, 05 21).

The 2002 - 2004 outbreak of SARS is a modern example of containing a global epidemic through recognised NPIs. The interventions included finding and isolating case-patients; quarantining contacts; measures to "increase social distance," such as cancelling mass gatherings and closing schools; recommending that the public augment their personal hygiene and wear masks; and limiting the spread of infection by domestic and international travellers, by issuing travel advisories and screening travellers at borders (Bell, 2004).

This article now reflects upon the term "following the science" and a number of themes are considered here to examine similarities and divergencies in the synthesis of scientific evidence into policy and advice on NPIs during both crises. The authors explore whether it was going to be possible to contain the COVID-19 pandemic with the same measures as used for SARS in 2002 - 2004.

2.1 Quarantine

Quarantine is not a new concept and can be traced back in history where the importance and value of quarantine was recognised even though at the time there was no concept of a pathogen causing the disease (Hines et al. 2020). The modern concept of quarantine differs greatly from quarantine in past centuries. In SARS 2002 - 2004, in several countries, quarantine was legally mandated and monitored and in others, compliance was "requested" (Ying-Hen Hsieh et al. 2005). In the SARS epidemic, identifying those infected combined with rapid identification and management of contacts, including quarantining contacts, were highly effective in interrupting transmission in several countries.

Quarantine and isolation of infected individuals has also been used as a strategy in COVID-19 and it can be argued that this strategy was going to be less effective than for SARS in 2002 – 2004 because in SARS-CoV1 the peak phase of viral shedding occurred after patients were symptomatic with respiratory symptoms. Compare this with COVID-19 where transmission occurs during the early phase of illness; therefore, quarantine and isolation of symptomatic individuals may be too late to ensure transmission is interrupted. In addition, temperature screening is less effective because of the higher transmissibility of COVID-19 and community spread is also more prevalent with COVID-19. However, in minutes of SAGE meetings held in March 2021, they concluded that identifying and isolating infectious people can have a significant impact on transmission by eliminating many of the opportunities for transmission and that Test, Trace and Isolate (TTI) systems are key, along with self-isolation and quarantine after international travel. The decision to implement this strategy was largely based on evidence from SAGE and modelling studies (SAGE 2021, Grassly et al. 2021). The strategy was later revised in October 2021 when more data became available on the use of daily lateral flow testing or a combination of lateral flow tests and polymerase chain reaction (PCR) tests having the potential to control transmission (SAGE SPI-M-O 2021, Steyn et al. 2022).

While the two outbreaks (SARS-CoV1 and SARS-CoV2) were very different with respect to transmission, for both outbreaks quarantine and isolation were probably important in slowing down the spread of the viruses and, with COVID-19, this and the later addition of testing, slowed the spread until vaccines became available.

2.2 Facemasks or Face Coverings

The use of face masks as a control measure has also been seen in the past. Many people living in heavily polluted cities have got used to wearing protective face masks and it followed that they were willing and keen to wear them during outbreaks and epidemics in the 20th century such as SARS-CoV1 and Middle Eastern Respiratory Syndrome (MERS). In the example of face masks, at the beginning of the COVID-19 pandemic, there was little direct scientific evidence as to whether face masks are effective in reducing the spread of respiratory infections. However, many practices that we consider essential for good hygiene, such as washing hands to reduce transmission of infections, or the wearing of masks by surgeons, prior to COVID-19, were not based on evidence from research studies. Rather, they were based on our understanding of how infections spread. In the case of COVID-19, people can be infectious even when they are pre-symptomatic and they can transmit the virus by coughing, sneezing, and even talking or breathing which releases droplets from the mouth that are a key mode of transmission of COVID-19.

In April 2020, the guidance on the wearing of face masks in community settings was confusing with the World Health Organisation (WHO) at the time not recommending the use of face masks for healthy individuals, Public Health England (PHE) made a similar recommendation. By contrast, the United States Center for Disease Control (US CDC) advised the wearing of cloth masks and many countries such as Canada, South Korea and the Czech Republic, required or advised their citizens to wear masks in public places. Eventually, WHO and PHE revised this guidance (Harrison and Duval 2021). This, in addition to other evidence was reviewed by SAGE in April 2020 and they concluded that “the evidence is not clear or is weak”. Although it has become accepted by scientists that the precautionary principle seems to argue that masks should be recommended even if the case for adopting them is not 100% watertight. In addition, recent evidence shows that face masks or face coverings have some effect in reducing the spread of these droplets and can provide some protection to the wearers and those they come into contact with (Brainard et al. 2020; Cheng et al. 2022; Stutt et al. 2020).

Therefore, when the threat and risk stakes are high, employing the precautionary principle may be the appropriate approach to take, especially if the scientific data is uncertain, incomplete or absent. It was the development of the understanding of modes of transmission of SARS-CoV2 and the need for precautionary action that convinced governments to recommend or mandate the use of face masks as mandatory in situations where physical distancing is not possible such as public transport, shopping centres and other crowded public spaces or workplaces.

Given the central role that "following the science" has taken in this and other strategic decisions that the government has made during the COVID-19 pandemic, this serves to further demonstrate how the tensions between science and policy can arise as policy makers so often use the evidence presented selectively or may even ignore it completely while still maintaining that they are "following the science".

2.3 Social Distancing

In the SARS-CoV1 epidemic in 2002- 2004, measures to increase social distancing, for example, cancelling mass gatherings; closing schools, theatres, and public facilities; and requiring masks for all persons using public transport, working in restaurants, or entering hospitals, were implemented in areas where extensive community transmission was suspected. Many people in these areas also chose to wear masks outside their homes. These measures were often applied simultaneously with other measures, including enhanced contact tracing.

Is this also the case for the SARS-CoV2 virus and did the scientific evidence support the development of policy in this area? As with the previous examples of quarantine and the wearing of face coverings, there are a number of expert views on social distancing during the COVID-19 pandemic (Jones et al. 2020). There is consensus on social distancing being an important measure for controlling the virus but scientific argument as to exactly how, for example, 1 or 2 metres, and for how long (Jones et al. 2020). A paper produced by SAGE in June 2020 serves to demonstrate the different scientific views and sets out the environmental and personal mitigation measures in a number of countries. While there are differences with respect to other mitigation measures, there is a consensus on recommending 1 – 2 metres social distancing across different countries. These findings ultimately influenced the policy on 2 metres social distancing as a mitigation measure in the UK (SAGE, June 2020).

It could be argued that at the time of writing, the evidence on social distancing remains incomplete and for both SARS-CoV1 and SARS-CoV2 it may have been the simultaneous introduction of a variety of mitigation measures that was temporally associated with declines in new cases. Again, it may be that when data is incomplete or missing, policy needs to take account of the science but also follow the precautionary principle and take rapid and decisive actions so as not to communicate confusing and conflicting messages to the public and those working in professional settings. Adopting the approach and messaging of simply "following the science" does not take into account the complex scientific, behavioural and other issues that need to be considered and this may ultimately lead to considerable delays in implementing the critical policy and actions needed to limit the spread of a highly contagious pathogen (Arbuthnott and Calvert 2021).

2.4 Communication of evidence-based health messages

The synthesis of scientific evidence into advice that inform government decision making and policy is also important in producing evidence-based health massages from government to the public. Effective communication with the public is critical in promoting protective behaviours for the individual and communities. The use of catch phrases has consistently proved effective in terms of delivering public messaging during past pandemics and epidemics. In the 2009 Swine Flu pandemic the phrase 'Catch It, Bin It, Kill It ' was advertised widely and was also used again during the COVID-19 pandemic in the UK. Also, during the COVID-19 pandemic, in daily press briefings, we were reminded to 'stay at home, protect the NHS, save lives ', later we were told the more confusing message to 'stay alert, control the virus, save lives', where "stay alert" is arguably more subjective and less clear than "stay at home". The other aspect of this is for government and public health officials to work with the media to provide a clear interpretation of public health messages so that actions can be taken by the public to protect individuals and society as a whole (Hines et al. 2021). Therefore, "following the science" needs to be more clearly explained to the public so that the rationale for health interventions is clear and more likely to be trusted and adopted. Again, successful communication of 'following the science' needs to carefully balance clear messaging of recommendations and outcomes that will be based on complex scientific and behavioural issues and concepts.

Within reason, scientific advice should be made public, plus the names of those giving it. The UK government has been criticised for keeping secret the membership of SAGE. This led eventually to the minutes of scientific meetings being published. For clarity and transparency, this should have been done promptly, in the same way as other publicly accountable committees. The public can then weigh politicians' pandemic choices against advice they receive. Clear messaging and transparency is vital when exceptional sacrifices are being demanded of the public.

This pandemic has tested the role of science and scientists in the management of a national and global challenge and it is important that the advice is independent. COVID-19 is a new virus and a highly contagious and mutating disease, therefore, the shifting of policy based on changing data is to be expected. However, the conflicting advice (with other countries and even with other nations in the United Kingdom) and guidance on face coverings and other issues may erode the trust of the public in science and experts, unless the cause of the shifts in strategies is clearly explained. In early May 2020, a survey conducted by the Open Knowledge Foundation found that public trust in science had increased following the pandemic but that transparency is key (Greenhalgh 2020). By taking time to explain the scientific evidence, rather than using the simplistic term "following the science", governments will be accountable by being as transparent as possible during a rapidly developing crisis when the nature of evidence is ever-changing.

3. Planning for future pandemics and the integration of scientific advice

As we saw with the SARS-CoV1 epidemic and now in the current COVID-19 pandemic, there are actions that need to be taken to ensure effective planning for future health emergencies. These include, evaluating the effectiveness of public health interventions in terms of cases detected, cases prevented, costs, and alleviating public concerns; identifying ways to make quarantines and other restrictions more focused and less burdensome for society; an assessment of how "leaky" restrictions can be before they become ineffective; and developing rapid diagnostic tests (WHO 2004). The WHO report following the SARS-CoV1 epidemic also stated that in the event of future outbreaks, these issues would need to be studied so that decisions can be based on the best scientific evidence and information (Abbasi, K. 2020). In this way, the science can be considered for the public good; incorporating awareness and appreciations of the complex factors that may be impactful, such as human interactions and behaviours, rather than government using the term "following the science" without providing the evidence and reasoning behind the policy decisions.

Added to this, scientists advising government committees should not feel constrained in warning politicians, who, in turn, need to engage sufficiently to challenge the scientific evidence and ask the crucial questions, for example, "what does this mean for beds? What would this mean for care? Can we track these people? Can you do contact tracing? How many tests would we need to do?”. There is a danger that scientists will try to present data in relation to what they expected was feasible politically and it is up to the politicians to pose questions that will open up as many options as possible to inform decision making (Arbuthnot and Calvert 2021).

While it is important to take forward recognised priorities after each health emergency, scientific advice should not be seen as important only during emergencies. For many years, pandemic influenza has been the highest risk on the UK Government’s National Risk Register (this was updated in 2020 to pandemics). The Government tested its pandemic planning in Exercise Cygnus in 2016. Exercise Cygnus provided a realistic scenario and demonstrated that a pandemic would severely stretch the resources of the health system in the UK. Therefore, in planning for future pandemics there needs to be provision for an escalation in the response to novel viruses with the potential to cause a pandemic and the capacity to deal with a surge in demand across the health and social care sector. Some of the lessons from Exercise Cygnus were not taken forward fully into preparedness planning (House of Lords Select Committee Report 2021; Guardian 2020, 05 07). Effectively implementing lessons from simulation exercises as part of the planning and preparation for the most important known risk of the emergence of a novel virus with pandemic potential is critical. Pandemic planning has historically focused on pandemic influenza and not on other potential causes. Likewise, exercises tended to focus on the health system response rather than a wider systems approach. In future planning, it is critical to take a wider systems approach and not purely focus on health preparedness and response (Reddin et al. 2021). This should include building the concept of “following the science” into and be tested in simulation exercises to discern the level of impact and the implications for the options open to policymakers and emergency managers during the onset of pandemics.

Those countries that had first-hand experience of SARS-CoV1 and of MERS were also the best prepared for COVID-19. However, putting large resources into pandemic planning, is perceived as being at the expense of capacity in health services. Yet as we have seen from the COVID-19 pandemic if planning resources are insufficient or delayed it can lead to huge human and economic costs. In many ways, it can now be argued that not putting resources into preparing for known high risks is false economy.

It is critical that an analysis of the mistakes made during the COVID-19 response is carried out and the lessons are identified and acted upon to develop resilience towards the known high-risk threats. Preparedness activities, such as simulation exercises do not just need to highlight the need for adaptation, they also need to be integral in the design of the future planning based on the outcomes stemming from them. Hence exercises should not be seen as just static instruments but also intrinsically linked to follow up and action plans, including the synthesis of evidence into scientific advice as an integral part of preparedness planning (Reddin et al. 2021).

Policy informed by the evidence base should be based on as complete knowledge of a problem as the evidence will allow (Gaillard and Mercer 2013). In addition to consulting academics and advisors during an emergency, more importance should be given to this as part of the planning for emergencies, such as in simulation exercises, in order to test the systems for gathering the evidence base, interpretation of the evidence and the synthesis of the evidence into policy and guidance which is clear without misleading people. Evidence can constrain uncertainty, but it cannot eradicate it (Alexander 2021).

To facilitate this more effectively, emerging technologies should be used in preparing for future emergencies (Whitelaw et al. 2020). Using Artificial Intelligence (AI) has the potential to use simulations and AI prediction models to inform preparedness and crisis response procedures and result in resources being utilised more efficiently. In addition, computer modelling continues to be used in simulation exercises to support decision-making. A combination of technologies, such as AI and Virtual Reality (VR), could be used in simulated scenarios to exercise the synthesis of scientific advice to support decisions made during the timeline of the exercise. This should not only be applied to simulations exercises in the health sector but instead should take an integrated, cross-sector approach. Furthermore, AI technologies could also be applied in preparing for outbreak detection, surveillance and containment in infectious disease scenarios and be a useful tool for providing immersive environments for simulation exercises for preparedness and response and associated interventions which may be particularly useful at the strategic level (Reddin et al. 2021). It is critical for the simulations to be realistic and scalable, and for the tools to be accessible and easy to use and accurately model the environment in which the data is collected (Kecskemeti et al. 2017).

4. Discussion and Conclusion

The current COVID-19 pandemic has had huge effects world-wide and it is reasonable to assume that a more severe virus will emerge in the future. This risk, combined with other risks, such as climate change and loss of biodiversity, has the potential to have a catastrophic impact on human and animal populations and the environment. It is, therefore, critical that extensive analysis of the learning from the COVID-19 response is carried out and the lessons are identified and acted upon to develop resilience towards known high-risk threats.

While there was a key difference between SARS-CoV1 and SARS-CoV2 in that pre-symptomatic transmission was not observed in the SARS-CoV1 outbreak, as with the response to any emerging virus, the synthesis of clinical and scientific evidence into scientific advice has been an important part of the response and key to informing government decision-making. It is also important to recognise the challenges that this presents and have systems in place that allow the experience from the current COVID-19 pandemic to inform planning for future crises.

Due the existential nature of the COVID-19 pandemic, it will take a long time for the evidence to be complete enough to establish how the evidence base was used and what lessons to take forward from this. Nevertheless, this does not mean that some of the principles discussed here regarding how the synthesis of the evidence into advice and guidance is integrated into future crisis planning should be delayed until a complete picture has emerged. There are actions that need to be taken now to ensure effective planning for future health emergencies. These include, evaluating the effectiveness of public health interventions and identifying ways to make quarantine and other restrictions more focused and less burdensome for individuals and communities and the ability to develop rapid diagnostic tests (WHO 2004).

The use of simulation exercises should carry increasing importance as an integral part of the planning process, as should the effective implementation of the lessons from these simulations. As COVID-19 has shown us, exercises as part of the planning and preparation for the most important known health risk of the emergence of a novel virus with pandemic potential, is critical. Pandemic planning has historically focused on pandemic influenza and not on other potential causes (Guardian 2020, 05 21) and simulation exercises have tended to focus on the health system response rather than a wider systems approach. Therefore, in future planning, it is critical to take a wider systems approach and not purely focus on health preparedness and response. This should include building the concept of “following the science” into and tested in simulation exercises to discern the level of impact and the implications for the options open to policymakers and emergency managers during the onset of pandemics and build in an assessment of not only what is the evidence?” but was it used and how it was used or was it ignored?

Preparing more effectively for identified risks and more transparency in the use of scientific advice in strategic decision making would support the case for building more resilience into health emergency preparedness. This will require significant and long-term investment and should take an integrated systems approach. During crises, as observed during both SARS-CoV1 and in the COVID-19 pandemic, there will invariably be a requirement for decisions on issues that will inform the re-opening of economies. This is irrespective of whether any re-opening is presented either as ‘returning to business as usual’ or as recognising ‘a new normal’. Therefore, the provision of advice must go beyond the clinical and scientific. Throughout COVID-19, advice was provided by clinicians, epidemiologists, psychologists and behavioural scientists, through SAGE and its sub-committees. This article concludes that respective expertise should be widened to include emergency planners, economists and business leaders to assist in advising governments on complex issues through a more integrated whole system approach. Although this will make ‘following the science’ more complex and challenging, politicians and policymakers must seek out and heed but also challenge advice in order to determine the science and evidence for policy rather than simply using the term “following the science” as a mantra during a crisis.

References

Abbasi, K. (2020). COVID-19: politicisation, "corruption," and suppression of science: *BMJ*; 371: m4425. Published: 13 November 2020. Available from: http://dx.doi.org/10.1136/bmj.m4425.

Alexander, D. E. (2021). On Evidence-Based Practice in Disaster Risk Reduction. *Int J Disaster Risk Sci.* Published online 15th November 2021. www.ijdrs.com. Available from: https://doi.org/10.1007/s13753-021-00381-3

Arbuthnott, G. and Calvert, J. (2021). *Failures of State : The Inside Story of Britain's Battle with Coronavirus.* HarperCollins Publishers London.

Bell, D.M. (2004). In Public Health Interventions and SARS Spread and World Health Organization Working Group on Prevention of International and Community Transmission of SARS1 : *Policy Review in Emerging Infectious Diseases* www.cdc.gov/eid; Vol. 10 (11).

Brainard, J., Jones, N., Lake, I., Hooper, L. and Hunter, P.R. (2020). Facemasks and similar barriers to prevent respiratory illness such as COVID-19: A rapid systematic review. Available from: https://doi.org/10.1101/2020.04.01.20049528

Carabine E. Revitalising Evidence-based Policy for the Sendai Framework for Disaster Risk Reduction 2015-2030: Lessons from Existing International Science Partnerships. *PLoS Curr*. 2015 Apr 23;7:ecurrents.dis.aaab45b2b4106307ae2168a485e03b8a. Published online 2015 April 23. doi: 10.1371/currents.dis.aaab45b2b4106307ae2168a485e03b8a

Cheng, K.K., Lam, T.H. and Leung, C.C. (2020). Wearing face masks in the community during the COVID-19 pandemic: altruism and solidarity. *The Lancet*.

Chow JY, Anderson SR, Delpech V, et al. (2003). SARS: UK public health response--past, present and future. *Communicable Disease and Public Health*; 6(3), 209-215. PMID: 14708270.

Donovan, A. (2021). Experts in emergencies: A framework for understanding scientific advice in crisis contexts. *International Journal of Disaster Risk Reduction*, 56. Available from: https://doi.org/10.1016/j.ijdrr.2021.102064. (https://www.sciencedirect.com/science/article/pii/S2212420921000303)

Grassly, N. C., Ainslie, K. et al. (2020). Comparison of molecular testing strategies for COVID-19 control: a mathematical modelling study *The Lancet Infectious Diseases*, 20 (12), 1381 – 1389. Available from: https://www.thelancet.com/article/S1473-3099(20)30630-7/fulltext

Greenhalgh, T. (2020). Face coverings for the public: Laying straw men to rest; *J Eval Clin Pract.*;26:1070–1077. Available at: wileyonlinelibrary.com/journal/jep. Accessed 17/01/2021

Guardian. (2020, 05 05). Alexander, D. *Britain is in a state of emergency. So, where are its emergency planners?* https://www.theguardian.com/commentisfree/2020/may/05/britain-emergency-planners-pandemic-government. Accessed 18th August 2022.

Guardian. (2020, 05 07). *What was Exercise Cygnus and what did it find?* Available from: The Guardian : https://www.theguardian.com/world/2020/may/07/what-was-exercise-cygnus-and-what-did-it-find. Accessed 14th December 2021.

Guardian. (2020, 05 21). *Covid-19: did the UK government prepare for the wrong kind of pandemic?* Available from: The Guardian : https:\\www.theguardian.com/world/2020/may/21/did-the-UK-government-prepare-for-the-wrong-kind-of-pandemic. Accessed 14th December 2021.

Harrison, S., Duval, D., Walters, B., Sadler, S., Pearce-Smith, N. and Clark, R. (2021).The effectiveness of face coverings to reduce transmission of Covid-19 in community settings : A rapid review. Available from: PHE document (koha-ptfs.co.uk).

Hines, K., Reddin, K.M. and MacDonald, G. (2021). Review of the UK's Preparedness and Response to the Covid-19 Pandemic, ICPEM; March 2021 provided as written evidence to the *House of Commons Health and Social Care and Science and Technology Committees on Coronavirus: Lessons Learned Report* 12th October 2021. Available from: HC_HSC Select Cttee_CoV LL to date_Oct2021.pdf

House of Commons (2021). *House of Commons Select Committee Report* (2021). Available from: HC_HSC Select Cttee_CoV LL to date_Oct2021.pdf

House of Lords (2021). *House of Lords Select Committee Report* (2021). Available from: House of Lords Slect Cttee Risk Assessment and Risk Planning REPORT Dec 2021.pdf

Jones, N.R., Qureshi, Z.U., Temple, R.J., Larwood, J.P.J., Greenhalgh, T., Bourouiba, L. et al. (2020). Two metres or one: what is the evidence for physical distancing in covid-19? *BMJ*; 370: m3223 doi: 10.1136/bmj.m3223.

Kecskemeti, G., Casale, G., Jha, D.N., Lyon, J. and Ranjan, R., 2017. Modelling and simulation challenges in internet of things. *IEEE cloud computing*, *4*(1), pp.62-69.

Lancaster, K., Rhodes, T. and Rosengarten, M., (2020). Making evidence and policy in public health emergencies: Lessons from COVID-19 for adaptive evidence-making and intervention. *Evidence and Policy*, 16(3), pp.477-490.

Lewandowsky, S., Gignac, G.E., Oberauer, K. (2013). The Role of Conspiracist Ideation and Worldviews in Predicting Rejection of Science. *PLoS ONE* 8(10): e75637. doi:10.1371/journal.pone.0075637.

Lurie, N., Manolio, T., Patterson, A.P., Collins, F. and Frieden, T. (2013). Research as a Part of Public Health Emergency Response. *N Eng J Med* 368;13.

Molloy, A. (2020). Knowledge Management In: *Healthcare Public Health.* Edited by: Martin Gulliford and Edmund Jessop, Oxford University Press. DOI: 10.1093/oso/9780198837206.003.0008.

Nohrstedt, D., Parkera, C. F., von Uexkulla,N., Mårda, J., Albrechta,F., Petrova, K., Nyberga, L., G¨otemana, M., Hilemana, J., Messoria, G., Di Baldassarrea, G. (2021). *International Journal of Disaster Risk Reduction* Vol. 67 (2022). 102661. Available online 29 October 20212212-4209/© 2021 www.elsevier.com/locate/ijdrr. Available from: https://doi.org/10.1016/j.ijdrr.2021.102661

Reddin, K.M., Bang, H. and Miles, L. (2021). Evaluating Simulations as Preparation for Health Crises like CoVID-19: Insights on Incorporating Simulation Exercises for Effective Response. *International Journal of Disaster Risk Reduction.* Available from: https://doi.org/10.1016/j.ijdrr.2021.102245

SAGE (2020). Available at: Transmission of SARS-CoV-2 and Mitigating Measures (publishing.service.gov.uk). Accessed 17th January 2022.

SAGE (2021). Considerations in implementing long-term 'baseline' Non-Pharmaceutical Interventions (NPIs). Available at: S1216_Considerations_in_implementing_longerterm_baseline_NPIs.pdf (publishing.service.gov.uk). Accessed 19th January 2022.

SAGE (2022). Available at: S0396_Twenty-seventh_SAGE_meeting_on_Covid-19.pdf (publishing.service.gov.uk) Accessed 17th January 2022.

SPI-M-O (2021). Summary of modelling for scenarios for COVID-19 autumn and winter 2021-22 Date: 13th October 2021. Available at:

S1383_SPI-M-O_Summary_autumn_winter_scenarios.pdf (publishing.service.gov.uk) accessed 19th January 2022.

So, E. and Baker, H.; Mask or no mask? A look at UK's policy over time – *CRASSH*. Available from (cam.ac.uk)

SteelFisher, G. K., Blendon, R. J., Ward,R. J. M., Rapoport, R., Kahn, E. B. and Kohl, K. S. (2012). Public response to the 2009 influenza A H1N1 pandemic: a polling study in five countries. *The Lancet Infectious Diseases*, 12 (11), 845-850. Available from: https://doi.org/10.1016/S1473-3099(12)70206-2. (https://www.sciencedirect.com/science/article/pii/S1473309912702062)

Steyn, N., Lustig, A., Hendy, S.C., Binny, R.N. and Plank, M.J. (2022). Effect of vaccination, border testing, and quarantine requirements on the risk of COVID-19 in New Zealand: A modelling study. *Infectious Disease Modelling*, 7, 184 – 198. Available from: https://doi.org/10.1016/j.idm.2021.12.006

Stutt, R.O.J.H., Retkute, R., Bradley, M., Gilligan, C.A. and Colvin, J. (2020). RA modelling framework to assess the likely effectiveness of facemasks in combination with 'lock-down' in managing the COVID-19 pandemic. https://doi.org/10.1098/rspa.2020.0376. Available at: https://royalsocietypublishing.org. Accessed: 2nd December 2020.

van Doremalen, N., Bushmaker, T., Morris, D.H., et al. (2020). Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. *N Engl J Med*. 382: 1564- 1567. Available from: https://doi.org/10.1056/NEJMc2004973

Whitelaw, S., Mamas, M. A., Topol, E. and Van Spall, H. G. C. (2020). Applications of digital technology in COVID-19 pandemic planning and response. *The Lancet Digital Health*; vol 2. Available from: www.thelancet.com/digital-health.

WHO (2004 a). World Health Organization Scientific Research Advisory Committee on Severe Acute Respiratory Syndrome (SARS). *Report of the first meeting, Geneva, Switzerland, 20–21 Oct 2003*. Available from: http://www.who.int/csr/resources/publications/WHO_CDS_CSR_G AR_2004_16/en/

WHO (2004 b). Best practices for communicating with the public during an outbreak. Report of the WHO Expert Consultation on Outbreak Communications held in Singapore, 21–23 September 2004. *Communicable Disease Surveillance and Response*. Available from: http://www.who.int/csr

WHO (2020). Available at: https://www.who.int/news-room/commentaries/detail/modes-of-transmission-of-virus-causing-covid-19-implications-for-ipc-precaution-recommendations. Accessed 14th December 2021.

WHO (2020). Available from: WHO Changes Stance, Says Public Should Wear Masks (webmd.com). Accessed 14th December 2021.

Wölfel R, Corman VM, Guggemos W, et al. (2020). Virological assessment of hospitalized patients with COVID-2019. *Nature*; 581; 465 – 469. *Modes of Transmission of Virus Causing COVID-19: Implications for IPC Precaution Recommendations*.

Ying-Hen, H., King,C-C., Chen, C.W.S., Ho, M-S., Lee, J-Y., Liu, F-C., Wu, Y-C. and Wu, J-S. J. (2005). Quarantine for SARS, Taiwan. *Emerging Infectious Diseases*. Vol . 11 (2). Available from: www.cdc.gov/eid