


A pyramid model to describe changing decision making under high uncertainty during the COVID-19 pandemic

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ABSTRACT

The COVID-19 pandemic put healthcare systems, hospitals and medical personal under great pressure. Based on observations in Germany, we theorise a general model of rapid decision-making that makes sense of the growing complexity, risks and impact of missing evidence. While adapting decision-making algorithms, management, physicians, nurses and other healthcare professionals had to move into uncharted territory while addressing practical challenges and resolving normative (legal and ethical) conflicts. During the pandemic, this resulted in decisional uncertainties for healthcare professionals. We propose an idealised risk-based model that anticipates these shifts in decision-making procedures and underlying value frameworks. The double pyramid model visualises foreseeable procedural adaptations. This does not only help practitioners to secure operational continuity in a crisis but also contributes to improving the conceptual underpinnings of the resilience of healthcare during the next pandemic or similar future crises situations.

INTRODUCTION

In view of the complexity and dynamism of pandemic events,¹ the resilience of all organisational processes in healthcare systems is challenged. Observations and data from German clinics during the COVID-19 pandemic (OnCovid-Trials) demonstrate that exceptional circumstances have made it necessary to adapt existing rapid decision-making structures and procedures. This includes the acquisition and the transfer of knowledge (evidence generation). The adaptation process had to be continued iteratively during the exponential phase of the infection process.² It added to the already considerable psychological stress for human decision making under complex conditions with insecure knowledge.³ Since the human psyche tends to react comparably in such critical crisis situations, modelling the necessary adjustments to decision-making procedures in phases of great uncertainty and high risks can support future decision-makers in their

KEY MESSAGES

- ⇒ The COVID-19 pandemic induced extensive decisional uncertainty and conflicts for all stakeholder groups.
- ⇒ While adapting decision-making algorithms, management, physicians, nurses and other healthcare professionals as well as patients faced practical challenges and severe normative conflicts.
- ⇒ The idealised risk-based model can assist in dealing with the underlying loss of evidence and strengthen the resilience of healthcare organizations during the next crises situations.

development of problem-solving skills. The insights derived from the dynamic adaptation processes are not specifically associated with the COVID-19 pandemic but can be seen as a particularly strong manifestation of a supply crisis in a healthcare system.⁴⁻⁶ Most of the considerations regarding the management of a pandemic situation in the healthcare sector can, therefore, be generalised and transferred to other transformation processes with a similarly high level of uncertainty.

DECISION-MAKING AND UNCERTAINTY

A characteristic defining the course of a pandemic is that professionals have to switch from normal operating mode to making urgent decisions against the backdrop of usually non-existing or deficient evidence and a complex spectrum of (scientific) uncertainty. While in the healthcare sector uncertainties in decision making are normal for everyday life, they usually remain within a limited area of action, which makes the application of limited clinical evidence (eg, in oncology) manageable. This 'common' uncertainty is expressed, for example, in statistical confidence intervals in clinical trial results, but also in parameter constellations in clinical situations that do not exactly match inclusion and exclusion criteria of



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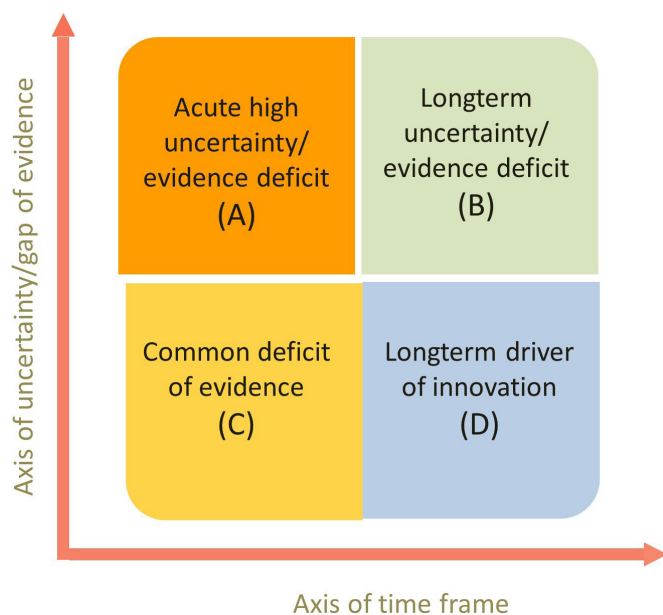


Figure 1 Determinants for the emergence of decision-making difficulties. Decisions can be classified on a time axis according to their effectiveness, both with regard to the required short-term nature of the decision-making process as well as the occurrence of significant effects ((A, C) short-medium term; (B, D) medium-long term). At the same time, there are different degrees of uncertainty and evidence gaps/scientific uncertainty for decisions to be made ((C, D) limited and assessable degree or (A, B) high levels of uncertainty/evidence gap).

trial results. In a crisis situation, however, the uncertainty regarding decision making in clinical processes massively increases both in individual areas and in the overall system. Physicians are confronted with a 'postnormal' situation determined by a lack of evidence or even empirical values to such an extent that previous decision-making patterns and paradigms cannot be continued without scrutiny.¹ Due to the growing scientific uncertainty, the usual structures for decision-making lose their referencing power.⁷ For example, dealing with the additional risks of the pandemic regarding patient-physician communication or risk-benefit ratios for intensive treatment strategies, such as cancer drug regimens, were not covered by available evidence in the beginning of the pandemic.⁸ In an cross-sectional questionnaire investigation (OnCovid trials) involving 910 participants (physicians N=212; nurses N=219; patients N=479) we found that this caused high rates of decisional uncertainty in all groups during the first waves of the pandemic, although the extent and intensity significantly varied between stakeholder groups and between different specialties (here oncology and psychiatry). These decisional uncertainties included patient communication, risk assessment and perception, availability of resources, perception of consequences for clinical processes, perception of consequences for patients. Interestingly, the individual perception of moral distress was not related in any group to objective pandemic trends, such as defined by regional

incidences.⁹ Furthermore, decisional uncertainty was identified as important factor determining patients' trust in healthcare during the pandemic.¹⁰

Alternative criteria and frames of reference gain a differentiating importance during decision making with regard to the direct and concrete process organisation. These decisional criteria may even get in conflict with the common normative framework composed of ethical and legal aspects. For example, compulsory versus voluntary vaccination or clinical triage systems (eg, priority for inpatient admission) are determined by societal perspectives and social value concepts (eg, personal vs social benefit, individual freedom/integrity of human body vs public protection perspective). In many of these situations, healthcare professionals, but also patients, were extensively confronted with moral distress, as decisions in either direction can lead to highly uncertain outcomes. The greater the need for such adapted criteria and frames of reference, the stronger the transitional paradigm shift. In our own clinical investigation⁸ as well as in the recently published OnCovid trial data,¹¹ we found that this loss of decisional certainty depends on the complexity of the given clinical situation and the experience of the healthcare professionals (compensation opportunities). Organisational leadership has to actively implement a new paradigm in order to rapidly adapt new algorithms for decision making and the underlying value system enabling adequate responses to the changed conditions of health provision.

Decision making and system complexity

Uncertainty and dynamic changes that are inherent to a healthcare crisis tend to reshape the significance of a large number of decision-making processes, increasing the system's and decision making's complexity considerably. Pronounced interactions¹² of critical system aspects with increased uncertainty provoke a transitional paradigm shift in decision making, in the processing of the underlying information and related knowledge production.^{13 14} Examples for essential systemic aspects with an intensive impact on decision-making leading to increased uncertainty include organisational versus personal perspectives of the agents, available time intervals for decisions and general availability of resources. In healthcare examples for those decisional tensions can be found, such as concerning the prioritisation of vaccination groups, changes in isolation measures, vaccine delivery and logistics of vaccination. A phase of disproportionate uncertainty occurs in parallel at different decision-making levels and can last for different periods of time. The time horizon of the resulting decision-making challenges varies depending on the particular system component, with the uncertainty about the expected time frame most extreme at the beginning of a crisis situation (figure 1).

Typology of decision uncertainties

Decision uncertainties can be attributed to two major determinants: time frame and extent of the evidence

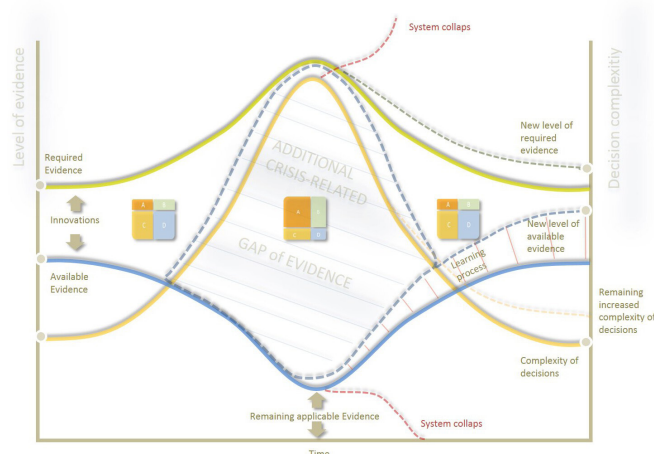


Figure 2 Relationship between complexity of decision-making (yellow line): available evidence (blue line), evidence gap (grey area) and the learning process during a healthcare crisis (dotted lines). Levels of uncertainty can rise within a short time frame (adapted miniature uncertainty diagrams). If the adaptation process is inadequate, a system collapse can occur, in which a sufficient knowledge basis for decision-making is absent due to excessive complexity (dotted red lines).

gap. By combining these two factors, a basic typology can be derived with which the types of uncertainty faced by healthcare participants can be described (figure 1).

- ▶ Type A is characterised by decisions with a short duration of action or a short decision horizon and a large evidence gap/scientific uncertainty.
- ▶ Type B is also determined by a large evidence gap/scientific uncertainty, but the decision-making horizons are medium to long term, and is characterised by potential destabilisation of the entire system.
- ▶ Types A and B of decision making represent the special situation caused by a crisis, while types C and D reflect the usual ('normal') state of uncertainty and the evidence gap that functions as a long-term driver of innovation.

This typology enables a stylised model to illustrate how the common boundaries of scientific knowledge required for normal decision-making are exceeded in a crisis. The initial state before a crisis has triggered change processes is characterised by a manageable degree of system and decision complexity. Evidence, scientific certainty and experience, often described as known knowns and known unknowns, have created a generally accepted decision-making framework with a corresponding framework of values. The available evidence enables a risk management system that offers a manageable balance of new information required for justified action. During this state, the difference between existing and required evidence covers the area of process innovation, that is, the known way of generating new evidence (areas C and D of the uncertainty diagram). People usually approach unknown situations by first applying tested strategies, trying out whether they work, subsequently modifying them.

Evidence gap, novel information and crisis preparedness

During a crisis, the required evidence increases suddenly in correlation with the growing uncertainty, interdependencies and complexity of decisions (figure 2). At the same time, the applicability of existing evidence decreases to a large extent, opening up gaps in evidence that cannot be satisfactorily filled in a timely manner and might even lead to a system collapse. This phenomenon is associated with critical decision-making uncertainty, especially for short-term time frames (figure 2: disproportionate area A).

As a result, the health system must immediately generate new evidence to reestablish boundaries of scientific certainty and implement adapted decision-making systems accordingly. To overcome the acute decisional dilemma and moral distress as part of achieved pandemic preparedness, a decision and value-driven negotiation processes in healthcare must take place at a different level of available information providing new, supplemented or adapted evidence.¹⁵ This new information may consist of fast-track data, preliminary investigations, rapid reviews, modelling based on experience and theoretical concepts, among others, and over time in more substantial data. For some systemic aspects, an organization may return to the decision-making pattern of the precrisis period.

As the experience of German hospitals illustrates, the evidence gaps and scientific uncertainty usually foster a learning process.¹¹ The development of new evidence begins at a low level and with a time lag but increases continuously. For example, in cancer care, during the pandemic, handling of COVID-19 associated risk for treatment was initially provided as expert opinion (level 5 evidence) and followed by small case series (evidence level 4). The entire learning process ultimately led to an adapted level of available evidence that—regarding the critical topics of the crisis—reaches a level of evidence exceeding the initial one (eg, applicability of telemedicine-based follow-up). Without a learning process, the available evidence returns to the original level in many areas due to the restoration of the previous evidence's applicability to precrisis processes. However, the level of the required evidence might remain above the precrisis level after the crisis, as some changes to the system and the decision-making may remain effective permanently (eg, fast track radiooncology protocols). This can also be true for processes that are not immediately affected by the crisis and that do not depend on evidence-based decision making. It can, therefore, be expected that the difference between existing and required evidence will have become smaller compared with the baseline if the crisis-initiated learning process was successful and if it enabled additional progress in other sectors. For example, cancer management under pandemic condition induced novel investigations and understanding of vulnerability for toxicity and complications that were incorporated into treatment guidelines.^{16 17}

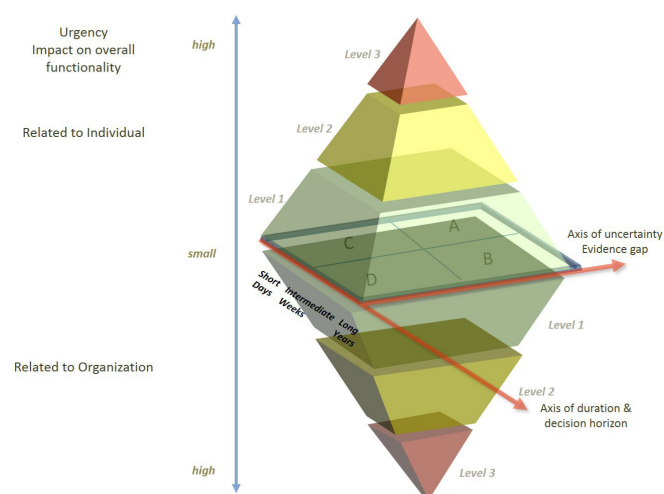


Figure 3 Pyramid model on urgency, overall functionality and organisational levels as cofactors for decision uncertainty in a crisis of the healthcare system.

EMERGENT MODES OF DECISION MAKING

For an emerging healthcare crisis, it should be anticipated that the established ethical framework underpinning decision making can only support transparent and socially accepted decisions to a limited extent. Growing crisis-induced uncertainty inevitably require the adaptation of underlying value priorities. This also applies to the legal framework, though, it is apparent that crisis management in many countries is taking place within the usual legal framework despite an uncertain and unfamiliar situation.¹⁸ The disproportionate uncertainty, expected consequences, necessary compression of decision-making processes and major changes in a very short period of time lead to decision-making conflicts: the weighting of normative frameworks requires adjustments.¹⁹ For instance, the definition of vaccination priorities, which resulted from a persistent scarcity of resources (ie, the availability of the vaccine) and the resulting weighting of achievable benefits (reduction in risk of infection) can serve as an illustration of such a conflict between the individual and societal perspective. Individual normative factors must be adjusted in a crisis affecting the entire society,²⁰ especially in terms of their mutual weighting as basis for setting priorities in healthcare management. For vaccination priorities, a balance had to be found between the social health benefit from interrupting the chains of infection as thoroughly as possible and the individual benefits from vaccinating for those people with a particular high risk for a severe course of illness, since both cannot be maximized at the same time (as long as these resources are limited). Another challenge is that procedures and measures often have to be adjusted on short notice due to time pressure, combusting decision-making processes and horizons of efficacy. Normatively, this can be expressed as an assessment with many uncertainties. Those uncertainties mainly affect the validity of normative reference systems, making it necessary to adapt normative assessment for dealing with

the described determinants. In such a situation, sound practices of legal and ethical assessment are more in demand than evidence-based informed decision making. For example, at the beginning of the pandemic, the German courts predominantly used impact assessments to justify interference with fundamental rights.²¹ Later, when more evidence was available, they returned to the usual examination of proportionality.²² However, value-based ethical perspectives were rarely discussed resulting in very critical perceptions of these decisions within the society. In a second step and in parallel, the search for legal instruments within the existing legal system must be tackled after which necessary adjustments to the legal framework have to follow immediately. Similarly, procedures for the rapid inclusion of ethical perspectives need to be available.

The communication of this prioritisation or normative weighting process to all affected groups, sectors or organisational levels is a management imperative for creating an understanding and acceptance of crisis modes for decision making. Since decision-makers need to make decisions in a legitimate manner, they need a process to help them gain legitimacy.²³ In this regard, the necessary determinants and requirements for monitoring this process for legitimisation can be derived from the 'model for the adaptation of decision algorithms under crisis conditions', as well as a communication and integration strategy for target groups. The overall aim of this model is to increase the resilience at all organisational levels involved in these particular crisis scenarios as well as the legitimisation of decisions actors have to make in a time of great uncertainty.

ADAPTIVE PYRAMID MODEL

Extending the emerging literature the impact of volatile, uncertain, complex and ambiguous environments^{24–26} on organisations during COVID-19, the challenges for healthcare systems, and especially hospitals in a crisis situation can be characterised through different factors which add up to a pyramid model (figure 3) of decision making.

Evidence gaps

Evidence gaps and scientific uncertainties occur to various extents and with various temporal dynamics as mentioned before. The highly temporal dynamic of the pandemic overtakes the usual ways to generate evidence.²⁷ The problem of overcoming disproportionate evidence gaps, which has an extremely delaying effect on decision-making processes and effectiveness, has been observed in numerous examples since January 2020 (including the use and provision of face masks and antigen tests, definition of the vaccination strategy and prioritisation groups, indication and benefit of drug treatment of COVID-19, among others).²⁸ Overall, the evidence gap corresponds to the level of uncertainty at both the individual and organizational level.

Duration of action and decision horizon

The duration of action and the decision-making horizons play a central role as factors influencing decision-making schemes.²⁹ In crisis situations, the first decision is to declare a crisis mode. Secondary decisions are often required at short notice and can have short-term effects with strong impact on healthcare. For decisions with a systemic effect this is especially noteworthy, since under normal conditions the regular processes tend to be laid out in the medium and long term regarding their duration and their respective decision horizons (common innovation and adaptation processes). As an example for immediate response requirements, the pandemic-related blocking of health resources (hospital beds, access restrictions for patients, etc) can be used. Some of which need to be updated on a daily basis and can be justified by the need for infected people to get the required treatment, as well as protecting patients from the pandemic pathogen and the additional and difficult to calculate risk of reinforcing chains of infection by additional patients' contacts. At the same time, however, this reduction in treatment options can have health consequences for patients, whose treatment gets delayed or impaired as a result.

Urgency and impact on overall functionality

When adapting decision algorithms and implementing a monitoring system to recognise the urgency of required decisions, their effects on the overall functionality of healthcare need to be considered. The degree of the impact and the request for monitoring correlate closely with one another and must be taken into account when developing adapted decision-making algorithms. At the same time, an infrastructure for permanent crisis monitoring needs to be created in order to enable the early detection of the above-described need for a changed applicability of value structures and normative frameworks. Since the decision-making complexity and its determinants cannot be measured directly, this monitoring must use suitable surrogate parameters (examples in table 1).


Planes of reference

When developing and using adapted decision algorithms, it needs to be understood that—due to interdependencies in complex systems— modified algorithms have an impact both on individual agents (eg, physicians or nurses, but also patients) and on organisations (possibly also at different levels). These effects can be very different to both reference levels and may have to be weighed against each other regarding the overall assessment. This constellation reflects, among other things, the tension between the individual and society (public health) perspective. Figure 3 combines the previously developed typology of decision uncertainties with the degree of urgency and relates them to individual and organisational decision-making levels. The resulting double pyramid makes it possible to conceptually illustrate in a single model the different logics of decision-making under crisis conditions. On this basis, it is possible to phenomenologically capture what exactly 'happens' with decision-making processes during a crisis situation, such as the COVID-19 pandemic, and which options of adjusting decision making are available in order to prevent system overload or even system collapse. Corresponding cybernetic, systemic and communication-oriented modelling should additionally make it possible to give empirical and simulation-based statements about tipping points and phase transitions.

NEED FOR EMPIRICAL RESEARCH AND MONITORING

To improve the future management of pandemics, phases of high uncertainties and other crises of the health system require efficient models that guide a change of decision algorithms. The logic of the model corresponds with a decision-making process that requires a permanent balancing act between available evidence, scientific uncertainty, normative and social assessment of the evolving situation. The crucial legitimisation for decision-makers is only possible in a continuous interplay between empirical indicators and the development of a suitable monitoring system to observe crisis-related

Table 1 Examples of interaction between empirical indicators and monitoring of the health system's stability

Empirical indicators	Adjustment	Monitoring
Temporal course of the prevalence of required intensive care treatments		Pandemic-related additional demand for intensive care capacity compared with its availability
Identification of vulnerable groups in need for pandemic intensive care		<ul style="list-style-type: none"> ► Regional availability of necessary infrastructure ► Availability of qualified workers in terms of location and time
Process requirements for pandemic-related intensive care (hygiene concept, staff availability, etc)		
Pathogen-related options of intensive care therapy (eg, positioning, drug therapy, immune monitoring)		Prediction models for the course of the pandemic taking vulnerable groups into account

shifts in the health system. The empirical data generated during the COVID-19 pandemic cover various subaspects, taking into account the three main dimensions (impact on overall functionality, uncertainty and evidence gap, duration and decision horizon; [figure 3](#)), and need to be checked according to this model with regard to their significance for pandemic management. The goal is to characterise the resulting evidence gap in more minute detail and to derive a data-based approach to monitor critical thresholds. At the same time, evaluating the way health systems function based on these dimensions indicates requirements for indicators that are not yet available. Such a model should suggest a catalogue of criteria for dealing with decisions under scientific uncertainties, on the basis of a transparent value set, even in the case of large evidence gaps.

Two scenarios illustrate the need for changed decision algorithms. In the context of emergency medicine, irrespective of a pandemic, there can be mass casualties (eg, during a major accident or terror attack), which make it imperative to use modified treatment processes (eg, when assigning different treatment priorities). For this, changes to decision-making algorithms are necessary at short notice, which can have pronounced effects both on the directly affected patient group (eg, prioritisation according to severity) and on the indirectly affected healthcare (eg, postponement of surgeries). For this purpose, contingency plans and decision-making schemes are available based on evidence and thus, the existing evidence gap is low. Monitoring for such events can, for example, concern the threshold range for the number of injured people, which can vary from region to region and be adapted to the respective care situation.

Second, a pandemic leads to large evidence gaps in the health system, such as the constant assessment of the availability of intensive care capacities necessary to plan medical care and operation processes.³⁰ At the onset, there are numerous influencing factors which, among other things, depend heavily on the characteristics of the respective pathogen and are therefore only transferable to a limited extent from previous pandemics. The virology of the pathogen can change significantly even during the course of a pandemic. Short-term and flexible adjustments to the epidemiological dynamics over the course of the pandemic are required. These operational changes can strongly affect the functioning of the entire health system. So, in addition to the required adjustment of the normative value basis for the resulting decisions, flexible adjustments in monitoring the intensive care capacity as well as the thresholds for changes in the decision algorithms are necessary. [Table 1](#) shows the interaction between empirical data and monitoring of the system's stability. To link data and monitoring during a crisis efficiently is crucial for business continuity in healthcare.

MODEL APPLICATION FOR PANDEMIC PREPAREDNESS

In the clinical setting, managing risks and coping with uncertainties in decision-making are part of everyday operations. Stakeholders are used to deal with various scenarios. However, under the postnormal conditions of a pandemic permanent changes in monitoring and conceptualising the critical connections between decision uncertainties, evidence gaps and learning processes are essential for successfully coping with a crisis situation in clinical practice. Applying the new model enables decision-makers to classify much faster the status of the crisis, its related evidence gap and decisional uncertainty. Due to the requirement for fast decisions on how to execute in phase A (acute high uncertainty/evidence deficit), surrogate markers should be used that have been already implemented in precrisis times and that are constantly available in the respective reporting systems. The model also suggests to immediately start a structured learning process targeting the evidence gap on one side but also intensively focusing on the monitoring of decisional uncertainty on the other side. The model can be used to translate change, uncertainty and learnings into an active doing and execution based on a structured process. Finally, the model structure can assist to implement decisional assist systems for crisis situations for monitoring, surrogate adaptation and evaluation of the respective levels of uncertainties for organisations as well as for individuals.

Understanding the interdependencies between a decision's urgency, its effects on the overall functionality of the system and the organisational levels concerned, are fundamental for the ultimate success in handling a crisis. A shift away from the usually manageable, evidence-based uncertainty spectrum into the area of overwhelming uncertainty without sufficiently available or applicable evidence puts the usual equilibrium between social and individual interests in the healthcare system into an imbalance. This does not only have effects on behaviour and perception of healthcare professionals, but also impacts the larger legal framework. The pandemic generates a rupture in the usual fabric of reality, creating the need to reflect on the underlying assumptions of risk management and to develop better approaches for the associated challenges of uncertainty and risk monitoring.³¹ The establishment of a permanent interdisciplinary monitoring of decisional uncertainties, the extent of the evidence gap and their potential impact on the basis of surrogate parameters, that need to be developed as a consequence of the pandemic, should be considered by health policies and established on a scientific basis. To that end, the pyramid model suggests a heuristic for uncertainty monitoring which supports resilient behaviour in novel crisis situations and anticipates the dynamics of potentially necessary paradigm shifts.

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Author note Although the manuscript does not report primary data an ethical approval was obtained by the Ethics Committee of the Hannover Medical School (9199_BO_K_2020, 1 July 2020). Patient representatives were involved in the design of the underlying study and the questionnaire development.

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REFERENCES

- Czada R. Planning and Decision as Controlling Task and Interaction Challenge. In: Kamp G, ed. *Long-Term planning: importance of social and cognitive resources in sustainable action*. Springer Heidelberg, 2016.
- Baum F, Freeman T, Musolino C, et al. Explaining covid-19 performance: what factors might predict national responses? *BMJ* 2021;372:n91.
- Dörner D. *The logic of failure: strategic thinking in complex situations*. Rowohlt Hamburg, 1989.
- Funtowicz SO, Ravetz JR. *The emergence of post-normal science. in science, politics and morality*. Dordrecht: Springer, 1993: 85–123.
- De Marchi B, Ravetz JR. Risk management and governance: a post-normal science approach. *Futures* 1999;31:743–57.
- Gross M. The unknown in process: dynamic connections of ignorance, non-knowledge and related concepts. *Current Sociol* 2007;55:742–59.
- Scherzberg A, Lepsius O. Risikosteuerung durch verwaltungsrecht: ermöglichung oder begrenzung von innovationen? *VVDStRL* 2004;63:214–58.
- Ivanyi P, Park-Simon T, Christiansen H. Protective measures towards sars-CoV-2 pandemic for cancer patients – is oncology at its best form the answer? *Clin Exp Metastasis* 2021.
- Haier J, Beller J, Adorjan K, et al. Decision conflicts in clinical care during COVID-19: a patient perspective. *Healthcare* 2022;10:1019.
- Beller J, Schäfers J, Haier J, et al. Trust in healthcare during COVID-19 in Europe: vulnerable groups trust the least. *Z Gesundh Wiss* 2022;24:1–10.
- Beller J, Schäfers J, Geyer S, et al. Patterns of changes in oncological care due to COVID-19: results of a survey of oncological nurses and physicians from the region of Hanover, Germany. *Healthcare* 2021;10:15.
- Dörner D. Planning in complex systems, On the functionality of interactions in complex systems. In: Kamp G, ed. *Long-Term planning: importance of social and cognitive resources in sustainable action*. Springer Heidelberg, 2016.
- Choo CW. The knowing organization: how organizations use information to construct meaning, create knowledge and make decisions. *Int J Inf Manage* 1996;16:329–40.
- March J. How decisions happen in organizations. *Hum Comput Interact* 1991;6:95–117.
- Appel I, Mielke S. *Strategies of risk regulation: the meaning and function of a risk-based approach to regulation in environmental law*. Nomos Baden-Baden, 2014: 78.
- Moujaess E, Kourie HR, Ghosn M. Cancer patients and research during COVID-19 pandemic: a systematic review of current evidence. *Crit Rev Oncol Hematol* 2020;150:102972.
- Serraino D. COVID-19 and cancer: looking for evidence. *Eur J Surg Oncol* 2020;46:929–30.
- Jones Day White Paper. European LitigationCovid-19 measures at a glance, 2020. Available: <https://www.jonesday.com/en/insights/2020/04/covid19-measures-in-european-courts> [Accessed 22 June 2021].
- Donati. The coronavirus crisis in Europe – is this the time OFT He precautionary principle? EU Law Live; 2020. <https://eulawlive.com/weekend-edition/weekend-edition-no11/> [Accessed 22 June 2021].
- Klafki A. *Risiko und Recht: Risiken und Katastrophen Im Spannungsfeld von Effektivität, demokratischer Legitimation und rechtsstaatlichen Grundsätzen am Beispiel von Pandemien. Studien und Beiträge zum Öffentlichen Recht*. 29. Tübingen: Mohr Siebeck, 2017. ISBN: 978-3-16-155051-5.
- Hestermeyer H. Coronavirus Lockdown-Measures before the German Constitutional Court, 2020. Available: <https://constitutionnet.org/news/coronavirus-lockdown-measures-german-constitutional-court> [Accessed 22 June 2021].
- Coronavirus: can German courts overturn all lockdown measures? Available: <https://www.dw.com/en/coronavirus-can-german-courts-overturn-all-lockdown-measures/a-55477209> [Accessed 22 June 2021].
- Klafki A. *Risiko und Recht Risiken und Katastrophen Im Spannungsfeld von Effektivität, demokratischer Legitimation und rechtsstaatlichen Grundsätzen am Beispiel von Pandemien. Studien und Beiträge zum Öffentlichen Recht*. 29. Tübingen: Mohr Siebeck, 2017. ISBN: 978-3-16-155051-5.
- Worley CG, Jules C. COVID-19's uncomfortable revelations about agile and sustainable organizations in a VUCA world. *J Appl Behav Sci* 2020;56:279–83.
- Murugan S, Rajavel S, Aggarwal A. Volatility, uncertainty, complexity and ambiguity (VUCA) in context of the COVID-19 pandemic: challenges and way forward. *Intern J Health Systems Implement Res* 2020;4:10–16.
- Schulze C, Welker A, Kühn A, et al. Public health leadership in a VUCA world environment: lessons learned during the regional emergency Rollout of SARS-CoV-2 vaccinations in Heidelberg, Germany, during the COVID-19 pandemic. *Vaccines* 2021;9:887.
- Curigliano G, Banerjee S, Cervantes A, et al. Managing cancer patients during the COVID-19 pandemic: an ESMO multidisciplinary expert consensus. *Ann Oncol* 2020;31:1320–35.
- Katz JN, Sinha SS, Alviar CL, et al. COVID-19 and disruptive modifications to cardiac critical care delivery: JACC review topic of the week. *J Am Coll Cardiol* 2020;76:72–84.
- eds. Hoffmann-Riem W. Ermöglichung von Flexibilität und Innovationsoffenheit im Verwaltungsrecht – Einleitende Problemskizze. In: Hoffmann-Riem W, Schmidt-Aßmann E, eds. *Innovation und Flexibilität des Verwaltungshandelns*. Baden-Baden: Nomos, 1994: 50.
- Arabi YM, Azoulay E, Al-Dorzi HM, et al. How the COVID-19 pandemic will change the future of critical care. *Intensive Care Med* 2021;47:282–91.
- Fisher E. Framing risk regulation : a critical reflection. *Eur j risk regul* 2013;4:125–32.