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Keeping healthcare afloat: a protocol for a 5-year multi-sited interdisciplinary research project into preparedness of healthcare for floods in the Netherlands

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Abstract

Introduction The 2021 European floods in Germany, Belgium, and the Netherlands significantly impacted healthcare. With climate change increasing flood risks, healthcare preparedness is essential. Floods affect healthcare directly and indirectly by disrupting patient access, damaging infrastructure and impeding care continuity. Our interdisciplinary research in the Netherlands systematically assesses flood impacts on healthcare, optimises disaster preparedness, patient logistics, and continuity and explores crisis governance, incorporating lessons from coronavirus disease-2019 (COVID-19).

Methods Our multi-sited, interdisciplinary project titled "Pandemic lessons for flood disaster preparedness" includes literature reviews on: (i) the (in) direct impacts of floods on healthcare, (ii) disaster decision-making strategies and (iii) patient logistics during crises. Empirically, ethnographic methods (interviews, focus groups, document analyses, and observations) will: (a) assess hospital flood preparedness, (b) explore decision-making and crisis management strategies and (c) analyse the dynamics of health system governance during floods. Data from these sources and flood scenarios will inform models on healthcare impacts and decision-making, culminating in a simulation game for research and training.

Discussion This study offers a comprehensive, interdisciplinary approach to understanding and improving healthcare system preparedness for floods. By integrating diverse fields such as healthcare governance, disaster risk management, logistics and hydraulic engineering, we provide a unique lens on resilience. A key strength is the incorporation of lessons from the COVID-19 pandemic, allowing us to draw parallels between pandemic response and flood preparedness. In addition, our simulation game serves as a robust tool for translating knowledge into practice. However, the study's reliance on collaboration with busy healthcare and disaster response professionals may limit engagement. Moreover, the absence of direct public and patient involvement in the research design, though partially mitigated by engaging representative organizations, presents a potential limitation. Lastly, the challenge of obtaining real-time data from flood events could introduce recall bias, but triangulation of various data sources aims to address

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this issue. Despite these challenges, the study's integration of long-term data from recent floods and focus on healthcare-specific crisis governance provides valuable insights for improving disaster preparedness.

Keywords Floods, Healthcare, Resilience, Disasters, Crisis, Governance, Uncertainty

Background

Globally, the COVID-19 pandemic has revealed many vulnerabilities in healthcare systems and their governance networks. Decision-makers had to manage uncertain and unpredictable human behaviour, overstretched health services, incompatible coordination structures, disrupted (health) supply chains and other critical services [1–3]. Cascading effects are typical of networked systems, such as the infrastructure underpinning the healthcare sector, during disasters, be they pandemic or environmental. The relevance of cascading effects was also demonstrated during the catastrophic floods in north-western Europe in the summer of 2021. Several European countries, including Belgium, Germany and the Netherlands, experienced severe flooding events caused by excessive rainfall and subsequent bursting of riverbanks due to extreme discharge of water in the rivers Meuse and Rhine [4, 5]. As a result, both Belgium and Germany experienced significant numbers of casualties, and all affected countries had severe damage to (critical) infrastructures, including parts of the healthcare system [6, 7].

Historically, most countries in north-western Europe have invested in the prevention of inundation floods [henceforth: floods] [8]. With its stretched coastline, the Netherlands is an exemplary country in this regard. After a major flood in 1953, the Dutch government progressively invested in the so-called Delta works infrastructures that were meant to prevent such disasters from happening again. The past decades, however, have shown an increase in water-related disasters worldwide. Effects of the climate crisis, such as rising sea levels and extreme precipitation, disproportionally affect coastal regions with elevations below sea level [9, 10]. Moreover, and as exemplified by the 2021 events, riverine and coastal floods have become an increasing concern. Such changes produced impetus for the Netherlands to shift from a flood-risk culture of prevention towards an attitude of preparedness and mitigation [8]. While the former implies that we need to keep the water 'out', the latter signifies that decision-makers in the Netherlands must ensure that appropriate plans, structures and networks are in place to deal with a water-related crisis as it unfolds.

Floods are known to affect healthcare systems in several ways. Foremost, healthcare providers and (healthcare) crisis organisations must be equipped to deal with the inflow of patients and displaced persons. Even more salient are the effects that floods may have on critical healthcare infrastructure and continuity of care: the facilities of not only nursing homes and hospitals but also storage units can be compromised, or even completely destroyed, such as was the case during the recent 2021 European floods [6, 7, 11]. An extreme example that highlights the potential vulnerability of healthcare to floods, was the flooding of Memorial Medical Center in New Orleans during Hurricane Katrina in 2005 and the subsequent evacuation of that hospital under dreadful and isolated circumstances. During this disaster, almost 147 fatalities (20% of the registered total) occurred in hospitals and other medical facilities [12].

Furthermore, during a disaster, such as a flood, it is not only the formal rescue and healthcare actors who act to mitigate against its impacts but also a diverse set of informal and voluntary organisations whose actions can both help and hinder the protection and mitigation efforts taking place. This was also evident during the COVID-19 pandemic, where informal initiatives often entangled with formal care routines [13]. These effects emphasise the relevance of studying the wider impact of floods on healthcare, including what role informal actors play in this. Recent work underscores this relevance, showing that the likelihood of severe flood events that affect health systems will only increase in the future [14]. Similarly, the Sendai Framework [15] highlights the critical role of health systems in reducing disaster risk and emphasises the importance of strengthening their capacity to prevent, prepare for and respond to hazards. This study contributes to that agenda by focusing on preparedness for flood-related health impacts.

Starting January 2023, we set out in an interdisciplinary research team in the Netherlands to study different aspects of flood preparedness and flood risk governance in healthcare. In this protocol paper, we tease out the different elements of our multi-sited and interdisciplinary research consortium, including the different involved disciplines and their overarching methodologies. We will conclude the protocol paper with a short reflection in which we explicate how our project seeks to contribute to existing scholarly debates and what the potential limitations of our approaches are. We will also explain why we think that the results of our study will have implications not just for the Netherlands but also for healthcare systems and preparedness for floods worldwide.

Design

Aim

The overarching aim of our research project is to study, understand and strengthen the preparedness of healthcare against floods in the Netherlands. This aim is achieved by fulfilling the following objectives: (i) studying the impacts of large-scale flooding events on the health system (WP1), (ii) assessing how healthcare continuity for patients can be ensured and logistics optimised during disasters (WP2) and (iii) exploring which governance arrangements help improve healthcare continuity in relation to floods (WP3).

Study design

Our project, formally titled "Pandemic lessons for flood disaster preparedness" adheres to a multi-sited and interdisciplinary methdology and is divided into four work packages (WPs). The WPs correspond with the three aims of our study, whereby the fourth WP explicitly combines and integrates insights from the different WPs. The WPs are not sequential and work activities within the WP will commence simultaneously. We outline the WPs, their activities and methods in the paragraphs below. It is important to note that the WP leads meet on a weekly basis to ensure interaction and collaboration between the different WPs.

WP1: Floods and health impacts

Floods are known to have disastrous impacts. Inventories have been made of the general health impacts of floods, [16] or specific impacts, such as loss of life [17]. However, a comprehensive overview of the various types of physical health impacts as a function of flood characteristics, societal characteristics and time after the event is not yet available. While predictive relationships are available for economic impacts [18], and loss of life after floods, these are not yet available for other types of health impacts [19]. In addition, research has been carried out on the impacts of floods on interconnected infrastructure systems [20, 21]. However, quantitative analyses of healthcare impacts are still scarce. Hence, the objective of this WP is to develop methods to predict the various healthcare impacts of flood events. The main focus will be on large-scale riverine or coastal flooding, typical for the Netherlands and other delta areas.

This WP includes the following activities:

- Perform a literature review on healthcare impacts, logistics and governance for international floods (in collaboration with WP2 and WP3).
- Conduct a flood risk assessment for hospitals in the Netherlands, with an emphasis on simultaneously affected facilities.
- Build a quantitative model framework to predict various dimensions of healthcare impacts and risks due to flooding events, with a focus on hospitals.
- Generate flood scenarios for selected regions in the Netherlands (e.g., South Holland and Limburg) using hydraulic modelling and assess the effects on healthcare facilities and other relevant critical infrastructures.

Data collection and analysis We will conduct a systematic literature review to identify the direct and indirect impacts of floods on healthcare facilities, as well as the strategies and measures the facilities implemented to reduce the impact. We will search medical and engineering research databases, such as MEDLINE, Embase, Web of Science and SCOPUS. The review will be conducted following the PRISMA 2000 statement [22]. For the second activity, the exposure of hospitals in the Netherlands will be assessed by building a flood model and overlaying hospital locations over the resulting inundation maps. The flood modelling will include various scenarios such as dike breaches and extreme precipitation and current and future scenarios exacerbated by climate change. Hospital locations are freely available from the Dutch National Institute for Public Health and the Environment (RIVM). To assess the vulnerability and preparedness of exposed hospitals, we will conduct qualitative studies through observations and semi-structured interviews ($n=15$) with hospital emergency managers. The assessment will address utilities (such as water, telecommunication and energy), evacuation strategies and logistical aspects (such as medicines and food supplies and accessibility), among others. Hospitals will be purposefully sampled on the basis of criteria such as hospital size, construction year/typology and flood type to which they are potentially exposed. Finally, for the last activity, existing flood models will be either directly used or modified to generate flood scenarios that will be used in the other WPs.

WP2: Real time logistics of patients and decision-making strategies for disasters

Patient flow logistics are increasingly a concern for health systems worldwide. Problems in patient flow management have been associated with a variety of problems. These problems include supply shortages, systemic bottlenecks, long queues, delays in access to care and unpredictable workloads for healthcare staff and, increasingly, also shortages in workforce [23, 24]. A variety of methods and tools have been developed to assess evacuation

possibilities [25] and improve patient flow logistics [23, 26–30]. However, the fields of disaster logistics and health (care) logistics remain largely separated, even though there are numerous crossovers that might be considered. Besides, patient flow management conventionally focuses on one facility (a hospital), instead of including the numerous feedback moments between hospitals, ambulance services, general practitioners, nursing homes, or – in the case of large-scale disasters – other emergency services and volunteers. The presence and actions of these formal and informal actors can both help and hinder efforts in mitigating the impacts of the disaster. What is therefore missing is a comprehensive model that optimises the flow of patients across the different sites – from the disaster site and throughout the health system at large – and which is considerate of the uncertainties and infrastructure disruptions that are related to large-scale disasters. In this WP, we therefore aim to develop a new comprehensive model and approach that starts from the patient flows throughout the health system against the backdrop of disrupted infrastructures and high levels of uncertainty.

This WP includes the following activities:

- Perform a literature review on patient flow logistics during disasters
- Conduct interviews ($n=20$) and qualitative research with a diverse set of actors involved in disaster response, from health care providers and emergency services at different levels, and potentially informal volunteers.
- Develop a conceptual model representing patient flow logistics in disasters and taking into account emergent behaviours and their influence on decision-making.

Data collection and analysis In WP2, we will also perform a literature review in collaboration with an information specialist from the Erasmus Medical Center (Erasmus MC). A protocol will be drafted, including a search string and eligibility criteria. Following the literature review, we will perform case studies into decision-making strategies that took place during floods. The selection of case studies will be guided by which recent flooding events significantly affected health systems. It is therefore likely that the 2021 West-European flooding event will be one of the cases. We will conduct qualitative interviews ($n=20$) on the decision-making prior to, during and after flooding events with hospital (crisis) managers and a broader set of actors from emergency responders and community members, to explore the coordination, involvement and decision-making strategies of these different actors. The interviews will be recorded and transcribed, and major discussion points and trends will be extracted using qualitative data analysis tools. By synthesising the data collected during the literature review and the case studies, we will develop a conceptual model. This model aims to provide an overview of the patient flow logistics dynamics during crises. The model will facilitate strategies for the improvement of overall operations, including which actors play a role in crisis management, their behaviours, transport modes, and necessary facilities.

WP3: Governance and crisis organisation of health care systems for floods

Responses to crises often rely on a combination of formalised structures, informal coordination and the development of new emergent structures to enable decision-making, the flow of information, scientific advice and the coordination of activities [31, 32]. Environmental disasters such as floods are particularly well known to exacerbate coordination and governance issues, as they can destruct crucial governance infrastructures, making the relation between formal and informal, as well as existing and emergent structures, even more pertinent [33]. When flood events affect the health system, either by producing significant care demands or by destroying crucial (infra) structure, an additional layer of governance complexity is added. In the Netherlands, for example, such events would mobilise the water management boards, Rijkswaterstaat (the National water authority), the safety regions, the regional councils for acute care and municipalities' medical emergency preparedness and planning units—each with their own specific domain logics, organisational structures, knowledge infrastructures, and geographical boundaries and jurisdictions. Whilst literature recognises the particularities of governing these different domains, the consequences of their interaction for governance have been paid scant attention. In this WP, we seek to contribute to bridging that gap by studying the layered, dynamic and interactive nature of health system crisis governance during flooding events.

This WP includes the following activities:

- Conduct a secondary analysis of ethnographic data of (health system) governance during the Covid-19 pandemic [13, 34, 35].
- Perform ethnographic case studies with semi-structured interviews ($n=150$), observations, and document analyses related to the wider south-west area of the Netherlands and the province of Limburg.
- Carry out a demand-driven international case study in collaboration with WP1 and WP2.

Data collection and analysis In our ethnographic study, we will collect primary data, and we will perform an analysis of secondary data. For the primary data collection, we will employ a combination of methods, including observations, interviews and document analysis. Three researchers will be involved in the primary data collection. The observations will focus on relevant (crisis) meetings, daily work practices and disaster exercises within the domains of healthcare, water management and crisis management. Observational notes will be drafted within 24 h following the observations. We will focus on decision-making processes and interactions between the actors involved. Furthermore, we will engage in walking ethnography, which includes walking around neighbourhoods, focusing on the relations with the surrounding water system; photos and notes will be taken [36].

Interviews will be conducted with actors involved in the health domain, such as care providers, managers, crisis coordinators and policymakers. Furthermore, actors within the water management and crisis management domain will be included. The interviewees will be asked about their experiences during prior floods and their current work in preparing for new flooding events. Document analysis will examine relevant documents such as evaluations following flooding events and policy documents on crisis mitigation. Policy documents may be revised after a flooding event or disaster exercises. However, we do not perceive these documents as passive reflections of events but as actors that are part of an interdependent process [37, 38].

In addition, we will build on data collected through ethnographic research during the COVID-19 pandemic. These data provide unique insight into governance dynamics at various layers of the healthcare system—including decision-making within hospitals, acute care regions and medical emergency organisations. We seek to draw on these data to show to what extent floods produce particular governance dynamics in healthcare and in which cases more generic aspects or lessons might be articulated. We will analyse all data using an abductive approach, which involves moving back and forth between theory and data to generate new insights [39].

WP4: Policy game, stakeholder engagement and knowledge translation

On the basis of the empirical research in the other WPs, we will formulate different propositions on crisis responses, which we will translate into a simulation game. The development of this game will be based on insights from the serious game literature and literature on experimenting in Science and Technology Studies (STS) [40–42]. The game will both be used as a research method as well as for training purposes. We will use the flooding risk scenarios produced in WP1 and the logistic modelling and decision-making insights from WP2 to build different types of crisis responses (including early warning, readiness and stand-by) within different flood scenarios. The insights into crisis governance constellations and dynamics from WP3 will be used to build representative coordination and governance mechanisms and dilemmas into the game. Investigated topics will include: the uptake of information in decision-making, behavioural and motivational biases, group processes across different levels and domains of governance, relations to and coordination between existing institutional infrastructures, and power dynamics. The simulation game will not only allow us to attain deeper insights into the organisational patterns and mechanisms in healthcare during floods, but it will also allow us to offer trainings at the level of decision-makers in healthcare and crisis and disaster management. The game is explicitly co-produced with key actors and embedded in an existing field of ethnography dedicated to gaming [43, 44].

Study context

This project is embedded in the Pandemic and Disaster Preparedness Center (PDPC), which is one of the programmes under the "Convergence" collaborative agreement between Erasmus University Rotterdam (EUR), the Erasmus MC and Delft University of Technology (TU Delft), in the Netherlands. All initiatives under this collaborative agreement, including the PDPC, are explicitly interdisciplinary and seek to combine the strengths of the three organisations involved.

For this particular project, we have initiated a collaboration between Erasmus School of Health Policy & Management (ESHPM), which is based at the EUR, the Faculty of Technology, Policy and Management, and the Faculty of Civil Engineering and Geosciences, both at TU Delft. The research team at ESHPM specialises in healthcare governance, with a disciplinary background in public administration, sociology, anthropology, science and technology studies, health sciences and epidemiology. The research teams at TU Delft have expertise in environmental engineering, public policy, healthcare infrastructure management, disaster and risk management, humanitarian logistics and hydraulic engineering. Besides these research organisations, we also structurally collaborate with key health systems actors (see "Engaged key actors").

The project is geographically confined to the Netherlands. As part of an international case-study, we will also investigate Belgium and Germany as neighbouring countries.

Engaged key actors

Key actor engagement is an integral part of our project design. Following the engagement design principles of Boaz et al. [45], we engage key actors from the onset and throughout the entire course of our project. Before the start of our project, we therefore composed an expert committee as part of our project team. This expert committee includes a public health director, two medical specialists, a crisis expert, and climate researcher. Our main purpose with such engagements is to establish reciprocal relationships in which we can learn from practical cases, whilst feeding back our analyses of these cases into practice. Thereby, we specifically seek to translate knowledge between different parts of the health system and our project [46]. There are several organisations with which we structurally collaborate within this project, including the Erasmus MC (Emergency Department and Department of Traumatology), International Red Cross Red Crescent Climate Centre, Institute of Physical Safety, Trauma Center South-West Netherlands, a national long-term care organisation, and six safety regions in the Netherlands.

Patient and public involvement

Patients and the general public were not involved in the design of this study. For WP3 specifically, we will explicitly include a general public perspective by interviewing and observing civil society members in their contexts. Where relevant, we will actively engage with patients and the general public during the dissemination of our research findings, especially where it pertains to results that are likely to affect the general public or patients.

Status of study

This 5-year study commenced on 1 January 2023 and will end by 31 December 2027. At this stage of the project (July 2024), literature review of WP1 is ongoing, whereas a first review of literature for WP2 has been completed, and the formal analysis and write-up is scheduled for early 2025. Data collection for WP3 is ongoing, and the activities of WP4 will commence early 2025.

Discussion

With our 5-year multi-sited and interdisciplinary research project we want to study and strengthen the preparedness of healthcare against floods in the Netherlands, thereby making use of data gathered during the COVID-19 pandemic. Our research project is well aligned with the European Disaster Resilience Goals [47], particularly because we contribute to building anticipatory capacities among healthcare actors for floods and increasing flood risk awareness in healthcare specifically, and Dutch society more generally. We explicitly aim to study the Netherlands in relation to the neighbouring countries, and we anticipate that the implications of our studies will extend beyond north-western Europe. Our study has three different analytical angles that resemble the different disciplinary backgrounds of the study group: healthcare governance, disaster and risk management and logistics, and hydraulic engineering. While there is a comprehensive evidence base on each of these analytical angles within the different disciplines, it is far less common to integrate and collectively analyse insights from these different angles. Besides, even within these domains, there is considerable dissonance. For instance, while there is a substantial body of international literature about crisis governance, [31, 48–51] also specific to the Netherlands, [52–54] these literatures are usually less attentive to governance dynamics that are specific to healthcare, including coordination between emergency care and crisis management services. Moreover, they hardly ever take into account coordination across sector boundaries. Similarly, disaster health literature is largely separate from literature on humanitarian logistics, even though they might address comparable topics such as patient evacuation from affected areas and premises. Nonetheless, there is recognition that such crossovers between scientific disciplines in their study of disaster preparedness are of utmost importance for making systems more resilient to crises and disasters, [55] including explicit calls to engage the health sector in the disaster sector dedicated to flooding events [56]. With our project, we respond to such calls.

While the interdisciplinary nature and extensive emphasis on knowledge translation are key strengths of our study, there are also potential limitations to our approach. In this study, we do not plan on engaging the general public, or patient population, in the design of our study and analysis. As described before, WP3 explicitly seeks to apply a layered governance framework to analyse previous flooding events, which includes how the general public prepared for and experienced these flooding events. Besides, throughout our project, we engage organisations that represent the general public or patient populations. These include the Dutch safety regions and regional networks for acute care delivery. A second potential limitation is the extent to which we will be able to gather real-time data about flooding events. In writing the project proposal, we anticipated an option to attach our work to recent flooding events. However, in practice, it is likely that we will not have direct access to crisis sites, potentially inducing a recall bias in our data. We will mitigate this limitation by maintaining active relations with organisations that are involved during flood events and by collecting paper trails throughout such events. By triangulating such paper trails with other types of data,

such as interviews and observations, we seek to gather as much detail in our data as possible.

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Author contributions
Robert A.J. Borst—data curation, project administration, supervision, and writing—original draft. Yared Abayneh Abebe—writing—review and editing. Karin van Vuuren—writing—review and editing. Julien Magana—writing—review and editing. Bert de Graaff—supervision and writing—review and editing. Saba Hinrichs-Krapels—conceptualization, funding acquisition, supervision, and writing—review and editing. Bas Kolen—conceptualization, funding acquisition, supervision, and writing—review and editing. Maria Pregnolato—supervision and writing—review and editing. Anja Schreijer—supervision and writing—review and editing. Tina Comes—conceptualization, funding acquisition, supervision, and writing—review and editing. Sebastiaan N. Jonkman—conceptualization, funding acquisition, supervision, and writing—review and editing. Roland Bal—conceptualization, funding acquisition, project administration, supervision, and writing—review and editing.

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Availability of data and materials
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
As researchers of two Dutch universities, all our work abides by the Netherlands Code of Conduct for Research Integrity. This code stipulates that researchers must act in an honest, scrupulous, transparent, independent and responsible manner throughout their scientific work. Considering that our team, and thus our institutional embedding, are spread across three faculties from two different universities, we have opted for a decentralized and stepped ethical design. This approach means that each WP applies for ethical clearance separately at the relevant Research Ethics Review Committee (RERC) of their faculty or university. In accordance with accepted academic practice in the Netherlands, ethical clearance is generally sought for empirical studies only and always prior to the start of the data collection. Within our wider project, ethical clearance has been received from Erasmus School of Health Policy & Management, EUR (RERC reference ETH2223-0381) and the TU Delft Human Research Ethics Committee (ID 122466). Particular care will be taken of how our research might potentially intervene in the risk behaviour or perceptions of the actors with whom we engage throughout the project. Flooding events are known to produce emotions that linger over time, including the likelihood of developing post-traumatic stress disorder [57]. Besides, we may unintentionally confront people with their risk of flooding, thereby, fuelling anxiety among such people. To minimise the risk of such interactions, a team of ethicists will advise us during the entire course of our project.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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