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Editorial

# Data needs for better surveillance and response to infectious disease threats



As of December 2022, the World Health Organization (WHO) had reported over 600 million cases of COVID-19 and 6 million deaths (World Health Organization, 2023a). These figures, likely far from the true burden (Adam, 2022; Wang et al., 2022; World Health Organization, 2023b), highlight the critical need to improve surveillance, monitoring and control of infectious disease threats. Such improvements are urgent for the current response to COVID-19, which continues to impact much of the world (World Health Organization, 2023a), and will also benefit the monitoring of and response to future epidemics. The recent succession of infectious disease threats that followed COVID-19, e.g. the emergence and re-emergence of monkeypox (Thornhill et al., 2022), poliovirus (Shahnoor et al., 2022) and Ebola (Kiggundu et al., 2022), provides a stark reminder of such needs.

The unprecedented impact of the COVID-19 pandemic resulted in an unprecedented response. This included a marked shift towards proactive and dynamic outbreak monitoring and analysis, aimed at anticipating future epidemic trajectories and informing the epidemic response in real time (Sonabend et al., 2021). Such a shift was made possible by the increased availability of data and innovations in data processing and data analysis. As we mark three years of SARS-CoV-2 circulation, we present a special issue on "*Data needs for better surveillance and response to infectious disease threats*", to revisit, based on the COVID-19 experience, how data are used to detect, monitor, and respond to epidemics and how evidence generated from these data, as well as uncertainties, are presented to stakeholders and policy-makers. This collection of articles showcases examples and highlights successes and future challenges in data for epidemic surveillance and response. While focusing on COVID-19, the lessons learnt will be relevant to other ongoing and future epidemics.

## 1. Capitalising on successes

Our special issue illustrates a wide scope of innovation in data collection, processing and analysis, with successes broadly falling into three themes: surveillance, contextual understanding, and data analytics.

During the COVID-19 pandemic, we witnessed considerable improvement in surveillance to inform situational awareness through traditional and innovative methods. These advances consisted in tremendous scaling up of existing systems as well as implementation of fundamentally novel approaches. While the increase in testing capacity, especially in high-income countries, was remarkable, perhaps even more significant was the increased reliance on population representative surveys of infection levels (Donnici et al., 2022), including large scale, repeated, cross sectional community prevalence studies (Eales et al., 2022). Genomic-based and wastewater-based surveillance was also rapidly adopted globally (Chen et al., 2022; Nourbakhsh et al., 2022), to complement traditional surveillance and in particular to identify new clusters of transmission and new variants.

However, understanding the drivers of an epidemic and how to control it, relies on assessing not only the pathogen circulation, but also the population and environment amongst which it is spreading. For decades, scientists working on infectious disease outbreaks have highlighted the importance of contextual information to understand pathogen transmission (Cori et al., 2017), and this special issue showcases some successes. Studies have illustrated the importance of understanding, at a fine spatial and temporal scale, the characteristics of the population affected: its demographics (Tatem, 2022), as well as behaviours (Martin-Lapoirie et al., 2023), including mobility (Wardle et al., 2023) and contact patterns (Nelson et al., 2022; Nixon et al., 2022; Thindwa et al., 2022; van Zandvoort et al., 2022). Tracking environmental and climate data (Rawson et al., 2023) adds further context to understanding pathogen emergence and spread.

Finally, this wealth of information must be appropriately and robustly handled, to present timely and relevant evidence, and inform stakeholders and decision-makers. This includes the design of new methods to optimise the use of surveillance data (Eales et al., 2022; Groves-Kirkby et al., 2023; Inward et al., 2022; Larremore et al., 2022). The development of robust data infrastructures was also highlighted as critical to collate and process data streams increasing in number, size and frequency, in particular in the context of genomic data (Chen et al., 2022). Finally, the pandemic has demonstrated the increased relevance of data and model synthesis in infectious disease modelling, including the need for inter-disciplinary approaches. Several studies highlighted the importance of combining multiple data sources and analyses to improve confidence in estimates and ensure robustness and usefulness of results for operational planning (Dankwa et al., 2022; Groves-Kirkby et al., 2023; Haw et al., 2022).

## 2. Remaining gaps

Despite these major advances in the type and amount of data collected, collated and analysed to support epidemic monitoring and response, many gaps remain.

Though critical to characterise the populations at risk during an epidemic, and to appropriately scale intervention efforts, simple demographic and mobility data are still often inadequate (Tatem, 2022; Wardle et al., 2023). Basic subnational scale data on populations, their demographic characteristics and their mobility are often non-existent, outdated or based on inaccurate data, particularly in Low- and

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Middle-Income Countries (LMICs). Although much progress has been made to develop population estimates where data is missing, those remain proxies, and their adoption and use for epidemic surveillance and response remains challenging in certain contexts. Where possible, more regular collection of granular demographic data between epidemics should be a priority. Better communication and capacity building to understand how demographic proxies are built, and how they should be interpreted, are also needed. Benefits of such efforts will go beyond emerging disease preparedness and response with broader applicability, for example in the context of responses to natural disasters. Demographic data should be complemented, where relevant, by data on migrations and vital statistics which may be rapidly changing during epidemics.

Detailed data on contacts and how they vary over time are also important to inform dynamic transmission models but also to evaluate in real-time potential changes in contact patterns, for example as a result of non-pharmaceutical interventions (Thindwa et al., 2022). Predicting the level of adherence to protective behaviours is difficult (Martin-Lapoirie et al., 2023), but the pandemic has driven novel efforts to collect direct quantitative data on contacts in different populations (including in LMICs or refugee camps). However, several issues remain. Response rates are typically low, and therefore responses aggregated at large geographical scales do not capture fine spatial heterogeneities (Nelson et al., 2022; Nixon et al., 2022). Where high levels of contacts are detected, for example in high population density settings such as displaced camps, no mechanism is in place to ensure transmission rates can be effectively reduced (van Zandvoort et al., 2022).

Direct surveillance data, through frequent large-scale community prevalence surveys, is the gold standard to monitor prevalence in a population. However, these surveys are expensive and therefore typically only available in a few High-Income Countries. In the absence of such data, monitoring the true levels of transmission is difficult, although possible through the analysis of detailed high resolution case-based data (Eales et al., 2022; Inward et al., 2022) and optimal use of testing strategies (Larremore et al., 2022). Genomic surveillance and environmental data, such as climate data, remains similarly skewed towards high-income countries (Chen et al., 2022; Rawson et al., 2023). Even where pathogen sequence data is available, their full exploitation is often hampered by challenging linkage with other patient information and by technical and analytical limitations associated with the large size of the datasets (Chen et al., 2022). Use of seroprevalence data, while shown to be a timely and robust indicator of transmission intensity, was hindered by the lack of repositories that would allow for rapid dissemination of such data (Donnici et al., 2022). Developing robust infrastructures for more systematic linkage of different datasets, including those collated by the private sector, while adhering to personal and healthcare data protection standards is critical (Ferretti and Vayena, 2022).

The COVID-19 experience suggests that novel promising data sources e.g. wastewater surveillance (Nourbakhsh et al., 2022) are primarily useful in complement, not replacement, of traditional epidemic surveillance. Novel rigorous analytical approaches therefore need to be developed to jointly analyse these different data streams and in turn inform public-health decisions (Dankwa et al., 2022; Nourbakhsh et al., 2022). However, calibration of complex models to multiple data streams is challenging with potential model identifiability issues (Dankwa et al., 2022; Groves-Kirkby et al., 2023). This highlights opportunities for further development of statistical inference methods for epidemic models, and for research into quantifying the information value of different data streams, which could inform future epidemic surveillance.

Finally, the scale of the pandemic and its societal impact clearly highlighted the need to better understand the wide-ranging implications of interventions, and the trade-off when considering their implementation, for instance on education (Recch et al., 2023) or the economy (Haw et al., 2022). Again, this highlights the need for more consistent contextual data streams, not directly related to pathogens themselves. Equally challenging is the need to develop frameworks to handle such inter-disciplinary data and problematics, e.g. socio-epidemiological or eco-epidemiological models.

## 3. Next steps

We call for the creation of global data sharepoints, accompanied by protocols for data collection, data linkage, data sharing and data analysis. Leadership from international agencies or global academic consortia are needed to ensure centralisation of these efforts along with standardisation and harmonisation of data formats and data analytics. Modellers should play a unique role in developing such data sharepoints by designing clear protocols for what data and data linkages are needed during each phase of an outbreak to answer specific public health questions. Local capacity building and increased transparency regarding data biases will be key for building trust and for data analytics to be operationalised globally to impact policy and address health inequalities.

In conclusion, this special issue showcases recent successes while highlighting remaining gaps to support the needs of expanded and reshaped disease surveillance and risk assessment systems, and to inform policy decisions for better epidemic preparedness and response. Each dataset individually has limited value. Different sources of data, from traditional public health surveillance data to data that were not originally collected for public health purposes, will need to be combined, together with the appropriate analytical tools, to provide robust and actionable public health insights. Investing in data linkages, data analysis pipelines (Gaythorpe et al., 2023) and understanding the value and biases of different datasets will be as important as collecting and collating the data itself. Strengthened and new collaborations that include academic centres across different research fields, public health agencies, the public (Piggin et al., 2022), governments, and private entities such as telecommunications companies and news media agencies (Desai et al., 2021) will be key to building systems that can scale and adapt to each new emerging pathogen while providing ethical frameworks for the use and re-use of personal data.

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