PNAS LETTER

Reply to Ekström and Ottersen: Real-time access to data during outbreaks is a key to avoid a local epidemic becoming a global pandemic

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Ekström and Ottersen (1) correctly observe that improved real-time data access is needed for a digital twin to be effective and reliable, and that this is a caveat for our work on using digital twins to inform decisions that could prevent local epidemics becoming global pandemics (2). Data-availability in support of operational decision-making must be an important part of a "pandemic treaty" (3). Here, we further discuss the importance of data-availability (Fig. 1).

1. As mentioned by Ekström and Ottersen (1), pathogen genomics is crucial for phylogeography: tracing the origin and movements of the pathogen world-wide (4).
2. For a novel zoonotic disease, data on pathogen spread is essential to understand its transmission dynamics [e.g., by droplets or direct contact, or via an intermediate host—like mosquito in the case of malaria (5)].
3. With real-time data access, a digital twin may leverage AI and Machine Learning methods to obtain insights on decision-relevant time scales, using feedback loops to update the parameter estimation and to explore whether predictions can improve by increasing model detail [such as age-structured vulnerability and social interactions (2)].
4. For diseases where the pathogen is spread by humans, travel and other mobility data are essential—local, national, and global—in real-time. Data from contact tracing, mobile phones, and other location-based services can help to identify hotspots and track the effectiveness of interventions (6).
5. Other categories of data, including weather and readiness of key response infrastructure, as well as social media posts, search engine queries, and waste water sampling can also potentially be used for pandemic early warning and intervention (7, 8).

Data-availability to support operational decision-making must be accompanied by the protection of personal information and responsible use of AI-based technologies. Although much data can be delivered in aggregated and anonymized form, the precision of predictions may depend on the data being *sufficiently precise*, which is difficult to know in advance. Complementary techniques to approximate data are needed to handle delayed, low-quality, or unavailable data, although these will necessarily decrease precision. For this, a coordinated international data-sharing hub, like GISAID, and the recently established WHO Hub for Pandemic and Epidemic Intelligence will play important roles. During an epidemic, international agreements need to be in place to ensure compliance with established protocols related to data rights, privacy, and aggregation, as well as agreements with nongovernmental entities that might host relevant datasets. These issues are nontrivial and need to be addressed in a "pandemic treaty" (9).

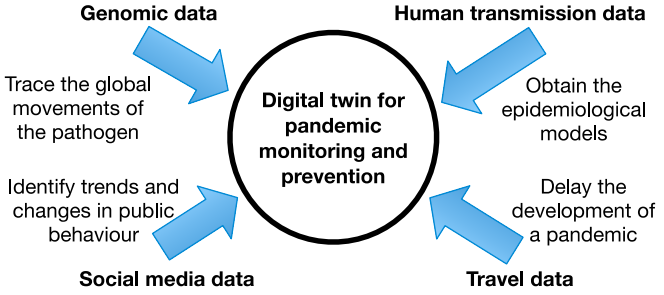

Fig. 1. Real-time access to epidemic-related data.

Every effort must be made to avoid that any pathogen [be it known, such as Lassa virus (10), or novel, such as SARS-CoV-2] spills over to the human population. Procedures are needed for reporting unusual events (such as a local disease outbreak in some wildlife population or a research-related incident). Such data might significantly help in avoiding global pandemics.

Improvements in operational systems of disease warning and response are critical to avoid new pandemics. Real-time

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sharing of a broad spectrum of data with specified protocols (as opposed to "open data") in a digital twin can be an important tool to achieve this.

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