Global Public Health Database Support to Population-Based Management of Pandemics and Global Public Health Crises, Part II: The Database

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Abstract
This two-part article examines the global public health (GPH) information system deficits emerging in the coronavirus disease 2019 (COVID-19) pandemic. It surveys past, missed opportunities for public health (PH) information system and operational improvements, examines current megatrend changes to information management, and describes a new multi-disciplinary model for population-based management (PBM) supported by a GPH Database applicable to pandemics and GPH crises.


Introduction
The 2019 novel coronavirus (SARS-CoV-2, 2019-nCoV) disease (COVID-19) has become the first pandemic of the 21st century. Viral contributory causes include high virus shedding from upper respiratory tract secretions, symptomatic and pre-symptomatic virus transmission, reproduction ratio estimates up to 3.58, little effective antiviral therapy, and no effective vaccine. Health system and community contributory causes include wide-spread community seeding through unrestricted air travel, inadequate implementation of non-pharmacologic control measures, limited contact tracing and viral diagnostic capabilities, overwhelmed clinical care facilities, and threat minimization by elected officials.

These contributory causes have drawn attention to potential remedies for pandemic management by public health (PH) authorities. Part I reviewed past missed opportunities for PH information systems and operational improvements, then examined important PH megatrends heralding future advances in pandemic management—evidence-based decision making, data literacy, ascent of PH information services, and ascent of remote management. Part I also reviewed the emergence of population-based management (PBM) of health crises. A multi-disciplinary model led by PH professionals is required to ensure data driven decisions can be made that reflect the PH needs and risks of local communities. This approach builds on the evolution of disaster management systems, which are used in most countries across the world, to regularly deal with local, state, national, and international crises. This article examines database requirements and modalities of functioning for PBM teams (PBMTs).

Digital Technology
Digital technologies may help perform a wide range of functions in pandemic management, as summarized in Table 1. Health authorities in some countries have attributed their disease control successes to early adoption of such technology. Nonetheless, major issues have arisen on data oversight, privacy, protection of personally identifiable health information, and redress for errors that implementing jurisdictions must confront. The scientific community has seen retractions of papers published in The Lancet and The New England Journal of Medicine due to post-publication concerns over provenance.

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of proprietary data and inconsistencies from electronic health records. This experience is cautionary about the importance of data source/origin, data audit trails, and oversight in managing such datasets.

Core Databases
Core Databases for PBM are characterized below in three overriding domains:

1. Background Information (Table 2) describes the affected population pre-pandemic—demography, access to essential services, health status, and socioeconomic status.
2. Clinical Case and Virological Data (Table 3) encompasses case definitions, case identification and outcomes, and clinical dynamics (case-fatality rates, death rates, and time course to death).
3. PH Control Measures and Consequences (Table 4) encompasses details of contact tracing, quarantine measures, travel restrictions, and all epidemic modelling.

The Database Challenge
The technical standards for disease surveillance and surveillance systems comprise an extensive literature. The Centers for Disease Control and Prevention (CDC; Atlanta, Georgia USA) published its first guidelines in 1988, which were re-issued in 2001. The World Health Organization (WHO; Geneva, Switzerland) Program on Disease Control in Humanitarian Emergencies published numerous adaptations of communicable disease and surveillance guidelines for epidemic-prone diseases in natural disasters and complex emergencies through the 2000s. Recent emerging infectious diseases such as Ebola have prompted global attention, including tracking of critical mobility-related information.

Table 1. Applications of Digital Technology in Pandemics
Source: Adapted from Whitelaw. Abbreviations: AI, artificial intelligence; PDA, personal digital assistant.

<table>
<thead>
<tr>
<th>Function</th>
<th>Technology</th>
<th>Early Adopters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infection Screening</td>
<td>Digital thermometers, infrared thermal cameras, web-based tools</td>
<td>China, Iceland, Singapore, Taiwan</td>
</tr>
<tr>
<td>Contact Tracing</td>
<td>GPS, mobile phone apps, facial recognition technology</td>
<td>China, Germany, Singapore, South Korea</td>
</tr>
<tr>
<td>Quarantine and Isolation</td>
<td>GPS, mobile phone apps, surveillance of mobile devices for voluntary or involuntary tracking</td>
<td>China, Iceland, South Korea, Taiwan, Australia</td>
</tr>
<tr>
<td>Clinical Management</td>
<td>Lab test pooling, telemedicine, video-conferencing, AI algorithms for clinical outcome prediction</td>
<td>Australia, Canada, China, USA</td>
</tr>
<tr>
<td>Medical Logistics</td>
<td>Mobile apps for transactions, barcode scanners for commodities, robotics, and drones for delivery</td>
<td>US, China</td>
</tr>
<tr>
<td>Epidemic/Pandemic Tracking</td>
<td>Data dashboards, real-time data transmitted by smartphones and PDAs</td>
<td>China, Singapore, Sweden, USA</td>
</tr>
</tbody>
</table>

The WHO concludes that working together with data firms and health agencies (ie, PBMTs) before a disaster strikes mitigates searching for data at the start of an outbreak, which is too late, reiterating a multi-stakeholder collaboration archives more than working in isolation.
### A. Population at Risk

<table>
<thead>
<tr>
<th>1. Census</th>
<th>M</th>
<th>F</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. &lt; 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. 1-4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. 5-14</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>d. 15-44</td>
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<td></td>
</tr>
<tr>
<td>e. ≥ 45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. total</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Demography
   - race, ethnicity, religion
   - languages
   - socioeconomic status
   - urban vs rural
   - average family/household size

### B. Settlements

1. Locations
   - community size, geographic separation
   - access to transportation hubs and communication links

2. Population Mobility
   - diurnal and seasonal occupational travel flows
   - recreational and tourist travel flows
   - migration flows

3. Community Density
   - geographic separation of families within the settlement

4. Hazard Exposure (eg upcoming seasonal natural hazards)

5. Discrimination and Conflict within the Community

6. Emergency Preparedness

7. Known Coping Mechanisms

### C. Access to Essential Services

1. Public Utilities (infrastructure)
   - % population with access to improved water
   - % population with access to improved, unshared sanitation
   - % population with electricity
   - % population with cell phones

2. Health Services
   - skilled health care workers (ally)/10,000 p (22)
   - physicians/10,000 p (0.2)
   - nurses/10,000 p (1)
   - midwives/10,000 p (1)
   - community health workers/10,000 p (10)
   - % population with provider coverage (100%)
   - consultations/p/yr (1)
   - immunization rates — measles vac in 1 y/o (90%)
   - hospital beds/10,000 p (10 - 120)
   - admissions/10,000 p

3. Underserved Areas (by location and type of service)

### D. Health Status

1. Mortality and Other Rates
   - CBR (10 - 50)
   - CMR (5 - 25)
   - AGFR (%)
   - IMR (3 - 200)
   - U5MR (3 - 300)
   - MMR (5 - 2,100)

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Table 2. Datasets and Visualizations Pre-Pandemic (continued)
Artificial Intelligence in support of the GPH Database

Expectations were high for AI to help fight COVID-19. However, before AI tools can make an impact, global collaboration and high-quality data and model sharing are needed. Nature Machine Medicine emphasized that early warning and alerts, prediction and detection of outbreak of diseases, real-time disease monitoring world-wide, analysis and visualization of spreading trends, prediction of infection rate and infection trend, and rapid decision making to identify the effectiveness of management. Other authors emphasize challenges that need to be addressed before AI can have a beneficial global impact. They point out that a first challenge is knowing where to start with developing AI tools that can be most effective, which requires close cooperation with practitioners at the health care frontline, those that manage the PDMTs. The best solutions may involve adapting already validated systems rather than building new tools from scratch. Furthermore, Hu, et al described how clinical needs are evolving as the pandemic is moving through different stages, from early detection and anticipation, to containment and mitigation, and finally eradication. During these transitions, the specific types of AI models may need to change too. Ideally, the AI system itself becomes a smart, intelligent, and adaptive system.

Table 2. (continued) Datasets and Visualizations Pre-Pandemic

<table>
<thead>
<tr>
<th>Dataset Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutritional Status</td>
<td>% infants with low birth weight (LBW) (7% with &lt; 2.5 kg)</td>
</tr>
<tr>
<td>Endemic Diseases and Comorbidities</td>
<td>Chronic Illnesses and Conditions (1) hypertension</td>
</tr>
<tr>
<td>Endemic Diseases and Comorbidities</td>
<td>Infectious Diseases (1) HIV prevalence</td>
</tr>
<tr>
<td>Endemic Diseases and Comorbidities</td>
<td>Other Major Diseases</td>
</tr>
<tr>
<td>Endemic Diseases and Comorbidities</td>
<td>Routine/Baseline Disease Surveillance Data</td>
</tr>
<tr>
<td>Endemic Diseases and Comorbidities</td>
<td>Health Beliefs and Traditions</td>
</tr>
<tr>
<td>Endemic Diseases and Comorbidities</td>
<td>Sources of Care</td>
</tr>
<tr>
<td>Endemic Diseases and Comorbidities</td>
<td>Referral System</td>
</tr>
</tbody>
</table>

E. Macroeconomic Status

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor force occupations</td>
<td></td>
</tr>
<tr>
<td>Unemployment rate</td>
<td></td>
</tr>
<tr>
<td>GNI per capita (SUS) ($700 - $70,000)</td>
<td></td>
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<tr>
<td>Inflation rate</td>
<td></td>
</tr>
<tr>
<td>% population in extreme poverty (&lt; $1.90/d income)</td>
<td></td>
</tr>
<tr>
<td>Current health expenditures per capita ($30 - 10,000)</td>
<td></td>
</tr>
</tbody>
</table>

F. Educational Status

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult literacy rate</td>
<td></td>
</tr>
<tr>
<td>Female literacy rate</td>
<td></td>
</tr>
<tr>
<td>Adolescent literacy rate</td>
<td></td>
</tr>
</tbody>
</table>

Artificial Intelligence in support of the GPH Database

The origins of this pandemic can be attributed to climate change and the emergence of complex GPH crises such as climate extremes, biodiversity loss, emergencies of scarcity, rapid unsustainable urbanization, migrant and refugee surges, domestic and international terrorism, the civilianization of war and conflict, and the global rise of resistant antibiotics that have resulted in an unprecedented rise in direct and indirect mortality and morbidity, among others. In 2019, The Tohoku Journal of Experimental Medicine recognized the emergence of complex GPH crises that are beyond the current decision-making and operational capabilities of traditional disaster management and its providers, most of who are community-level practitioners representing every discipline.

The 1930s “disaster cycle” concept described a phase-related approach to meeting the strategic, operational, research, educational, and training components required of disasters; this presents an opportunity for the structured development of a Health Crisis Management Framework to oversee the phase-related strategic and operational requirements for prevention, preparedness, response, recovery, and rehabilitation challenges of major GPH crises. No longer will physicians, for example,
focus on the response phase alone. Future PBMTs will be trained across the entire disaster cycle. Operational knowledge on prevention and preparedness will lessen the number of victims more than any other action. The Japanese Editorial launched academic interest in training multi-disciplinary Health Care Crisis Managers and Scientists to fill the full- and part-time roles required of PBM, PBMTs, and those managing the GPH Database. For example, the university-centered CRIMEDIM (Research Center in Emergency and Disaster Medicine) in Navaro, Italy has worked diligently to offer both Masters and PhD degrees leading to training Health Crisis Managers and Scientists from many contributing disciplines to fill these proposed PBMT positions. A global effort is recommended post-COVID of multi-disciplinary educational programs to help prepare the potential PBMT and GPH Database experts that this study recommends.

Clinical and Virological Data:

A. Clinical Data
   1. Case Definitions (suspected, probable, confirmed)
   2. Severe Cases (admissions, ICU cases, ventilated cases)
      a. Age/gender/race data
      b. Comorbidities
      c. Clinical course, complications, and outcomes
      d. Data on use of antivirals, antibodies, and vaccines
      e. Discharge diagnoses
      f. Causes of death
   3. Clinical Dynamics—population morbidity and mortality rates, age & gender-specific CFRs, time course to death
   4. Hotspot Definitions—cases linked temporally or geographically triggering further outbreak investigation and/or control measures

B. Virological Data
   1. Sentinel Site Testing
   2. Confirmatory testing for new cases in the community meeting the surveillance definition (before sustained community transmission is identified)
      a. daily new positive cases
      b. 14 day running average
   3. Confirmatory testing for hospital admissions and unexplained deaths that are compatible with the disease
   4. Community seroprevalence testing once community transmission is established
   5. On-demand individual testing (depending on resource availability, may be targeted at vulnerable groups)
   6. Antiviral Sensitivity Testing

Table 3. Datasets and Visualizations Intra-Pandemic

Modelling, Control Measures, and Impact:

A. Epidemic Modelling Data
   1. Population sizes and subgroups at risk
   2. Compartment models
   3. Spot maps (geolocated plots of disease outbreaks)
   4. Kinetics models of transmission dynamics—incubation period, reproduction ratio, contacts per case
   5. Epidemic curves
   6. Epidemic projections showing impact of non-pharmaceutical mitigation measures

B. Public Health Control Measures
   1. Travel restrictions
   2. Arrival testing
   3. Contact tracing effectiveness
   4. Quarantine requirements (site specification, duration, monitoring), social acceptance of quarantine measures, overall adequacy of quarantine
   5. Social distancing recommendations
   6. Mask recommendations
   7. Restrictions on social gatherings
   8. Lockdown onset, duration
   9. Population sizes & community densities of populations affected

C. Socio-Economic Impact Data
   1. Displacements
   2. Unemployment rates
   3. Evictions
   4. Business closures
   5. Direct costs in health care
   6. Indirect costs of business losses
   7. Government expenditures for unemployed persons and distressed businesses

Table 4. Datasets and Visualizations Intra-Pandemic

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References


