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Novel Disease Event Monitoring Tools

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Disclosures

- None of the presenters at this session have received financial support or in-kind support from a commercial sponsor.
- The presenters have potential conflicts of interest to declare.

Presenter Disclosures

Nature of relationship(s)	Name of for-profit or not-for-profit organization(s)	Description of relationship(s)
Funded grants or clinical trials	International Society for Infectious Diseases	Funding for research program support
Funded grants or clinical trials	PandemicTech	Funding for research program support

Mitigating Potential Bias

This presentation was peer-reviewed to ensure that principles of scientific integrity, objectivity, and balance have been respected.

Polling Question 1

- Have you used digital disease event monitoring tools over the past 18 months?

Learning Objectives

- 1. Identify the role of informal disease event monitoring and reporting
- 2. Define specific applications of informal disease event monitoring systems for outbreak detection
- 3. Discuss data limitations in real-time epidemic forecasting

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PHOTOGRAPH: GETTY IMAGES

Published Date: 2019-12-30 23:59:00

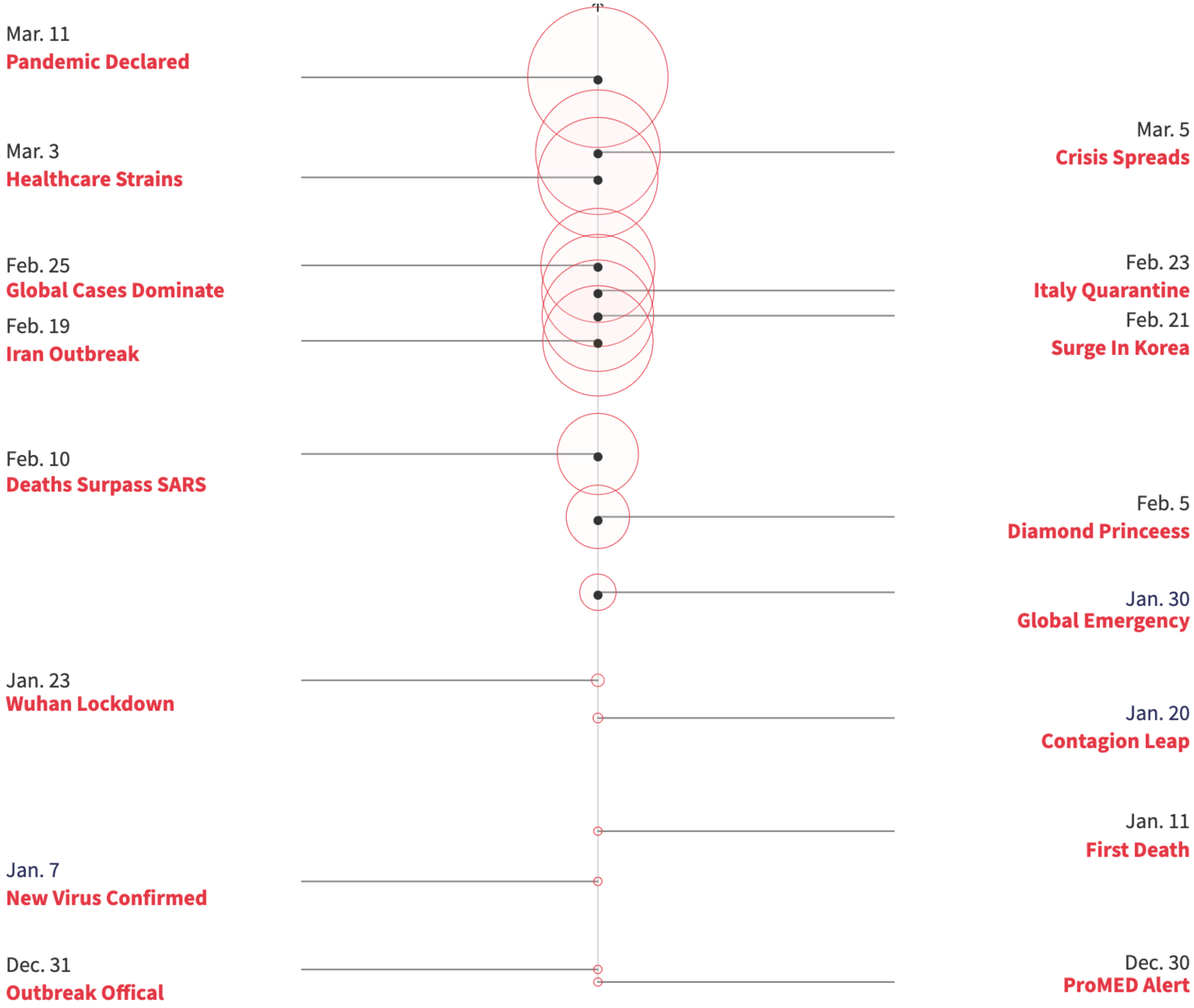
Subject: PRO/AH/EDR> Undiagnosed pneumonia - China (HU): RFI

Archive Number: 20191230.6864153

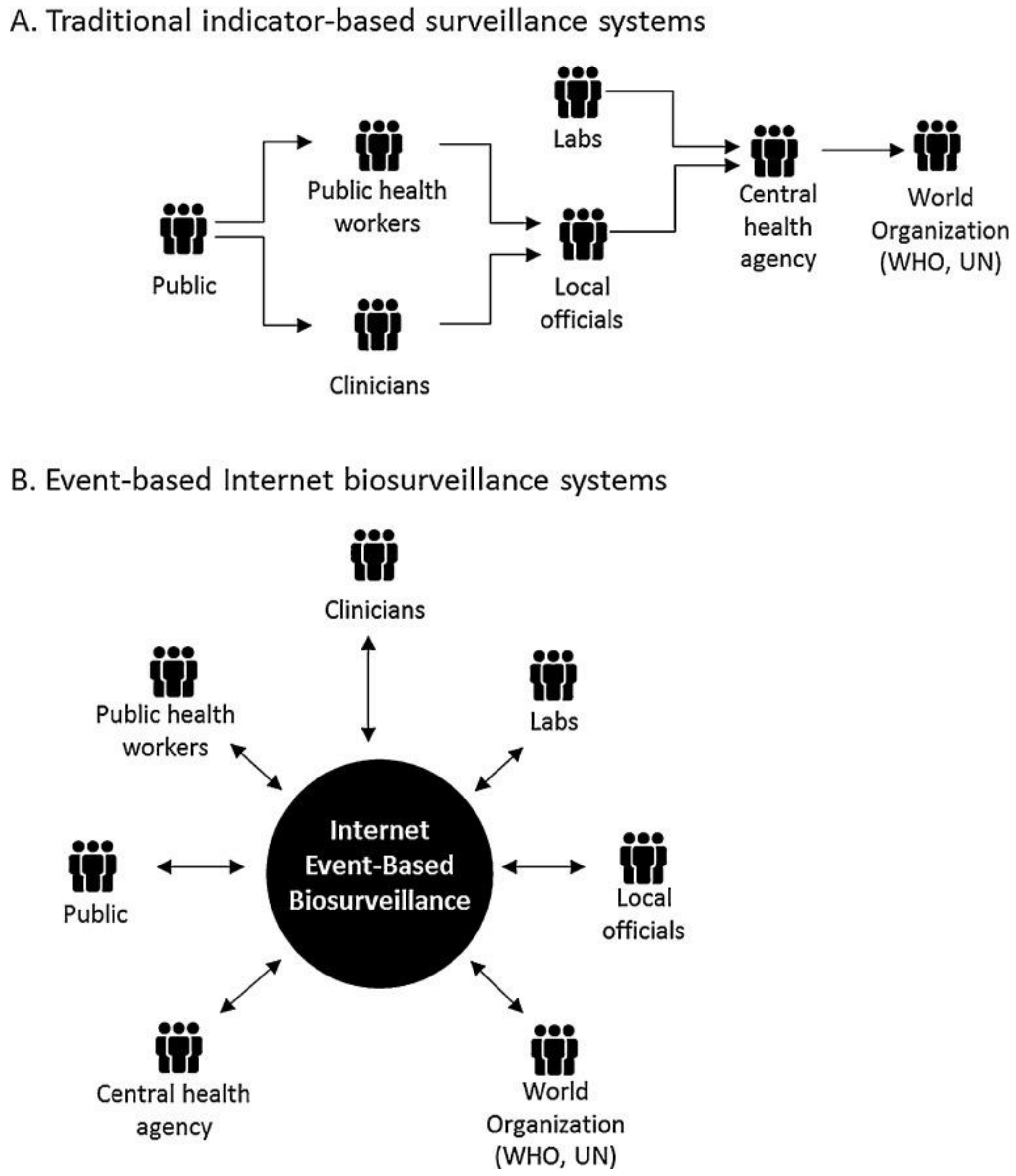
UNDIAGNOSED PNEUMONIA - CHINA (HUBEI): REQUEST FOR INFORMATION
****
A ProMED-mail post
http://www.promedmail.org
ProMED-mail is a program of the
International Society for Infectious Diseases
http://www.isid.org

[1]
Date: 30 Dec 2019
Source: Finance Sina [machine translation]
https://finance.sina.cn/2019-12-31/detail-iihnzahk1074832.d.html?from=wap

Wuhan unexplained pneumonia has been isolated test results will be announced [as soon as available]



Johns Hopkins University Center for Systems Science and Engineering



O'Shea J. Int J Med Inform. 2017

Table 2
List of Event-Based Internet Biosurveillence Systems Identified.

System Name	Category	Founding Country	Year Started	Currently online	Prototype
Argus	Moderated	USA	2004	No	No
BioCaster	Automatic	Japan	2006	No	No
GeniDB	Automatic	Japan	2012	No	No
GODSN	Automatic	USA	2006	No	No
MiTAP	Automatic	USA	2001	No	Yes
EWRS	Moderated	EU	1998	Yes	No
Proteus-BIO	Automatic	USA	2000	No	Yes
MedCOLLECTOR	Automatic	Portugal	2009	Yes	No
nEmesis	Moderated	USA	2013	No	Yes
EpiSPIDER	Automatic	USA	2006	No	No
Digital Disease Detection Dashboard	Moderated	USA	2014	No	Yes
MedISys and PULS	Automatic	EU	2004	Yes	No
GPHIN	Moderated	Canada	1997	Yes	No
HealthMap	Automatic	USA	2006	Yes	No
InSTEDD	Moderated	USA	2006	Yes	No
ProMED-mail	Moderated	USA	1994	Yes	No
Foodborne Chicago	Moderated	USA	2013	Yes	No
GET WELL	Automatic	Sweden	2010	Yes	No
Google Trends	Automatic	USA	2009	Yes	No
De Grote GriepMeting[a]	Moderated	Netherlands Belgium	2003	Yes	No
Gripenet[a]	Moderated	Portugal	2005	Yes	No
Influweb[a]	Moderated	Italy	2008	Yes	No
FluSurvey[a]	Moderated	UK	2009	Yes	No
InfluenzaNet[a]	Moderated	EU	2009	Yes	No
Influmeter[a]	Moderated	Denmark	2012	Yes	No
GripeNet[a]	Moderated	Spain	2012	Yes	No
Grippenet[a]	Moderated	France	2011	Yes	No
Halsorapport[a]	Moderated	Sweden	2011	Yes	No
FluSurvey.Ie[a]	Moderated	Ireland	2013	Yes	No
FluTracking	Moderated	Australia	2006	Yes	No
Reporta	Moderated	Mexico	2009	Yes	No
Flu Near You	Moderated	USA	2011	Yes	No
Salud Boricua	Moderated	Puerto Rico	2012	Yes	No
Dengue na Web	Moderated	Brazil	2011	Yes	No
Crowdbreaks	Moderated	USA	2012	Yes	Yes
Doctor Me App	Moderated	Thailand	2011	Yes	No
GermTrax	Automatic	USA	2012	Yes	No
SickCity	Automatic	USA	2009	No	No
FluDetector	Automatic	UK	2009	No	No
Infovigil	Moderated	Canada	2009	No	Yes
M-Eco	Automatic	EU	2010	No	Yes
NowTrending (previously MappyHealth)	Automatic	USA	2012	Yes	No
FluTrackers.com	Moderated	USA	2006	Yes	No
GoViral	Moderated	USA	2013	Yes	Yes
BlueDot (previously BioDiaspora)	Moderated	Canada	2008	Yes	No
Mo-Buzz	Moderated	Singapore	2013	Yes	No
Sickweather	Automatic	USA	2011	Yes	No
FluCaster	Automatic	USA	2013	Yes	No
GOARN	Moderated	USA	2000	Yes	No
HealthTweets.org	Automatic	USA	2013	Yes	No

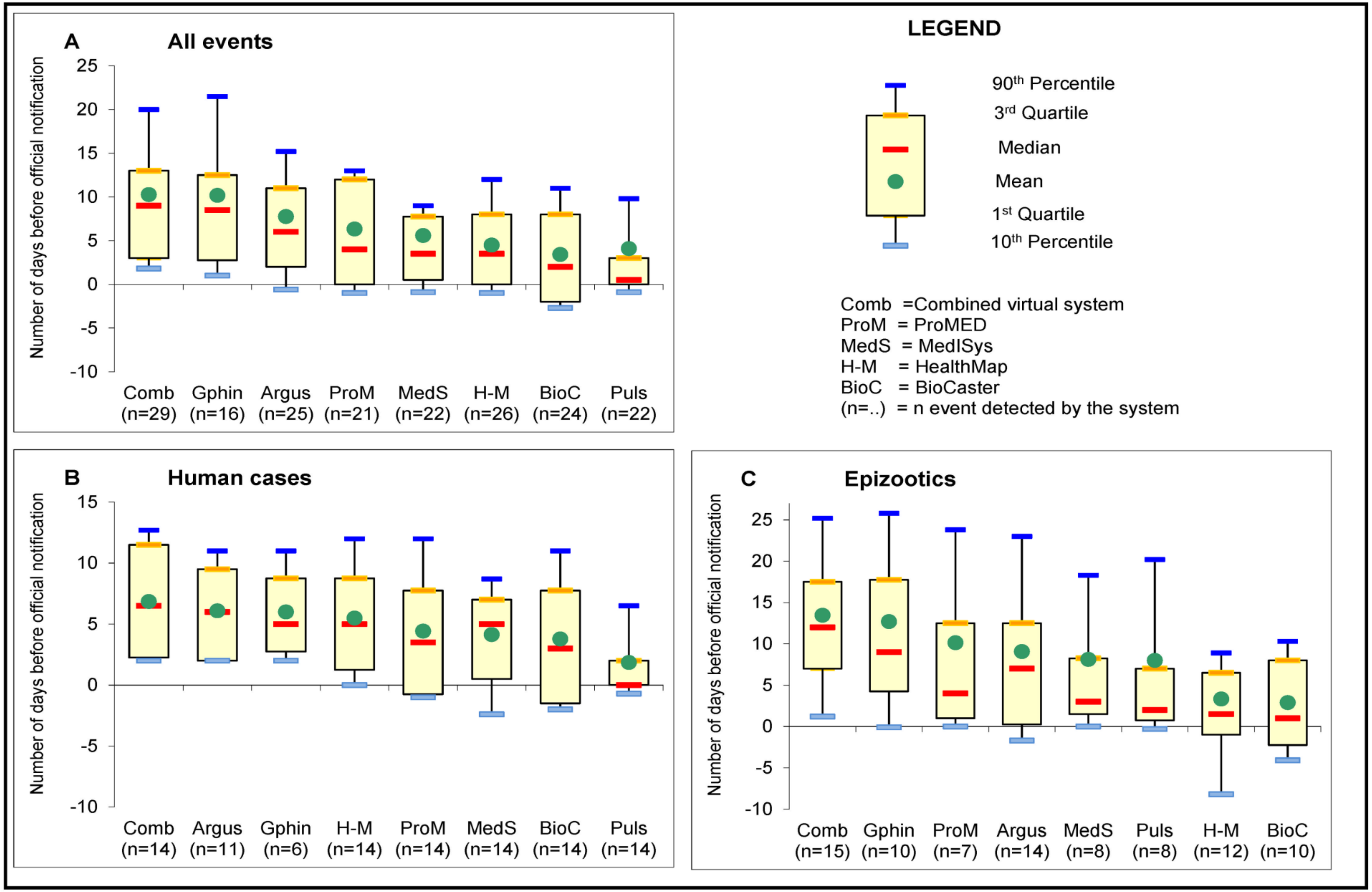
[a] Collectively can be called InfluenzaNet.

O'Shea J..Int J Med Inform. 2017

Pros	Cons
• Fast detection and reporting	• Information captured might not be accurate or significant
• Not constrained to certain events	• Sources may present biased information
• Multiple sources of information (e.g., clinicians, labs, media reports, internet blogs)	• Uses broad case definitions
• Leverages publicly available information, increasing transparency	• No standard data format, takes additional time to synthesize

- ProMED (Program for Monitoring Emerging Diseases)
- Global Public Health Intelligence Network (GPHIN)

- HealthMap
- MediSys
- EpiSPIDER
- BioCaster
- Wildlife Disease Information Node
- EIN
- GOARN
- Epi-X
- GHSA
- EpiCore
- Global.health



Barboza et al. PLOS One. 2013.

CDC Stands Up New Disease Forecasting Center

Press Release

For Immediate Release: Wednesday, August 18, 2021
Contact: Media Relations
(404) 639-3286

Today, the Centers for Disease Control and Prevention (CDC) is announcing a new center designed to advance the use of forecasting and outbreak analytics in public health decision making. Once established, the Center for Forecasting and Outbreak Analytics will bring together next-generation public health data, expert disease modelers, public health emergency responders, and high-quality communications, to meet the needs of decision makers. The new center will

US CDC. 2021.

A new understanding of pandemic and epidemic risks

World Health Organization. 2021.

Learning Objectives

1. Identify the role of informal disease event monitoring and reporting

2. Define specific research applications of informal disease event monitoring systems for outbreak detection

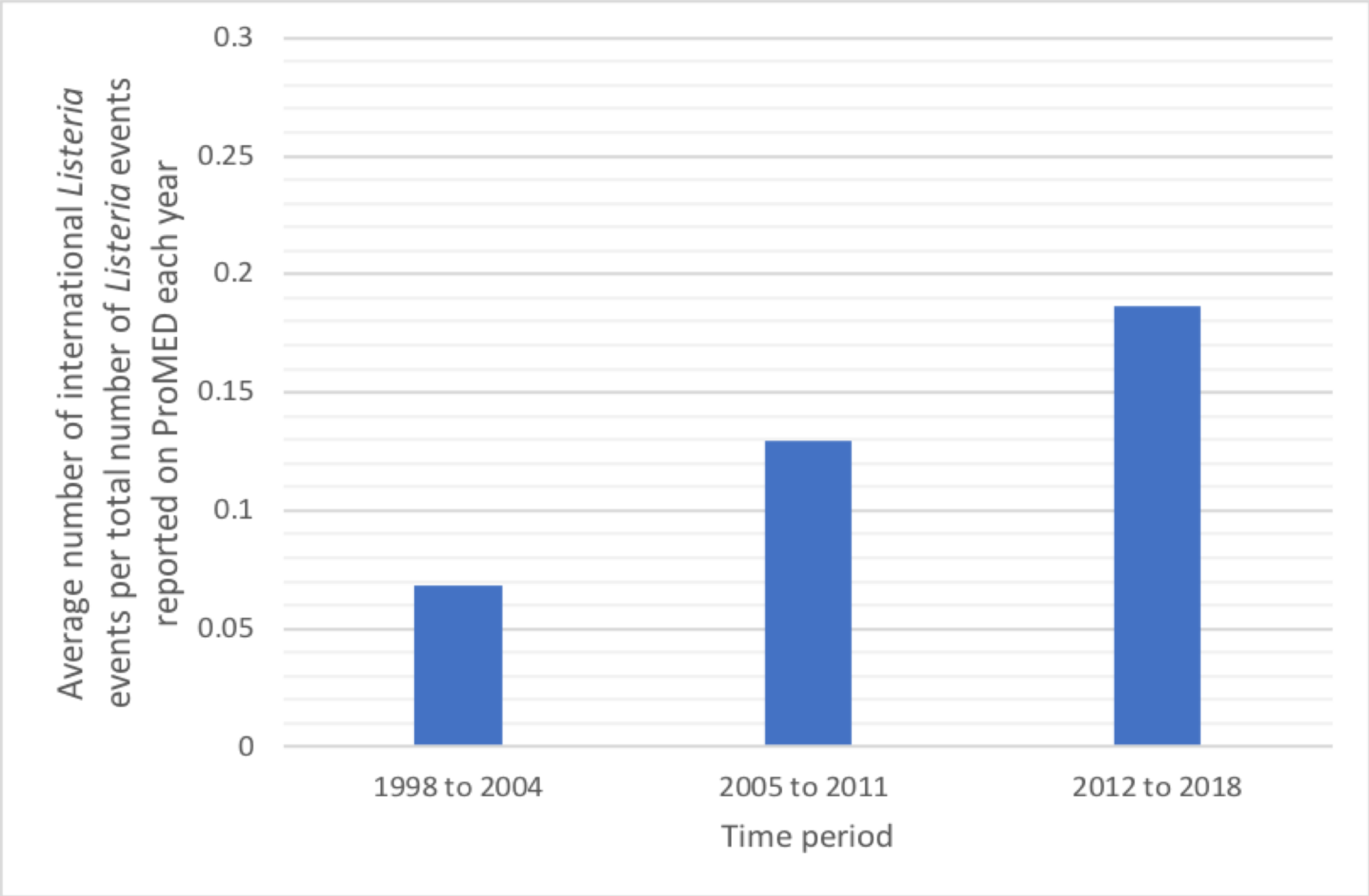
3. Discuss data limitations in real-time epidemic forecasting

An Aside…

- Travel Medicine
- ProMED-AMR

Results

Figure 3: Average number of international *Listeria* events per total number of *Listeria* events reported on ProMED each year over three time periods



Desai et al, Int J Infect Dis. 2019.

Results

Table I: Characteristics of *Listeria* events reported on ProMED

Events	N=Event Counts (%)
Total Events	123 (100%)
• Outbreaks (two or more human cases)	81 (65%)
• Sporadic cases	13 (11%)
• Precautionary recalls*	29 (24%)
Hospital-acquired events	10/123 (8%)
Events involving multiple countries	21/123 (17%)
Case-fatality rate, overall	487/2,383 (20%)

Desai et al, Int J Infect Dis. 2019.

MRIIDS

Mapping the Risk of International Infectious Disease Spread (MRIIDS)

A User-friendly Tool for Outbreak Response and Epidemic Preparedness

http://mriids.org https://github.com/ISIDOrg/MRIIDS/wiki/Mapping-the-Risk-of-International-Infectious-Disease-Spread

MRIIDS

Disease outbreak information is assessed with automated intelligence capabilities that incorporates population density information to estimate the number of cases for specific outbreak events.

Additionally, the algorithm provides a risk projection to describe where infectious diseases cases are most likely to arrive from and depart to for specific countries. The information generated by the platform is accessible free of charge and incorporated into a platform with extensive end-user testing.

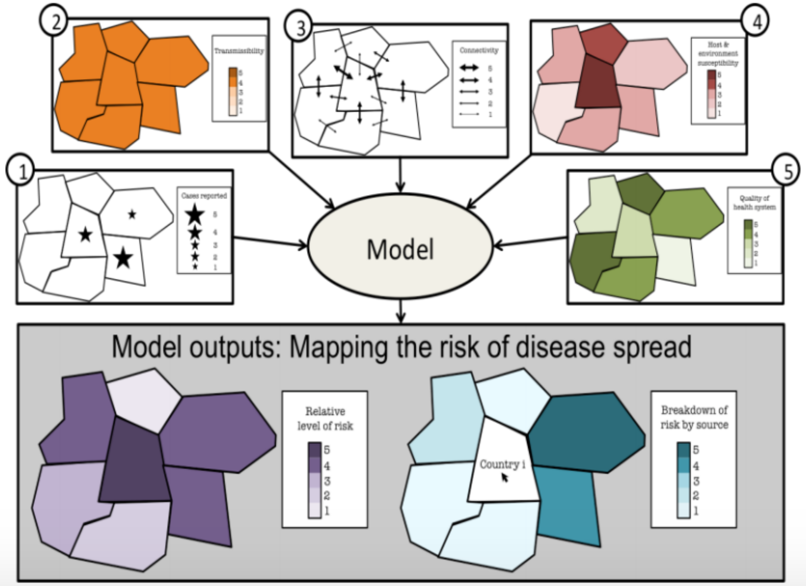
Developed based on data from the 2014-16 West Africa Ebola outbreak, the MRIIDS prototype was designed to be rapidly scalable by extending it to pathogens of significance to humans and animals on a global scale. The tool aims to inform key health decision-makers at national and regional levels of the risks of an outbreak spreading in real-time, and aids government and non-governmental decision-makers as they prepare for the possible arrival of an infectious disease threat to their region.

Mapping the Risk of International Infectious Disease Spread

- User-friendly tool to estimate and visualize the risks of outbreak events spreading
- Aimed at helping decision makers with health resource allocation and infectious disease threat preparedness
- Uses multiple data streams including ProMED, international flight data, and health center data
- Potential end-users include government, public health experts, health care workers, NGOs, and others

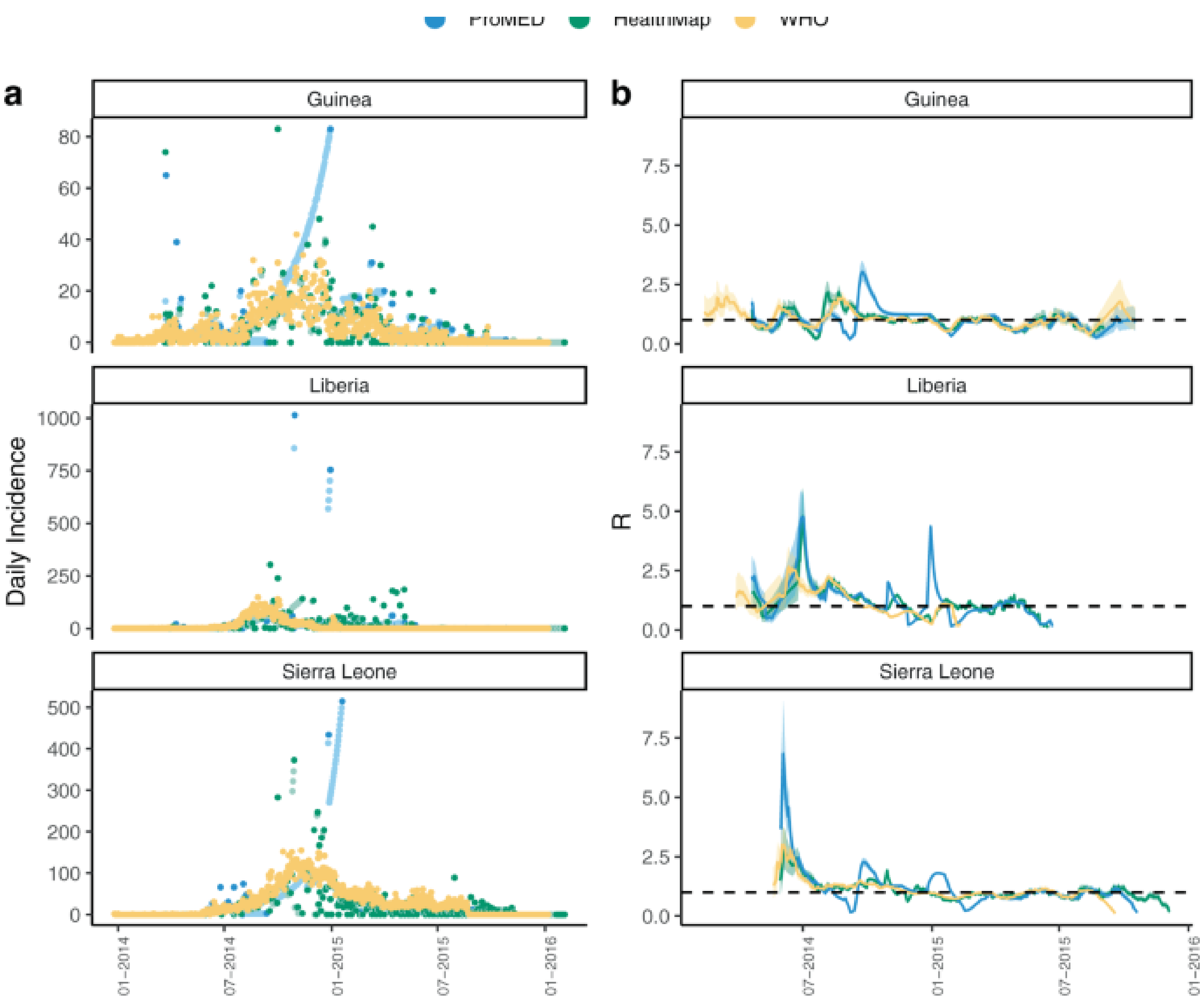
Project partners:

- **The International Society for Infectious Diseases (ISID)** and its **Program for Monitoring Emerging Diseases (ProMED)**
- **Imperial College London**
- **heathsites.io**
- **HealthMap**



Courtesy of Lawrence Madoff, MD

MRIIDS



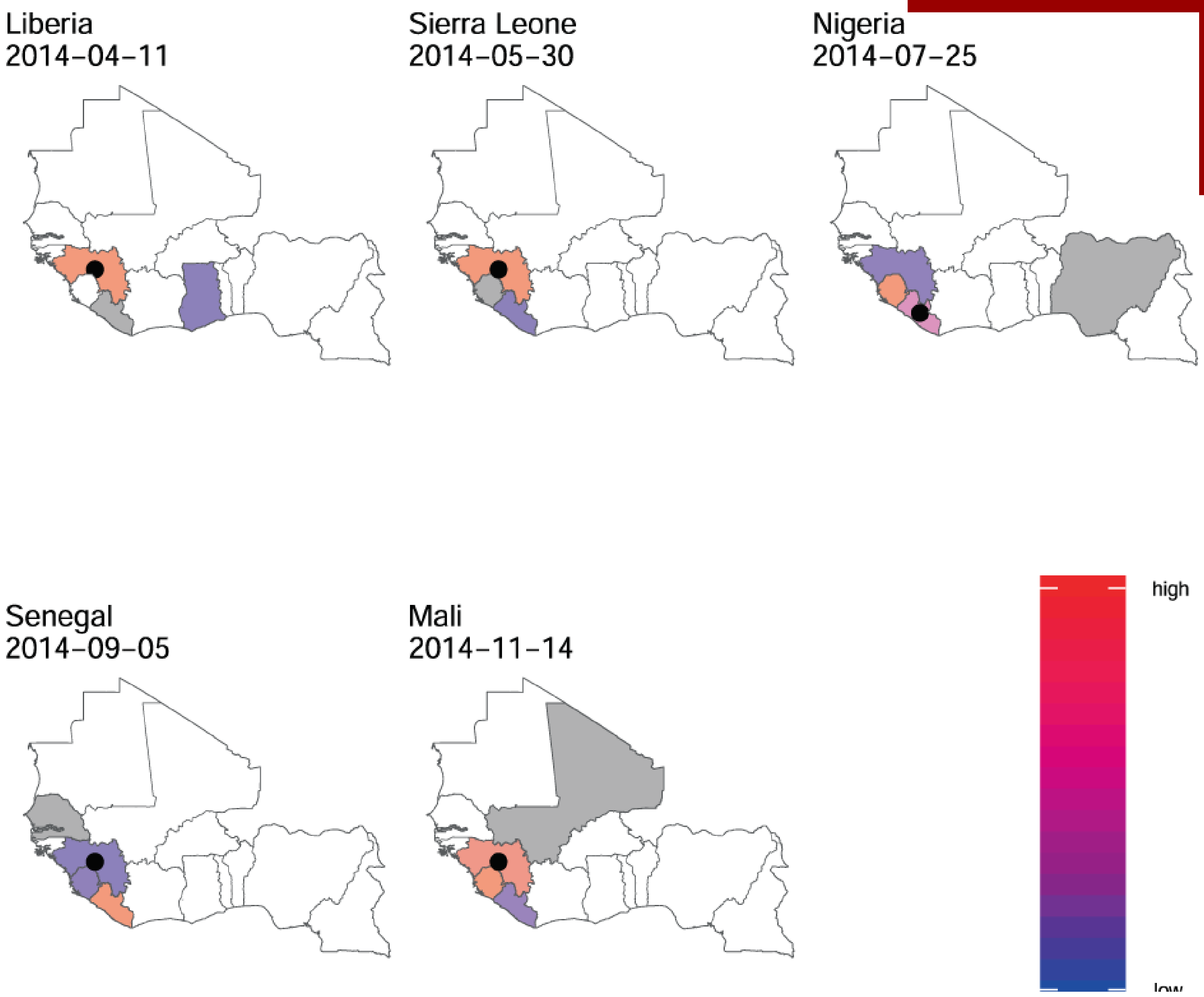
Bhatia et al. Nature Dig. 2021.

Risk of Importation

Fig. 3: Relative risk of importation of the epidemic.

From: Using digital surveillance tools for near real-time mapping of the risk of infectious disease spread

For each country with non-zero incidence, the figure shows the relative importation risk (see Methods). Since we forecasted every 7th day, the risk of importation was estimated using forecasts closest to and before the date of the first case in that country reported in the data used. The date on which risk was estimated for each country is shown in the figure. Blue indicates low relative risk while deeper shades of red represent higher relative risk of acting as a source of importation. White is used to denote no risk. The estimates presented here use ProMED data with a 2 week calibration window. The country for which risk is estimated is shown in grey. The black circle represents the actual source of importation as retrospectively identified through epidemiological and genomic investigations. For each country, the figure shows only the risk of importation from other countries and does not show the risk of transmission within the country.



Bhatia et al. Nature Dig. 2021.

Table. Disease drivers identified in the literature and examples of data availability*

Driver theme (references)	Global data examples†	Regional data examples†
Human susceptibility to infection (*1*,*2*,*4*)	Vaccine rumor surveillance, product distribution data from manufacturers, self-reported immunization status	US influenza vaccination rates, measles vaccination rates from the Mozambique Health Information System
Climate and weather (*1*,*2*,*4*)	Numerous satellite products, National Oceanic and Atmospheric; Administration, Climatic Research Unit, Center for Sustainability and the Global Environment, vulnerability to climate change	Climate data, social media reports of climate and air pollution effects on Twitter and Sina Weibo
Human demographics and behavior (*1*,*2*,*4*)	Night time lights, Gridded population of the world, mobile phone operator data	National census data products, Twitter, world population
Economic development (*1*,*2*,*4*)	International Monetary Fund, World Bank	National departments of economics
Land use and ecosystem changes (*1*,*2*,*4*)	Global agricultural lands, Center for International Earth Science Information Network, Global Forest Change 2000–2012, Global Forest Watch, global livestock distribution densities	National departments of agriculture, croplands in western Africa, Africa mining digital news reports, IMAZON Deforestation Alert System
Technology and industry (*1*,*2*,*4*)	Digital news, United Nations Global Pulse	NA
Human wildlife interaction (*2*,*4*)	Species distribution grids, digital news reports	State-level hunting data
Breakdown of public health measures (*1*,*2*,*4*)	Natural disaster hotspots	News of impending natural disasters (i.e., predicted hurricane landfall)
Poverty and social inequality (*1*)	Center for International Earth Science Information Network, Global Observatory	National census data
War and famine (*1*,*2*,*4*)	Famine early warning system, digital news and social media	Syria Tracker
Lack of political will (*1*)	Historical records, Transparency International, Cline Center for Democracy	NA
International travel and commerce (*1*,*2*,*4*)	Flight and shipping data	Regional distribution data of food products

*The table is purposely not exhaustive but provides a survey of types of available digital data that are associated with different drivers. NA, not applicable.
†See online Technical Appendix Table 1 (http://wwwnc.cdc.gov/EID/article/21/8/14-1156-Techapp1.pdf) for available references.

Olson et al. Emerg Infect Dis. 2015.

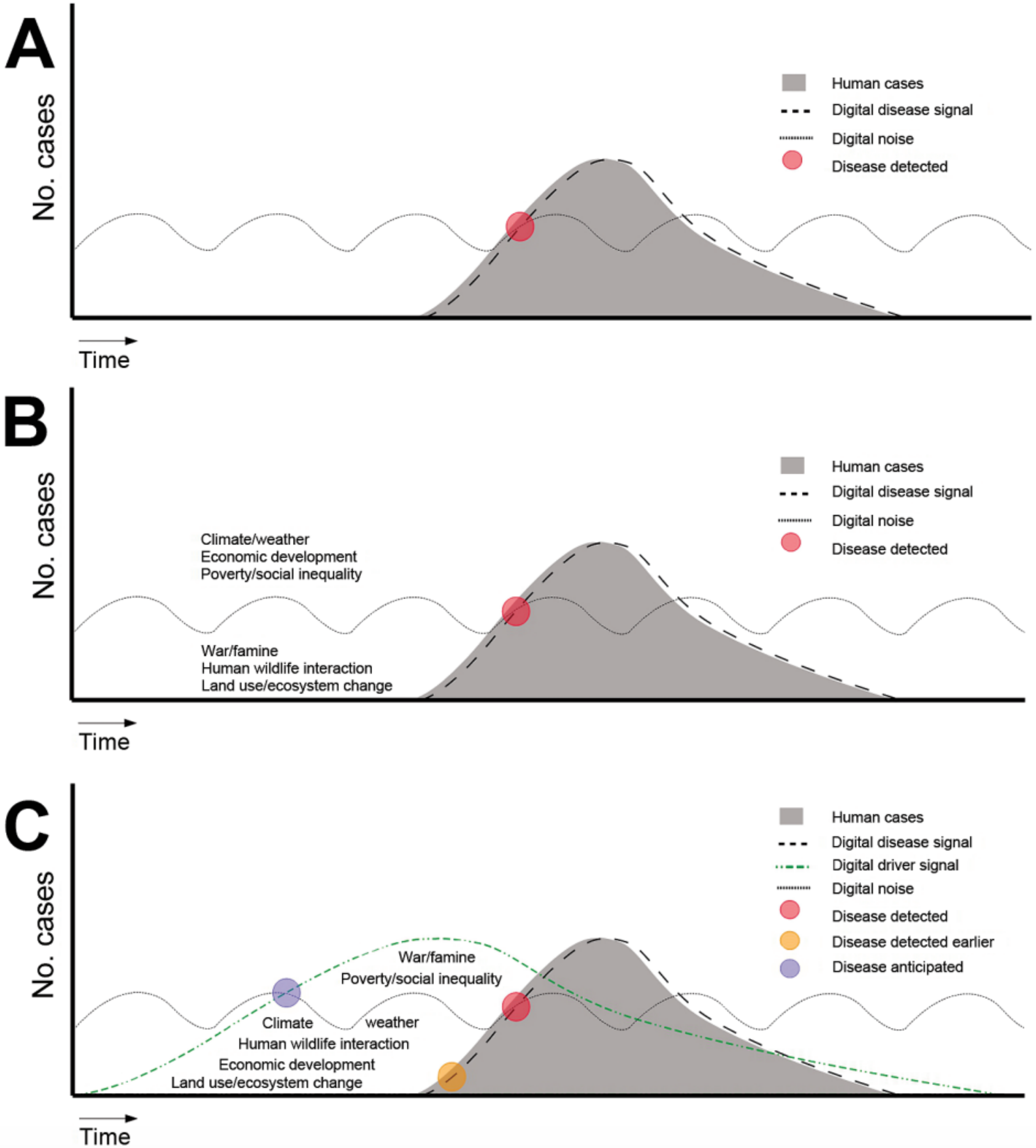


Figure 1. Surveillance and detection of disease by traditional (A, B) and digital (C) detection systems. A) Traditional disease detection, in which a close association exists between the number of cases and the digital disease signal. Disease is detected when the signal exceeds the noise. B) Disease emergence or outbreaks often occur following a driver. Examples of such drivers include climate and weather, economic development, poverty and social inequality, war and famine, human–wildlife interactions, land use and ecosystem changes. C) Detection of disease by using digital techniques. In this system, drivers of disease (not disease) are monitored, essentially to monitor for conditions suitable for disease emergence. Hypothetically, the careful surveillance of drivers that have been separated from digital noise could shorten the time to disease detection (as indicated by the orange dot).

Olson et al. Emerg Infect Dis. 2015.

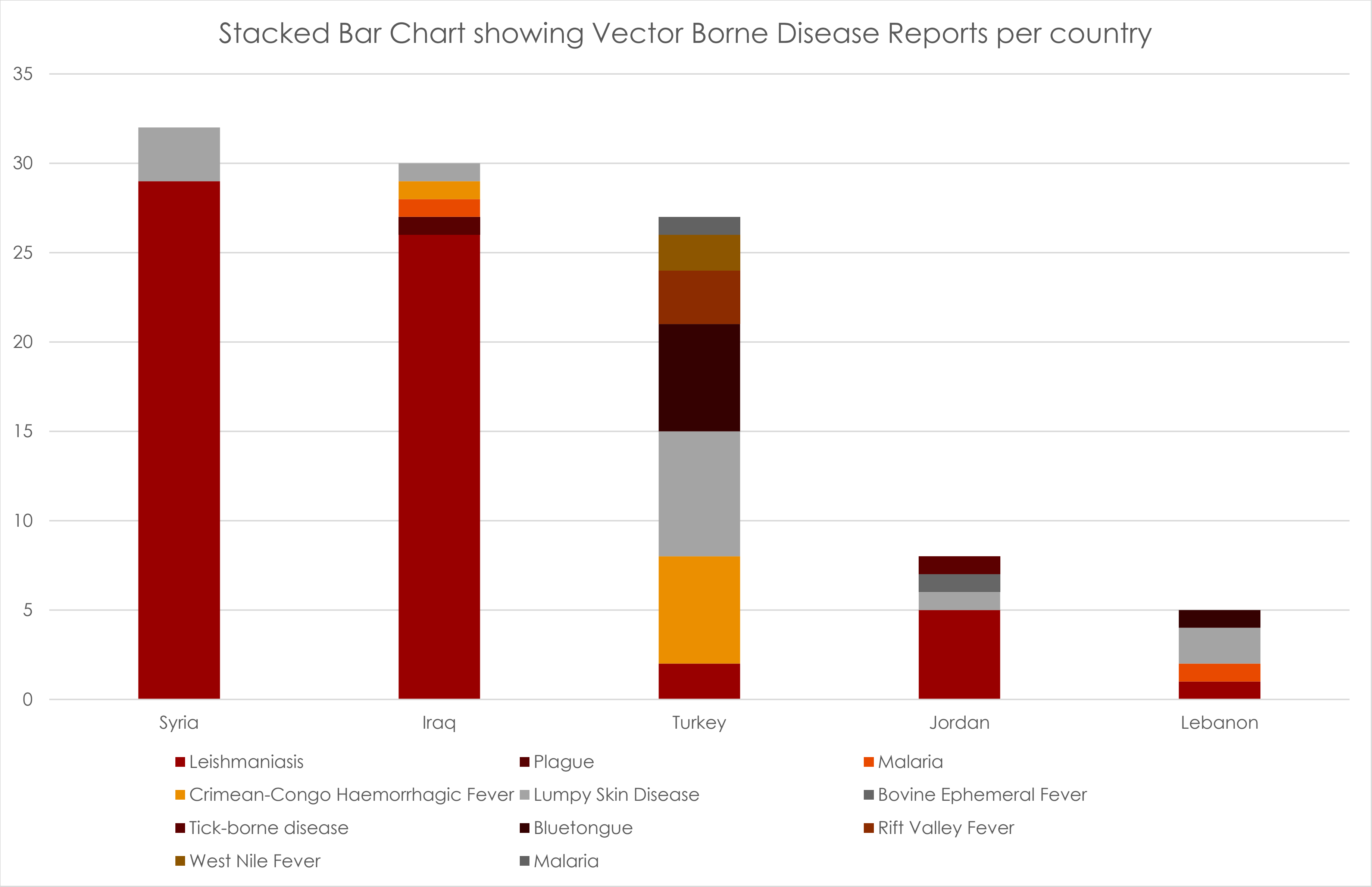
Table 2. Number of VBD events per pathogen and country for pre-conflict (2003-2010) and conflict (2011-2018) periods
a. VBD reported in an animal that *only affects animals*
b. indicates a VBD reported in an animal that can *also affect humans*

Pre-conflict period	
Pathogen by country	**Totals**
Iraq	**8**
Leishmaniasis	8
Jordan	**1**
Epizootic hemorrhagic disease [a]	1
Syria	**2**
Leishmaniasis	2
Turkey	**12**
Crimean-Congo hemorrhagic	7
fever	2
West Nile virus	1
Tularemia	1
Bluetongue disease [a]	1
Epizootic hemorrhagic fever [a]	
Total	**23**

Conflict period	
Pathogen by country	**Totals**
Iraq	**30**
Leishmaniasis	26
Plague	1
Malaria	1
Crimean-Congo hemorrhagic fever	1
Lumpy skin disease [a]	1
Jordan	**8**
Leishmaniasis	5
Bovine ephemeral fever [a]	1
Tick paralysis [b]	1
Lumpy skin disease [a]	1
Syria	**32**
Leishmaniasis	29
Lumpy skin disease [a]	3
Turkey	**27**
Lumpy skin disease [a]	7
Crimean-Congo hemorrhagic fever	6
Bluetongue disease [a]	6
Rift Valley fever [b]	3
West Nile virus [b]	2
Leishmaniasis	2
Malaria	1
Lebanon	**5**
Lumpy skin disease [a]	2
Malaria	1
Bluetongue disease [a]	1
Leishmaniasis	1
Total	**102**

Tarnas et al. IJID. 2020.

Unpublished Data



Learning Objectives

1. Identify the role of informal disease event monitoring and reporting

2. Define specific applications of informal disease event monitoring systems for outbreak detection

3. **Discuss data limitations in real-time epidemic forecasting**

Table 1. Summary of Data Needs for Real-time Global Epidemic Forecasting

Aim	*Data Needs*	*Examples of Open-Access Data Sources*
Case counts	Case counts including confirmed, probable, and suspected cases Open sharing of case data	ProMED[9] HealthMap[10] World Health Organization[11]
Mobility	Movement of individuals and populations Flight and travel networks	Flowminder[12] Flirt[13]
Host susceptibility	Immunization coverage data: pediatric and adult	GHSA[14] World Health Organization[11] UNICEF[15]
Environmental susceptibility	Climate data such as temperature and precipitation Environmental characteristics, eg, flooding Vector mapping Ecological niche mapping	NOAA[16] NASA Earthdata[17] Natural Earth[18]
Healthcare capacity	GPS latitude and longitude coordinates of hospitals, clinics, and health posts Number of beds Number of physicians Number of nurses Number of critical care beds	Healthsites.io[19] World Bank[20]
Population density and spatial demographic data	Census data Shapefiles for all countries Corresponding estimates of population sizes	LandScan[21] WorldPop[22] Facebook Population Maps[23]

Desai et al. Health Secur. 2019.

	Description	Data sources	URL
Financial Times: coronavirus tracker	The *Financial Times* analyses the scale of the COVID-19 outbreak including the collection and analysis of data on excess mortality (ie, numbers of deaths higher than the historical average) across the globe	WHO, the COVID Tracking Project, Johns Hopkins University, Our World in Data, US Centers for Disease Control and Prevention, and others	https://www.ft.com/content/a2901ce8-5eb7-4633-b89c-cbdf5b386938
The Economist: tracking COVID-19 excess deaths across countries globally	Global excess death tracker	Human Mortality Database, World Mortality Dataset, and EuroMOMO	https://www.economist.com/graphic-detail/coronavirus-excess-deaths-tracker
The New York Times			
The pandemic's hidden toll	Excess deaths during the COVID-19 pandemic	Data are compiled from official national and municipal data for 24 countries	https://www.nytimes.com/interactive/2020/04/21/world/coronavirus-missing-deaths.html
Tracking the coronavirus at US colleges and universities	COVID-19 tracker at US colleges and universities; with no national tracking system, and statewide data available only sporadically, colleges have been making their own rules for how to tally infections	*The New York Times* surveyed more than 1900 US colleges and universities for COVID-19 information	https://www.nytimes.com/interactive/2020/us/covid-college-cases-tracker.html
What we know about coronavirus cases in K-12 schools so far	Reporting focused on district-level and statewide COVID-19 case totals for public schools in the USA; the numbers presented are minimums because of differences in reporting	State and local health and education agencies or were identified by The Covid Monitor or the National Education Association and independently confirmed by *The New York Times*; *The New York Times* directly surveyed every school district in eight states: Colorado, Florida, Georgia, Illinois, Indiana, North Carolina, Texas, and Utah	https://www.nytimes.com/interactive/2020/09/21/us/covid-schools.html
How full are hospital ICUs near you?	Occupancy levels in US ICUs	US Department of Health and Human Services (hospital capacity data); US Department of Homeland Security (hospital locations); and the Covid-19 Hospitalization Tracking Project, University of Minnesota Carlson School of Management	https://www.nytimes.com/interactive/2020/us/covid-hospitals-near-you.html
The Atlantic: the COVID-19 tracking project	Collected, cross-checked, and published COVID-19 data from 56 US states and territories regarding testing, hospitalisation, and patient outcomes, providing ethnic demographic information and data on long-term-care facilities*	COVID-19 data from websites of US state or territory public health authorities; a public data API provides access to all their data at a national and state level	https://covidtracking.com
The Hindu: coronavirus India tracker	Collects, aggregates, analyses, and visualises state-level COVID-19 cases, deaths, and testing data from India and globally	Bing and Johns Hopkins University	https://www.thehindu.com/coronavirus/
Zeit Online: coronavirus in Deutschland und bei Ihnen [coronavirus cases in Germany and globally]	Collects, aggregates, analyses, and visualises COVID-19 cases, deaths, patients in ICUs, and vaccinations	Robert Koch Institute, websites of German counties and states, and Johns Hopkins University	https://www.zeit.de/wissen/gesundheit/corona-zahlen-deutschland-neuinfektionen-inzidenz-aktuelle-karte

ICU=intensive care unit. API=application program interface. *As of March 7, 2021, The Atlantic is no longer collecting new data.

Table: Examples of COVID-19 data collection, visualisation, and analysis

Desai et al. Lancet Digital Health. 2021.

Some additional thoughts

- Ethical Issues to Consider
- Zhao et al. JMIR. 2021 identified 6 domains
  - Awareness of implementing digital infectious disease surveillance
  - Digital integrity
  - Trust
  - Privacy and confidentiality
  - Civil rights
  - Governance

Extra Credit

- Wastewater Surveillance
- Building better buildings
- Genomic Surveillance

Extra Credit: Wastewater Surveillance

Notes from the Field: Early Evidence of the SARS-CoV-2 B.1.1.529 (Omicron) Variant in Community Wastewater — United States, November–December 2021

Weekly / January 21, 2022 / 71(3);103–105

Amy E. Kirby, PhD[1]; Rory M. Welsh, PhD[1]; Zachary A. Marsh, MPH[1]; Alexander T. Yu, PhD[2]; Duc J. Vugia, MD[2]; Alexandria B. Boehm, PhD[3]; Marlene K. Wolfe, PhD[4]; Bradley J. White[5]; Shannon R. Matzinger, PhD[6]; Allison Wheeler, MSPH[6]; Laura Bankers, PhD[6]; Kevin Andresen, MPH[6]; Cristal Salatas, MSGH[6]; New York City Department of Environmental Protection; Devon A. Gregory, PhD[7,8,9]; Marc C. Johnson, PhD[7]; Monica Trujillo, PhD[10]; Sherin Kannoly, PhD[8]; Davida S. Smyth, PhD[11]; John J. Dennehy, PhD[8,9]; Nicolae Sapoval[12]; Katherine Ensor, PhD[12]; Todd Treangen, PhD[12]; Lauren B. Stadler, PhD[12]; Loren Hopkins, PhD[12,13] (View author affiliations)

Extra Credit: Wastewater Surveillance

TABLE. Detection of mutations associated with the SARS-CoV-2 B.1.1.529 (Omicron) variant in wastewater — California, Colorado, New York City, and Houston, Texas, November 21–December 16, 2021

Location	Sample date	Test method	Results
California			
Sewershed A	Nov 25, 2021	Mutation-specific RT-PCRs targeting delHV69–70 and del143–145*	Both mutations detected at <1,000 genomic copies/gram wastewater solids
Sewershed B	Nov 30, 2021	Mutation-specific RT-PCRs targeting delHV69–70 and del143–145*	Both mutations detected at <1,000 genomic copies/gram wastewater solids
	Dec 2, 2021	Mutation-specific RT-PCRs targeting delHV69–70 and del143–145*	Both mutations detected at <1,000 genomic copies/gram wastewater solids
		Partial sequencing of S-gene using ARTIC v4 73R, 74L primers	Detected 9 bp insertion mutation in s214EPE and 3 bp N211I deletion
Sewersheds (10 sites)	Dec 17, 2021 10 of 10 sites	Mutation-specific RT-PCR targeting del143–145*	Mutations detected at >4,500 genomic copies/gram wastewater solids
Colorado			
Sewersheds (21 sites)	Dec 2, 2021 One of 21 sites	SARS-CoV-2-enriched tiled amplicon sequencing	Detected 13 of 17 Omicron-associated mutations
	Dec 6, 2021 Zero of 21 sites	SARS-CoV-2-enriched tiled amplicon sequencing	No Omicron-associated mutations detected
	Dec 9, 2021 Five of 21 sites	SARS-CoV-2-enriched tiled amplicon sequencing	Detected between four and 13 of 17 Omicron-associated mutations depending on the site
	Dec 13, 2021 12 of 21 sites	SARS-CoV-2-enriched tiled amplicon sequencing	Detected between six and 14 of 17 Omicron-associated mutations, depending on the site
	Dec 16, 2021 19 of 21 sites	SARS-CoV-2-enriched tiled amplicon sequencing	Detected between 12 and 14 of 17 Omicron-associated mutations, depending on the site
New York City			
Sewershed A	Nov 21, 2021	Short-read sequencing of S-gene amplicon†,§	Detected 12 Omicron-associated mutations including eight mutations unique to Omicron
	Nov 28, 2021	Short-read sequencing of S-gene amplicon†,§	Detected 12 Omicron-associated mutations including eight mutations unique to Omicron
Sewershed B	Nov 28, 2021	Short-read sequencing of S-gene amplicon†,§	Detected 12 Omicron-associated mutations including eight mutations unique to Omicron
Houston, Texas			
Sewersheds (39 sites)	Nov 29, 2021 Seven of 39 sites	SARS-CoV-2-enriched tiled amplicon sequencing using ARTIC v3 primers¶	Detected six Omicron-associated mutations
	Dec 6, 2021 25 of 39 sites	SARS-CoV-2-enriched tiled amplicon sequencing using ARTIC v3 primers¶	Detected 14 Omicron-associated mutations
	Dec 13, 2021 35 of 39 sites	SARS-CoV-2-enriched tiled amplicon sequencing using ARTIC v3 primers¶	Detected 18 Omicron-associated mutations

Abbreviation: RT-PCR = reverse transcription–polymerase chain reaction.
* https://www.protocols.io/view/quantification-of-sars-cov-2-variant-mutations-hv6-b2qmqdu6
† https://www.medrxiv.org/content/10.1101/2021.03.21.21253978v1
§ https://www.medrxiv.org/content/10.1101/2021.07.26.21261142v1
¶ https://www.medrxiv.org/content/10.1101/2021.09.08.21263279v1

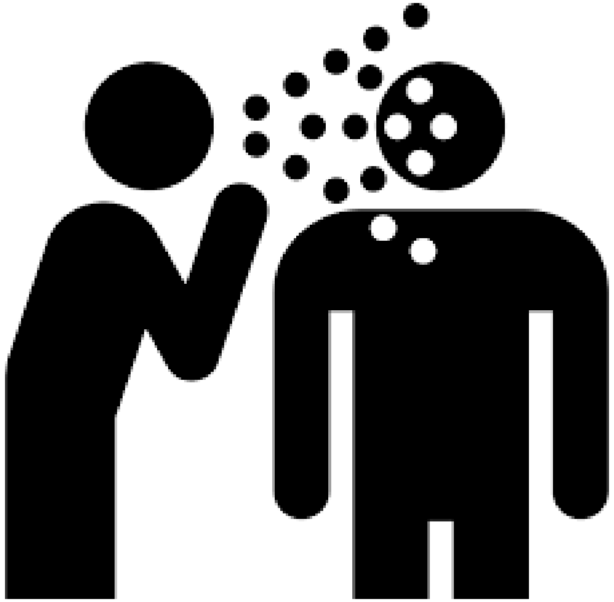
Kirby et al. MMWR. 2022.

Polling Question 2

- Would you consider consulting a digital disease event monitoring tool now after today’s Rounds session?

Thank You

- Britta Lassmann
- Lawrence Madoff
- ProMED/ISID



THANK YOU!
andesai@ucdavis.edu

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