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Syndromic Surveillance: Adapting Innovations to Developing Settings

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Surveillance, according to the World Health Organization (WHO), "is the cornerstone of public health security" [1]. In many developing countries, human, laboratory, and infrastructure limitations impede effective surveillance [2–5]. Such countries likely do not meet core surveillance and response capacities under the new International Health Regulations (IHR 2005) [6], which require detection of elevated disease and death rates, immediate implementation of control measures, and reporting to WHO of any event that may constitute a public health emergency of international concern [7]. (The previous IHR covered only cholera, plague, and yellow fever.)

In some high-income countries, "syndromic surveillance," a novel approach, uses pre-diagnostic data and statistical algorithms to detect epidemics earlier than traditional surveillance, including unusual diseases with nonspecific presentations [8–10] (Box 1). Syndromic surveillance also supports public health "situational awareness" [11,12], which means monitoring the effectiveness of epidemic responses and characterizing affected populations. Despite obstacles to implementation in resource-limited settings, the tools and strategies of syndromic surveillance hold promise for improving public health security in developing countries. Successful applications show that the obstacles can be overcome.

Box 1. Overview of Syndromic Surveillance Systems

Purpose

- Detect outbreaks earlier than possible with traditional surveillance
- Situational awareness (e.g., monitoring outbreak distribution and spread, characterizing affected populations)

Features

- "Indicator" (pre-diagnostic) data (e.g., syndromes, medication sales, absenteeism, patient chief complaints)
- Automated or partially automated data acquisition and analysis
- Statistical algorithms to detect unexpected elevations in indicator data
- Near-real-time data acquisition and analysis
- Computerized tools for visualizing data and analysis results

Synonymous terms (modified from [10])

- Outbreak detection systems
- Early warning systems
- Health indicator surveillance
- Prodromal surveillance

Potential Utility in Developing Countries

Syndromic surveillance offers a useful adjunct to diagnosis-based surveillance of emerging infections in developing countries. Where laboratory confirmation is not routinely used, syndromes associated with diseases of public health importance, such as influenza-like illness caused by multiple epidemic-prone tropical infections, could indicate outbreaks requiring laboratory-based investigation and control. Also, syndromic surveillance can identify outbreaks that do not fall into pre-established diagnostic categories, a capability essential for prompt control of new or changing diseases.

Another potential contribution of the syndromic surveillance field to developing countries is objective, automated approaches for detecting unusual morbidity trends, which could strengthen monitoring of syndromes, diagnoses, and other health-related data. Usually, these approaches involve entry of patient data into a computer, followed by (1) automatic, periodic application of statistical algorithms comparing the data to non-outbreak expectations (trends that depart from expectations by a predefined statistical threshold indicate possible outbreaks), and (2) visualization tools.

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Abbreviations: EWORS, Early Warning Outbreak Recognition System; IHR, International Health Regulations; WHO, World Health Organization

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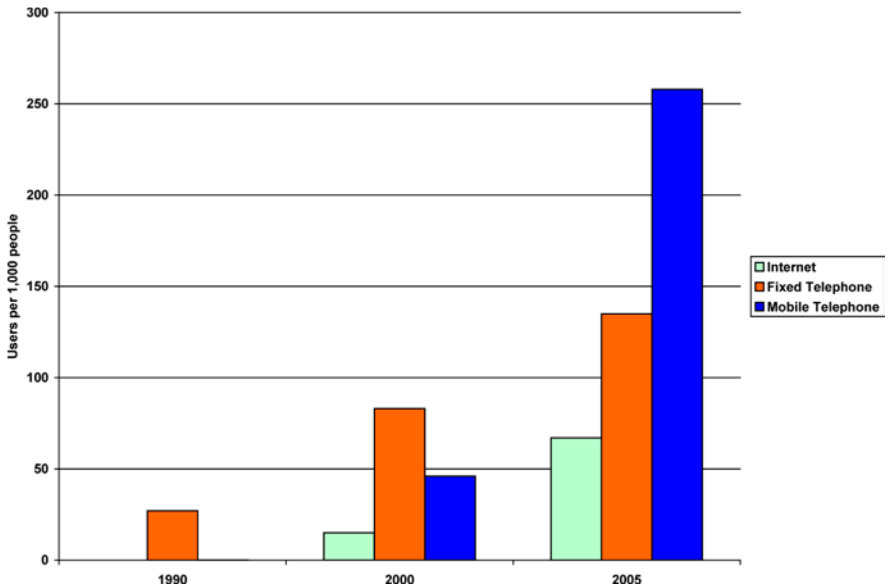

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Figure 1. Internet and Telephone Access in Developing Countries
Adapted from [22].

Objective criteria for identifying possible outbreaks complement subjective assessment, often the sole guide in developing settings, in two important ways. First, they can prevent unwitting bias, as in failing to account for readily explainable data behavior. For example, statistical algorithms can draw on historical data to remove effects of weekly clinic utilization cycles or seasonal disease cycles, uncovering unusual events that could reflect new or changing pathogens.

Second, objective procedures provide uniformity across health care facilities and personnel working separate departments or shifts within facilities. Without standardized approaches for identifying unusual health events, facility-level factors, such as the training, experience, and competing clinical responsibilities of personnel, influence the decision to notify higher authorities of potential outbreaks. Local notification protocols may vary markedly within decentralized Ministries of Health, which are common across developing countries.

Computer-based automation of routine data analysis is helpful because, with multiple reporting units and reportable events, the number of graphs or charts to inspect at public health offices likely exceeds the capacity of public health personnel (especially considering the competing responsibilities in short-staffed offices). The problem can be greatest during outbreaks—when thorough, rapid data assessment is critical for gauging outbreak extent and trajectory—as control activities take precedence.

Syndromic surveillance systems typically use computerized visualization tools to display algorithm results and morbidity trends [13–16]. Many software packages generate time-series graphs, maps, and data tables that are required routinely, and allow the user to produce other displays (e.g., focusing on specific age groups, surveillance sites, or syndromes) as needed. Tables and graphs summarizing key data and algorithm outputs, arranged to fit into a single computer screen view, can efficiently focus the user's attention on potential outbreaks.

Reason for Optimism

There is cause for optimism that syndromic surveillance approaches can feasibly be adapted to developing settings. First, they fit naturally with and could enhance existing strategies for outbreak detection and situational awareness in tropical areas. For example, with the goal of containing epidemics within two weeks of onset, WHO and African countries are implementing Malaria Early Warning Systems that use health data and climatology to forecast and detect epidemics [17]. Pre-diagnostic data have been evaluated as indicators for dengue outbreaks in French Polynesia [18], French Guiana [19], Puerto Rico [20], and elsewhere.

Table 1. Technology for Health Data Capture and Transmission in Remote Areas

Data Capture Technology	Data Transmission	Pros	Cons	Acquisition Cost (US$)[a]
Laptop—regular	USB flash drive (store and carry), dial-up modem, wireless modem, voice-over-IP	Captures detailed data, battery-powered, built-in networking	May be hard to replace broken parts, theft risk	$400
Laptop—special for developing areas[b]		Durable, energy-efficient, some self-powered (e.g., hand-crank)	Cons of regular laptop + limited functionality	$200
Cell phone	Voice/interactive voice response, texting, key entry	Inexpensive, cellular infrastructure ubiquitous globally	Entering detailed data may be difficult	$40
PDA	Laptop features	Captures data at point-of-care, some have intuitive interface	Entering detailed data may be difficult	$100
Smartphone	Cell phone and PDA features	Pros of cell phone and PDA	Entering detailed data may be difficult	$100–$400
Satellite phone	Cell phone features, Internet	Global service	Must be outdoors, calls short and expensive	$1400

[a]Approximate retail cost for basic models. Recurring costs, such as software licensing fees, are not included.
[b]For example, the XO Laptop by the One Laptop Per Child project (http://laptop.org/) and the Classmate PC by Intel (http://www.intel.com/intel/worldahead/classmatepc/).
IP, Internet protocol; PDA, personal digital assistant; USB, universal serial bus.
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Second, while existing electronic health data are unavailable in some developing areas, many Ministries of Health already require reporting of data that have proven useful for syndromic surveillance in high-income countries, such as International Classification of Diseases codes. Adapting strategies for grouping International Classification of Diseases codes into syndromes representing priority diseases, as done in syndromic surveillance systems in the United States [21], could facilitate syndromic surveillance in resource-limited settings without requiring collection of new data.

Third, expanding access to communication networks and technology will facilitate rapid electronic data entry, reporting, and analysis in resource-limited areas. Between 2000 and 2005, Internet access improved more than 4-fold in developing countries, and more than one quarter of the developing world uses mobile phones (Figure 1) [22], making these especially promising tools for timely transmission of surveillance data. As costs decrease and network availability improves, laptop computers, personal digital assistants, and other technologies may increasingly find application in developing country surveillance systems (Table 1).

Fourth, syndromic surveillance initiatives could dovetail with other efforts to improve health information systems. For example, the WHO-led Health Metrics Network, launched in 2005, aims to increase the availability and use of timely and accurate health information by catalyzing the joint funding and development of core country health information systems [23]. Though concerned with a range of health information systems (including vital registration, health surveys, disease surveillance, and others), its efforts to develop standards, as well as data management and analytic capacities, could lay essential groundwork for application of syndromic surveillance methods.

Results from Existing Systems in Developing Countries

Some developing countries have overcome resource constraints to establish effective electronic syndromic surveillance systems. The Indonesian Ministry of Health, together with a US laboratory it hosts in Jakarta, Naval Medical Research Unit-2, developed a simple but flexible syndromic surveillance system, Early Warning Outbreak Recognition System (EWORS), in 1998. For patients presenting to selected provincial hospitals, data on 29 signs and symptoms are collected and analyzed daily. Health authorities have used EWORS to detect outbreaks of dengue, diarrhea, influenza-like illness, and many other diseases.

For example, in 2002, EWORS facilitated detection and control of a diarrhea outbreak following a severe flood in Jakarta (Figure 2). A sentinel site in North Jakarta municipality reported above-average counts of watery diarrhea with other symptoms indicating moderate-to-severe disease in January, when heavy rains caused flooding with contamination of water sources. The first alert of a significant increase in cases, generated by an automated statistical detection algorithm, occurred during the second week of January. An outbreak investigation was initiated, including rectal swab sampling of patients with watery diarrhea. Culture tests identified *Vibrio cholerae* in 44 of 47 specimens collected, as well as *Salmonella* and *Shigella*. Health authorities implemented interventions immediately, including provision of clean water to flood-affected populations and rehydration for diarrhea patients; case counts returned to baseline levels by late February.

In 2007, the Ministry of Health, through three of its subordinate organizations (National Institute of Health Research and Development, Directorate General of Disease Control and Environmental Health, and Directorate General of Medical Service), officially adopted EWORS as a national surveillance system. The Ministry of Health plans to expand EWORS to many more hospitals throughout Indonesia, and to include its implementation as a criterion for hospital accreditation. To enhance EWORS syndromic surveillance with laboratory validation, eight laboratories in Indonesia have been designated as regional reference centers that support outbreak investigations.

In Peru, the Directorate of Epidemiology (part of the Ministry of Health), supported by a US laboratory in Lima, the Naval Medical Research Center Detachment, implemented a

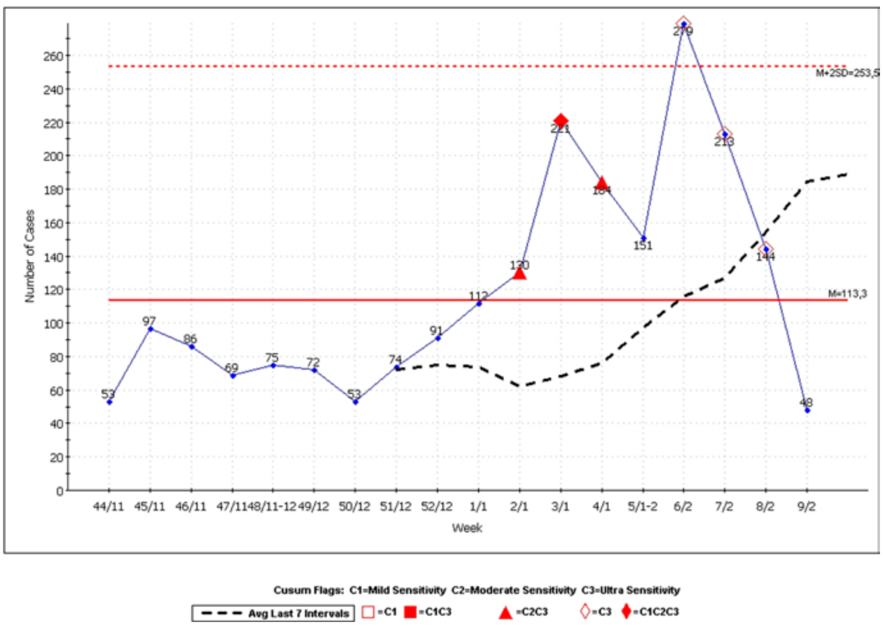

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Figure 2. Post-Flooding Diarrhea Outbreak in Jakarta, Indonesia, January–February 2002

X-axis labels are week/month, from the 44th week of 2001 (in November) to the 9th week of 2002 (in February). The blue line shows the number of cases per week reporting to an EWORS site in Jakarta with watery diarrhea and dehydration, fever, or vomiting. The "Cusum" (cumulative sum) C1, C2, and C3 alerts identify, with increasing sensitivity, significant increases in case counts using the Early Aberration Reporting System [27]. The horizontal red solid and broken lines represent the long-term mean and mean plus two standard deviations (sometimes used as an outbreak detection threshold in other surveillance systems), respectively.

Table 2. Strategic and Operational Surveillance Planning: Key Activities for Syndromic Surveillance Systems

System Components	Elements	Activities
Priorities	Prioritization exercise	• Identify priority diseases for rapid detection and tracking • Establish timely detection and situational awareness as surveillance priorities
System structure	IHR (2005) implementation	• Educate stakeholders on requirements for epidemic detection, characterization, reporting • Assess capacity to meet requirements • Assess potential role for electronic surveillance in strengthening existing capacity
	Surveillance strategy	• Define electronic surveillance objectives • Develop strategic plan to meet the objectives
	System organization	• Establish technical partnerships (South–South, South–North, multilateral)
	Intersectoral collaboration	• Establish collaboration with informatics-related programs and offices
	Coordination & integration	• Use the electronic system to integrate and streamline other existing systems
Core functions	Case detection	• Ensure system has flexibility to modify case definition in data capture and analysis phases • Define thresholds for epidemic alerts
	Confirmation	• Define criteria and procedures for initiating laboratory-based confirmation for alerts
	Reporting	• Install communication systems appropriate for infrastructure, budget, and timeliness goals • Establish paths for information flow
	Data analysis & interpretation	• Introduce software that meets user needs (commercial, freeware, or novel) • Develop protocols for routine data analysis
Support functions	Training	• Perform needs assessment for training in system operation • Provide initial and periodic refresher training for system operators
	Resources	• Provide hardware and software • Establish plan for updating and replacing hardware and software • Identify and train technical support unit
	Monitoring & evaluation	• Adapt and apply standard guidelines for evaluating surveillance systems
	Advocacy	• Conduct stakeholder advocacy to maintain support for the system
Surveillance quality	Timeliness, completeness, usefulness, other aspects	• Seek feedback from operators, technical partners, and others to identify interventions that improve quality and analyze before-after or intervention site-control site effects

Adapted from [28].
doi:10.1371/journal.pmed.0050072.t002

system modeled on EWORS in 2005 at two public health centers on the country's northern border. Following a favorable evaluation in 2006, the system was expanded to several sites in Lima, where detection of dengue outbreaks is of high concern (autochthonous dengue fever transmission was reported in Lima in 2005 for the first time in more than 60 years, but has not been detected since).

The US laboratory in Lima also partnered with the Peruvian Navy and Voxiva to develop the Alerta surveillance system in 2002 to monitor reportable events in sailors and their families. Alerta allows real-time data transmission by mobile phone, text messaging, or Internet from units across the country, including remote Amazon bases and ships. Alerta has identified many outbreaks and facilitated rapid laboratory confirmation by response teams equipped with field-use diagnostic tests or by central laboratories.

For example, in 2005, Alerta identified two diarrhea outbreaks at a Peruvian Navy training base in Lima [24]. Prompt investigations identified *Cyclospora cayetanensis* as the cause of both outbreaks, leading to appropriate treatment (cotrimoxazole or empiric fluorquinolone), investigation of food and water sources and meal preparation, and an epidemiological study to test a hypothesis about the incidence of *C. cayetanensis* infection in the local population. There have been no further large outbreaks of diarrhea at this training base.

Implementation

Syndromic surveillance tools and approaches are not appropriate for all developing settings. Where no health data are routinely collected, developing basic surveillance capacities [25], including laboratory-based surveillance, should be a high priority for local and national health authorities. Where electronic syndromic surveillance systems may be feasible, a combination of technical, financial, political, ethical, cultural, and societal factors all may contribute to successful implementation and should be considered from the outset of planning (Box 2).

The role of technical partnerships focusing on software, hardware, and analytical methods is especially important. While the need for improved outbreak detection and situational awareness is greatest in developing settings, most syndromic surveillance applications have been used in high-income countries. Technical partnerships involving research laboratories, public health agencies, and other organizations could bridge this gap, and should aim to foster lasting capacity for system development, operation, and improvement.

An example of such a collaboration includes epidemiologists and information technology specialists from Indonesia, Peru, and the Johns Hopkins University Applied Physics Laboratory, who partnered to learn from experience with EWORS and Alerta and consult on further system improvement. In September 2007, they joined colleagues from other developing countries with experience or interest in syndromic surveillance to develop an informal professional network, and identify common surveillance needs and possible solutions (https://secwww.jhuapl.edu/dsw/index.htm). The International Society for Disease Surveillance (http://www.syndromic.org/), which has a strong syndromic surveillance focus, provides another forum for

Box 2. Key Considerations in Planning Electronic Syndromic Surveillance Systems in Low-Resource Settings

Technical considerations

- Harvesting data already required for existing systems may be more acceptable than adding new data collection requirements.
- Even without Internet, automated decision support may facilitate timely transmission of key data through selective use of cell phones, radio, or Internet cafes.
- Initial and refresher epidemiological and electronic system training is essential.
- South–South, South–North, and multilateral technical partnerships can facilitate sharing of best practices and adoption of useful technologies.

Financial considerations

- Relatively low-cost hardware, including laptop computers designed for developing settings and personal digital assistants, can be used.
- Commercial software may involve license fees and recurring costs; open-source and custom software should be explored with technical partners.
- Surveillance programs may partner with other programs to seek funding for shared technology needs from development banks or other potential sponsors.

Political considerations

- New surveillance programs requiring significant initial investment may face strong competition for limited health resources from revenue-generating clinical programs.
- Local political support is especially critical in decentralized Ministries of Health, where funding and administration are shared with local levels.
- Engagement with key political stakeholders is needed to ensure that new systems do not conflict with existing priorities and that lines of authority are respected.
- Systems must not be seen as driven by foreign sponsor or collaborator priorities.

Ethical, societal, and cultural considerations

- Developing and explaining privacy safeguards may address patient concerns over electronic data capture and transmission.
- Community education on the clinical and public health uses of surveillance data may improve patient acceptability.
- Community education on local disease risks and presentations, and the importance of seeking care early, may enhance outbreak detection and patient care.
- Patient preference for private health care and pharmaceutical providers over public facilities can limit the effectiveness of Ministry of Health systems.

(Framework adapted from a model for assessing the potential success of particular health-related biotechnologies in resource-poor regions, in [26].)

international syndromic surveillance partnerships.

Planning a new syndromic surveillance system requires special attention to some of the issues usually considered in surveillance system planning (Table 2). For example, procedures for developing, maintaining, and evaluating proficiency with new technologies, and for replacing or repairing failing hardware, must be established. As with any new surveillance effort, the system should, to the extent possible, be integrated into existing reporting pathways.

Wider Benefits

By helping to rapidly detect and characterize unusual morbidity trends, syndromic surveillance holds promise as an early line of defense against new and emerging infections in developing settings. Considering the poor state of public health surveillance in those areas, syndromic surveillance tools and approaches may provide greater additional benefit than in high-income countries that already have other types of effective surveillance programs.

But implementation of syndromic surveillance tools and approaches may have wider public health benefits. Hardware, software, and communication infrastructure for timely outbreak detection and situational awareness could strengthen data collection, reporting, and interpretation for other public health programs (e.g., evaluating interventions and identifying resource needs). Perhaps most importantly, investing in human resources—through training in epidemiology, data management and analysis, use of computers, and other public health skills—would help address an important threat to public health security in developing countries. ■

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