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SUPPLY CHAIN AND LOGISTICS MANAGEMENT IN PUBLIC HEALTH SURVEILLANCE AND PROTECTION DURING COVID-19

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ABSTRACT

COVID-19 shed light on the vulnerability of United States public health logistics and supply change management infrastructure concerning pandemic testing, tracking, and response. Logistics management challenges related to virus testing and tracking have made the critical need for more innovative and more comprehensive healthcare surveillance approaches. Public health surveillance is a critical and often underutilized aspect of public health logistics and supply chain infrastructure planning. Wastewater treatment infrastructures offer an innovative approach to gaining public health data to provide appropriate public health responses. Understanding the logistics and supply chain aspects of virus tracking, testing, and response data-driven response decision making are the key to mitigating the impact of future outbreaks. This project explores the utility of this approach through qualitative focus group interviewing to gain information from public health subject matter experts in the field.

KEYWORDS:

COVID-19, public health surveillance, public health logistics, epidemiology

1. Introduction

Virus testing during a pandemic is an indispensable and essential factor of any tactic to relieve aggressive social distancing measures, keep businesses open, and eliminate the need for mask mandates (Heilweil, 2021). When united with contact tracing, precise test results direct verdicts about what individuals mingle with others and what individuals should be confined and insolated (Heilweil, 2021). Accurate test results also offer macro data and evidence about virus prevalence and transmission in specific communities (Kester, 2021; Hughes, 2021). The indication is escalating that numerous individuals infected with COVD-19 have nominal or no symptoms, making it crucial to incorporate supply chain and logistical management strategies to ensure that more individuals be tested (Kester, 2021). The more dependable the test results, the more targeted public health

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supply chain and logistical management strategies can become (Kester, 2021; Hughes, 2021). Deprived of enough test data, only the maximum and costly tactics like aggressive social distancing can shelter the healthcare system from the stress of COVID-related emergencies and hospital-lizations (Heilweil, 2021). An outpouring in new COVID cases is a result of the very infectious Omicron variant has overextended America's public health supply chain and logistics management testing abilities due to shortages of rapid antigen tests and limited locations to get PCR tests (Heilweil, 2021).

During the COVID-19 pandemic, the supply chain saw significant disruption when global demand for critical material increased and manufacturing levels simultaneously decreased (Heilweil, 2021). These trends resulted in competition for limited quantities of needed supplies. The U.S. did not have what it needed to respond to the pandemic, whether in stockpiles or quickly scalable industrial capacity (Heilweil, 2021). It also lacked the infrastructure to immediately engage in the most comprehensive public health surveillance methods, allocate and distribute scarce resources, and support rapid and sustained manufacturing.

These public health supply chains and logistics management processes for COVID-19 testing are overlaid on the existing industry and marketplace for biomedical testing apparatus (Heilweil, 2021). The foundation of public health biomedical testing infrastructure is mostly private corporate transportation companies, medical companies, and labs driven by profit-making activities and strategies. As a result, their public health supply chain logistics management processes are highly influenced by the marketplace and often cannot meet consumer demand with unpredictable marketplace disruptions (Heilweil, 2021). To fully engage public health supply chain and logistics management resources within the timeframe imposed by the growth and evolution of COVID-19, these organizations need to be more agile concerning demand signals, resources essential capital investments, and the ability to manage financial risks required to serve communities in need (Heilweil, 2021). The ability to meet each community's public health supply chain and logistics testing needs will require government policy, support, and interventions supporting best practices for public health surveillance, emergency response, and public health protection.

Contact tracing is the identification and monitoring of people who have been exposed to the infected patient and therefore have an ostensibly higher risk of developing infection (Kester, 2021). Contract tracing is an essential logistics management aspect of public health surveillance, public health emergency response, and public health protection. The subsequent separation of infected with COVID-19 from the overall populace is a risk management strategy focused on reducing the transmission of the virus (Kester, 2021).

2. Surveillance in healthcare

Before determining how to approach surveillance of public health, it is important to understand why it is useful to have surveillance of public health and what it means. Public health surveillance identifies relationships through reports (whether active, passive, or some combination of the two) from stakeholders (Groseclose & Buckridge, 2016). "*Data sharing in science maximizes the utility and impact of patient data and therefore contributes to improving clinical practice and public health*" (Devriendt, Borry & Shabani, 2021). To improve current systems, we must merge epidemiology, informatics, supply chains, and logistics especially in today's era of "*big data*", a term referring to "*vast electronic storehouses of information that include internet search transactions, social media activities, data from health insurance programs, and electronic medical records*

from receipt of health services" (Friis, 2018, p. 82). This data is critical to the evaluation of public health epidemiology because it involves the supply chain management and logistics of large population data collected through various medical systems and other resources. The logistics and data management processes around the collection of this data play a critical public health and safety role in the tracking of growth and movement of diseases and community health patterns locally, nationally, and globally (Kester, 2021; Hughes, 2021). Unfortunately, in many cases, the logistics and coordination concerning the capture and evaluation of this problem health data is often cumbersome, disjointed, and tedious in ways that diminish the effectiveness of pandemic response and public health surveillance (Kester, 2021; Hughes, 2021). Solving and standardizing the logistics and supply chain requirements of our data collections and our medical communication are critical to public health surveillance and public health response.

Public health hospital surveillance provides an ability to record and monitor COVID-19 patients treated at hospital but this population only represents 5 percent of those that are currently infected (Bivins, et al., 2021). As a result, a hospital approach to public health has limitations in its effectiveness because it only allows a tracking approach for those that are admitted to the hospital (Bivins, et al., 2021).

Lab testing as a COVID-19 public health surveillance approach can be effective in monitoring rates of about 10 percent to 50 percent of individuals in a community of but only if supply chain and logistics management issues have been solved to a level of where everyone wants to be tested or needs to be tested can actually have access to test and accurate rapid results (Bivins, et al., 2021).

Surveillance can be explored first by modes. Modes are the "*broad, overarching approaches to surveillance. [And] one or more modes of surveillance may be incorporated into the design of a surveillance model…depending on the surveillance objectives and nature of the condition, disease, or event*" (McNabb et al., 2016, p. 23). These modes vary widely including passive, active, community-based, population-based, laboratory, and sentinel surveillance. Passive surveillance would include surveillance that gathers information from all institutions willing to provide data about adverse health effects, and active surveillance would only include specific participants of a dedicated program who consistently report data (McNabb et al., 2016, p. 23). Community-based surveillance includes the gathering of data from active volunteers reporting cases of certain health conditions, whereas population-based identifies isolated reported instances of conditions that could spread quickly (McNabb et al., 2016). Laboratory surveillance identifies and tracks carriers and reservoirs of pathogens leading to epidemics such as specific animals, and sentinel surveillance relies on the reporting of specific health institutions such as hospital, laboratories, and clinics with quality data for a particular reason or with a suspect already in mind. Of these modes, genetic surveillance may be both the most freedom infringing and precise surveillance. This mode determines genetic propensities for specific illnesses or conditions and coupled with artificial intelligence could be used to tailor insurance costs to individuals based on historical genetic data (McNabb et al., 2016).

3. Adaptation

A second type of surveillance is seen in adaption. Adaption includes both vertical and integrated surveillance programs. Vertical surveillance programs are focused purposefully on particular conditions or events and are especially used during times when a conglomeration of resources and attention is drawn to a particular area. It provides a stable backbone for increasing

attention to other public health issues and helps document some of the best practices in disease prevention and control (McNabb et al., 2016). The stability of vertical surveillance comes from the single (vertical) course of information flow from reporters and reporting centers to a sole health program leading the way such as the acute flaccid paralysis (AFP) surveillance does for the Global Polio Eradication Initiative (GPEI) as well as many others (McNabb et al., 2016). Single type of surveillance. Single purpose. Single initiative.

The other adaption technique is integration. Integration routes information for many or all disease through the surveillance network for the purpose of cross-examination and universal service; although, many of the involved data relay techniques mimic that of vertical surveillance and often times particular diseases are highlighted. Unlike vertical surveillance which draws lots of resources, integration draws from pre-existing capacity, making it more affordable and efficient as a universal surveillance system. A couple of the drawbacks to integration include disproportional contributions from the donors involved in the system as well as a frequent lack of coordination across the programs, making the system less stable on a broader scale.

A critical aspect of the logistics and supply chain framework in public health surveillance is rooted in activity: reactive and proactive. These techniques are much newer than active and passive surveillance and are grounded in "*Algorithm-based alerts generated which notify epidemiologists (reactive) or trigger forecasts (proactive)*" (McNabb et al., 2016). Public health surveillance programs are neither passive nor active in nature but reliant mainly on the logistics concerning the use of the data instead of the technique by which data is collected. Reactive surveillance programs use the data to help health officials respond to "*statistical alerts*" which trigger emergencies and short-term actions (McNabb et al., 2016). However, proactive surveillance programs use the data to build out longer-term forecasts that help predict future states in order to "*surge capacity*" (McNabb et al., 2016). No matter which is used, the need to understand the supply chain management and logistics management issues influencing the effective implementation is critical to a program's success.

AIDS epidemic in the 1980s made the logistics and utility of public health surveillance a global priority (McNabb et al., 2016). This type of surveillance relied on multiple modes of surveillance including passive, sentinel, laboratory, and community-based with a primarily integrated approach. However, this method in the 1980s version was slow and characteristically disorganized in ways that created a need for more innovative and integrated systems and approaches (McNabb et al., 2016).

4. New technology

Today, the largest and most influential technology in modern epidemiology is the internet as a global data network and a building block upon which platforms are built to store information, sift through publicly available data, and interact with others for collaboration (Budd et al., 2020). The population-surveillance systems online rely heavily on data reported by laboratories, clinics, and non-internet-based surveillance networks interacting through digital means (Budd et al., 2020). However, when online surveillance networks rely on these specific reporters and stakeholders, cases of illness are often overlooked when medical attention is not sought out by the infected population (Budd et al, 2020). One example of this issue occurring is in 2020, prior to routine COVID-19 testing, when UK hospitals reported identifying an estimate of only 4.7 % of all cases in the UK (Russell et al., 2020).

Other newer technologies are also finding their applications in public health

surveillance. Outside of monetary exchange and NFTs, blockchain technology has begun to be used in the public health sector for surveillance purposes. A decentralized system for recording data, hospitals use blockchain technology to manage records, bills, and insurance (Bhattacharya et al, 2019). Blockchain stores information on decentralized nodes which allows data anomalies to be recognized in real-time and stored permanently (without any form of distortion) (Bhattacharya et al, 2019). Scientists at the Department of Health Promotion and Community Health Sciences at Texas A & M, as well as those in community medicine in both Dehradun and Chandigarh, India agree that the use of blockchain technology in public health surveillance "*might be able to automate secure data sharing and storage at different levels of healthcare organizations*" (Bhattacharya et al, 2019). "*This technology has a potential to give real time data/ information by sensing potential outbreaks or bioterrorism…if vaccinations, antibiotics, and other disease control measures are instituted promptly, massive casualties can be prevented*". And this is important because for epidemiology time is of the essence, and the benefit of automation is not only the speed at which anomalies are identified, but also the diminished need for "*man-power*" to process the data.

There is another advantage to using blockchain technology in public health surveillance: tampering. Unlike machine learning, which uses algorithms to identify patterns that increase the "*intelligence*" of the system through reported data, blockchain is much more difficult to hack (Bhattacharya et al, 2019). It was designed that way specifically. When the power of block chain is coupled with machine learning technology, the prevention, detection, and response efforts of public health programs skyrocket; unfortunately, there is a cost (Bhattacharya et al, 2019). Unfortunately, blockchain technology is very expensive today and lacks some of the security protection necessary for medical and health record (Bhattacharya et al, 2019).

Not every new technology is so potentially rights-infringing. Another technology or novel use for technology is the use of "*next-generation sequencing (NGS) for the identification of viruses present in urban sewage*" (Fernandez-Cassi, 2017). Although it has been thought of in the past, the protocol around its execution was lacking due to poorly identified means for effectively studying the sewage samples (Fernandez-Cassi, 2017). Using NGS for the study of local sewage samples is an easy way to identify viral infections and major pathogens being transmitted throughout populations, as it is cost effective and plenty of sewage is readily available to be studied (Fernandez-Cassi, 2017).

5. Program development

The COVID-19 public health logistics and supply management issues of tracking the movement and growth viruses is complex (Farkas et al., 2020). With COVID infections with mild symptoms or no symptoms can miss being recorded and tracked epidemiological models and assessments focused on tracking the pandemic in certain communities (Farkas et al., 2020). There is therefore a greater need to recognize the advancement of pandemics through the use of innovative and more comprehensive approaches (Farkas et al., 2020; Bivins et al., 2021).

Wastewater, also referred to as sewage, contains water from residential and commercial buildings (such as toilets, showers, and sinks) that encompass human fecal waste (Kreier, 2021; Keshaviah, Hu & Henry, 2021). Those people with COVID-19 will shed virus remnants in their bathroom stools, which is then present in wastewater (Kreier, 2021; Keshaviah, Hu & Henry, 2021). Tracking COVID in wastewater allows the ability to track the virus even with people who do not display symptoms

and in communities where testing may be limited. Wastewater surveillance allows public health professionals track officials COVID-19 infections trends in a way that that is cost effective and timely by analyzing water in the treatment plant (Kreier, 202; Keshaviah, Hu & Henry, 2021). Sequential variations in viruses in wastewater provide data on the population outbreaks and the processes to measure it measurement are a critical logistics management tool for public health surveillance and the mitigation of community outbreaks (Kreier, 2021; Keshaviah, Hu & Henry, 2021) Consequently, logistics management approaches to wastewater-based epidemiology represents and innovative and viable early alert approach for future virus outbreaks (Kreier, 2021; Keshaviah, Hu & Henry, 2021).

Supply chain shortages concerning tests have made the management of the pandemic more severe. Monitoring COVID-19 in wastewater is therefore ideally suited to describe the spatial and temporal trends in disease incidence (Kreier, 2021; Keshaviah, Hu & Henry, 2021). Wastewater-based epidemiology may be useful to identify emerging and re-emerging pathogens in a community and may serve as an early warning system, which would be useful for public health mitigation (Kreier, 2021; Keshaviah, Hu & Henry, 2021).

6. Data analysis

Data was collected from 12 public health officials with expertise in public health surveillance using waste water. 1 participant had a doctorate degree, 3 participants had a graduate degree, and 1 participant had a medical degree. Participants were questioned through qualitative focus groups questing using ZOOM. Participants were broken up into 3 groups of 4 participants each for ensure triangulation of the results from the various groups.

What do you see at the benefits of a wastewater public health surveillance system?

The results are as follows:

- Wastewater surveillance functions as an effective early alert approach to see if virus infections are spreading or diminishing.
- Dissimilar other forms of COVID-19 observation, wastewater surveillance is not dependent on someone accessing the healthcare center for treatment or testing to track the growth of the virus.
- Data for communities where timely COVID-19 clinical testing is underutilized or unavailable.

Participant 1 said: "*Wastewater surveillance captures presence of viruses and diseases shed by people with and without symptoms. By measuring virus levels in untreated wastewater over time, public health officials can see trends through data that can help with public health decision making and the allocation of resources*".

Participant 6 said: "*Wastewater surveillance can be implemented in many communities since nearly 80 percent of U.S. households are served by municipal wastewater collection systems*".

What kind of resources are needed to for the use and development of a wastewater public health surveillance system?

- Human capital resources in the form of staff and subject matter experts.
- An understanding of the percent of the population served by wastewater facilities.
- A variety of testing sites.
- Accountability structures, goals, expectations, roles, roles and responsibilities.
- Identifying the needed areas for internal and external organizational support and resources.

- Reporting and public health action structures which outline audiences and uses for testing results.
- Decision making processes concerning public health testing results and adequate responses.

Participant 4, said: "*Theses programs require the implementation of supply chain, logistics, and transportation networks concerning the collection process, testing processes, testing locations, and testing results delivery processes. This is one the most critical aspects to making this kind of program successful and effective*".

Participant 8 said: "*It is critical to have biomedical testing organizational partners for sample collection and testing. Laboratory infrastructure is critical because it takes time to build national and local lab capacity and validate testing protocols, especially when supply chain and logistics are limited. The safe implementation of a testing strategy requires secure supply chains for purchase, procurement, and distribution of necessary resources personal protection, testing supplies, sample storage, sample delivery, and data assessment*".

Participant 3 states: "*For a wastewater public health surveillance program to work with pandemics like COVID-19 you must have a variety of stakeholder and experts. You need the support from state, local, tribal, and territorial health departments. You need wastewater treatment plants workers, lab technicians, physicians, epidemiologists, public health professionals, environmental scientists, and academic researchers that are public health subject matter experts*".

How can communities used data collected from wastewater to improve public health outcomes?

Results

- Alert public health officials of large outbreaks earlier.

Participant 10 said, "*It has been my experience that wastewater data can indicate disease trends up to two to 14 days before clinical testing data*".

- Confirm clinical testing data.

Participant 12 said: "*Data from wastewater testing can show trends concerning the growth or decrease of infections in relation to clinical testing trends*".

- Shape public health policies.

Participant 5 said: "*Data from wastewater testing can provide an assessment of if public health policies and community interventions are working on not*".

- Direct resources where they are needed.

Participant 7 said: "*Wastewater data can help with identifying the communities in critical need of resources by identifying the communities have the highest levels of transmission, and how can resources be better allocated to them to reduce disease spread*".

What types of settings can be monitored using wastewater surveillance?

Results

- Public schools
- University/college campuses
- Correctional facilities
- Hospitals
- Community homes
- Businesses

How should wastewater public health surveillance programs be evaluated?

Results

- Purpose of the program
- The timeliness of data access.
- Data quality
- Utility of the data
- Cost and acceptability of the strategy
- Feasibility, flexibility, and sustainability
- Barriers and facilitators
- Potential adaptations for the next cycle
- Equity and ethical issues

7. Conclusions

COVID-19 shed light on the vulnerability of United States public health logistics and supply change management infrastructure concerning pandemic testing, tracking, and response (Heilweil, 2021). Logistics management challenges related to virus testing and tracking have made the need to innovative and more comprehensive surveillance approaches so critical. Public health surveillance is a critical and often underutilized aspect of public health logistics and supply chain infrastructure planning process. The use of wastewater treatment infrastructures offers an opportunity and innovative approach to gain public health data to provide appropriate public health responses. Understanding the logistics and supply chain aspects virus tracking, testing, and response data driven response decision making are the key mitigating the impact of future outbreaks.

8. Recommendations for future research

More research is needed to explore the impact and viability implementation of emerging tools and approaches to improve the availability of quality and timely surveillance data. More research is needed related to how to best implement crosscutting surveillance system initiatives to improve public health surveillance outcomes.

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