THE PROMISE OF PUBLIC HEALTH DATA MODERNIZATION: A SCOPING REVIEW OF CDC'S PUBLIC HEALTH DATA STRATEGY

by

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(Under the Direction of Danielle Lambert)

ABSTRACT

Historically, the United States (U.S.) public health system consists of siloed data systems that limit interoperability. Health Information Organizations (HIOs) are positioned to facilitate data sharing between healthcare and public health, yet their utility in supporting public health reporting remains underexamined. The COVID-19 pandemic exposed weaknesses of the U.S. public health system, underscoring the urgency of modernization. Recognizing the need for action, the Centers for Disease Control and Prevention (CDC) launched the Data Modernization Initiative (DMI) and the Public Health Data Strategy (PHDS) in 2023 to create a more efficient and responsive system. Although these strategies articulate ambitious goals, questions persist about how HIOs can contribute to public health.

This dissertation addresses the public health interoperability gap through two aims. The first aim uses a 2023 survey of HIOs, explicitly focusing on organizations with a state public health agency (PHA) as their primary PHA to determine HIO challenges and capabilities. Findings show that most HIOs operate as nonprofit entities with hybrid

governance models and support some PHDS reporting services, including syndromic surveillance, immunization registries, electronic case reporting (eCR), and electronic laboratory reporting (ELR). Persistent barriers include insufficient funding, limited PHA technical capacity, and workforce shortages. The second aim seeks to understand how key components of CDC's PHDS are reflected in the literature, employing a scoping review of peer-reviewed and grey literature documents. The review demonstrates the adoption of modernization activities across PHDS components, such as syndromic surveillance, eCR, ELR, and wastewater monitoring. Still, it highlights persistent challenges in workforce capacity, policy alignment, interoperability, and scalability across jurisdictions.

These findings suggest that modernization cannot be achieved through federal mandates or technology alone. Progress requires aligning policy with operational realities and sustained investment in people and systems. Future research could evaluate whether HIOs are fit to support public health surveillance activities and the continued integration of emerging surveillance domains and technology, such as Artificial Intelligence (AI) and machine learning (ML), for a responsive public health data ecosystem.

INDEX WORDS: Health Information Exchanges (HIEs); Public Health Data Modernization; Public Health Data Strategy (PHDS); Public Health Policy And Governance; Healthcare Data Interoperability.

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List of Acronyms

Acronym	Definition
ACO	Accountable Care Organization
AI	Artificial Intelligence
API	Application Programming Interface(s)
ASTP	Assistant Secretary for Technology Policy / Office of the National Coordinator for Health Information Technology
CDC	Centers for Disease Control and Prevention
CMS	Centers for Medicare and Medicaid Services
CRISP	Chesapeake Regional Information System for Our Patients
DMI	Data Modernization Initiative
eCR	Electronic Case Reporting
EHR	Electronic Health Record
ELR	Electronic Laboratory Reporting
EIS	Epidemic Intelligence Service
FHIR	Fast Healthcare Interoperability Resources
HDU	Health Data Utility
HHS	Department of Health & Human Services
HIE	Health Information Exchange
HIO	Health Information Organization
HIPAA	Health Insurance Portability and Accountability Act
HIT	Health Information Technology
HITECH	Health Information Technology for Economic and Clinical Health Act
ML	Machine Learning
NHSN	National Healthcare Safety Network
NLP	Natural Language Processing
NNDSS	National Notifiable Diseases Surveillance System
NSSP	National Syndromic Surveillance Program
OPHDST	Office of Public Health Data, Surveillance, and Technology
PHA	Public Health Agency
PHDS	Public Health Data Strategy
PRISMA-ScR	Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews

Acronym	Definition
RHIC	Regional Health Improvement Collaborative
PWH	People With HIV
ROI	Return on Investment
STLT	State, Tribal, Local, and Territorial
TEFCA	Trusted Exchange Framework and Common Agreement
U.S.	United States
UCSF	University of California, San Francisco
USCDI	United States Core Data for Interoperability
WBE	Wastewater-Based Epidemiology
1CDP	One CDC Data Platform

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CHAPTER 1: PUBLIC HEALTH IN THE UNITED STATES

The United States (U.S.) Department of Health & Human Services (HHS) defines health information technology (HIT) as "the processing, storage, and exchange of health information in an electronic environment" (U.S. Department of Health and Human Services, 2020). Public health data systems rely on HIT for efficient data collection, analysis, and communication, which are essential for managing disease outbreaks and enhancing public health emergency responses. For example, data from electronic health records (EHRs) offer the potential for real-time monitoring, predictive analytics, and seamless interoperability, ensuring timely and accurate information flow during public health emergencies (Hamilton & Hopkins, 2019). U.S. public health systems rely on data from state and local health departments, laboratories, hospitals, and other healthcare providers to effectively identify persons with suspected or diagnosed conditions (Centers for Disease Control and Prevention, 2023c). However, the Centers for Disease Control and Prevention (CDC) does not have direct authority to require reporting of data collected by state, tribal, local, or territorial (STLT) public health partners. Historically, the types and formats of data received by the CDC from states and jurisdictions vary significantly, affecting when and how the CDC gets these data and making data connections more challenging (Centers for Disease Control and Prevention, 2021b; Shapiro et al., 2011). These variations could pose serious challenges, such as delays in identifying and responding to public health emergencies. When data from different sources come in

various formats, standardizing and analyzing the information takes more time and resources, slowing the overall response time. For instance, during a pandemic, delayed data aggregation and analyses can lead to slower containment measures and increased spread of the disease (Centers for Disease Control, 2012; Richard et al., 2024).

Since 2009, the U.S. government has invested heavily in stewarding the adoption of HIT in clinical care settings. Two policies, the Health Information Technology for Economic and Clinical Health (HITECH) Act of 2009 and the 2016 21st Century Cures Act (the Cures Act), were imperative in adopting HIT, specifically, EHRs (Burde, 2011; Kesselheim & Avorn, 2017; U.S. Congress, 2009, 2016). The Congressional Budget Office estimated that the U.S. government spent $32.7 billion from 2009 to 2019 to support the adoption of EHRs through Medicare and Medicaid spending (Redhead, 2009). One of the chief goals of the HITECH Act was to promote the widespread adoption of interoperable EHRs. Despite incentivizing the adoption of EHRs, the HITECH Act failed to fully address interoperability and the standardized data exchange across different, and mostly private, healthcare systems and EHR vendors (Gold & McLaughlin, 2016). To address the HITECH Act's failures, the 21st Century Cures Act (the Cures Act) attempted to move the country towards a fully interoperable HIT exchange system by improving the interoperability and efficiency of healthcare information systems and prevent information blocking to ensure seamless nationwide health information exchange (Lye et al., 2018).

Since passage of the HITECH Act, adoption of EHRs has increased substantially, rising from 6.6% of providers with basic EHR functions in 2009 to 81.2% in 2019, and by 2021 nearly 78% of office-based physicians and 96% of non-federal acute care hospitals

had adopted certified systems, compared to only 28% of hospitals and 34% of physicians in 2011 (Jiang et al., 2023; Office of the National Coordinator for Health, Information Technology, n.d.). While the HITECH Act and the later Cures Act focus on improving clinical care and Health IT, their impact on clinical care logically impacts overall public health.

Statement of the Problem

The COVID-19 pandemic exposed significant flaws in U.S. public health data collection, including fragmented systems, outdated technology, inconsistent data standards, and chronic underfunding (Centers for Disease Control and Prevention, 2021a; O'Reilly-Shah et al., 2020). These issues led to delays, inaccuracies, difficulty tracking cases, and health disparities. Additionally, poor integration among different HIT systems hindered efficient data sharing. These vulnerabilities underscore the need for a more robust, integrated, and advanced public health data infrastructure, and improving data collection systems will require the support of automatic, real-time data, especially in public health emergencies (Centers for Disease Control and Prevention, 2021a; O'Reilly-Shah et al., 2020). The widespread adoption of HIT–especially EHRs – means that public health surveillance systems are well-primed to consider the universal adoption of systems like their clinical counterparts.

In 2020, the CDC launched the Data Modernization Initiative (DMI), the agency's first comprehensive strategy to modernize data and technology. DMI is a national effort to create modern, integrated, and real-time public health data and surveillance that can protect U.S. residents from any health threat (Centers for Disease Control and Prevention,

2023b). The multi-year initiative aims to move from siloed public health data to a connected, sustainable, and adaptable system that can respond to public health problems before they happen. CDC's DMI is a billion-plus dollar effort to help the agency strengthen its data reporting, management, and analytics across public health. As part of the CDC's DMI work, the Public Health Data Strategy (PHDS) aims to modernize surveillance, improve real-time guidance, and advance equitable outcomes by reducing reporting burdens, accelerating analytics, enhancing insights, and promoting interoperable data (Centers for Disease Control and Prevention, 2023a).

The Assistant Secretary for Technology Policy/Office of the National Coordinator for Health Information Technology (ASTP) developed the Trusted Exchange Framework and Common Agreement (TEFCA) for Health Information Networks. TEFCA aims to establish nationwide interoperability for healthcare data exchange by setting standards and guidelines to ensure the secure and seamless sharing of electronic health information among healthcare providers, patients, and organizations, which is crucial for advancing public health (Assistant Secretary for Technology Policy/Office of the National Coordinator for Health IT, 2024; Blumenthal et al., 2020). However, the specific impact of TEFCA guidance on data collected at the federal level remains unclear, primarily because the CDC typically obtains data from STLT partners rather than directly from healthcare entities.

TEFCA adoption and other HIT advances may not be straightforward. Despite HITECH's push for hospitals to electronically submit public health data to STLTs, a 2015 report found that 24% of hospitals either claimed exemption or did not report syndromic

surveillance data, and the public health sector struggled to leverage available data due to a lack of informatics specialists within public health agencies (Kadakia et al., 2021).

Although recognized benefits exist, such as more efficient data exchange and faster responses to public health emergencies, the high costs of developing interoperable systems have hindered widespread adoption. Health Information Organizations (HIOs) have created networks to facilitate Health Information Exchange (HIE) among various partners, primarily aimed at improving patient care and reducing costs, with the tangential potential for public health involvement (Shapiro et al., 2011). HIEs can play a pivotal role in this landscape by facilitating the secure electronic sharing of health-related information, fostering interoperability, and enhancing collaboration. HIEs are acknowledged as a significant contributor to big data in healthcare, offering public health the potential for a unified data stream compiled from various systems and origins (Baseman et al., 2017).

Although there is potential for HIE to transform public health, its utility is not fully realized due to many states not having sufficient HIEs that partner with public health agencies (Horrocks & Kansky, 2020). HIEs could transform public health by revolutionizing data access, enhancing surveillance capabilities, and optimizing resource allocation. By seamlessly sharing health information, HIEs enable swift responses to emergencies and proactive interventions and represent a crucial step towards a more interconnected and effective public health system capable of delivering better health outcomes for all.

Purpose of the Study

This dissertation examines public health surveillance and data modernization, including challenges faced by HIOs partnered with state public health agencies (PHAs),

prioritizing critical surveillance activities for modernization efforts, and identifying key barriers hindering the evolution of data-sharing practices and policies within public health agencies.

The specific aims of this dissertation are to:

1. Assess collaborations between HIOs and PHAs regarding public health surveillance activities and challenges encountered by HIOs whose primary PHA is a state entity.
2. Analyze how key components of the CDC's PHDS are reflected in the extant scientific and literature.

CHAPTER 2: LITERATURE REVIEW

This literature review provides an in-depth understanding of critical components central to the study's objectives. It covers the history and current state of public health surveillance at the federal level, the role of HIOs in facilitating data exchange, the evolution of federal health policy, and its impact on data-sharing practices. This review aims to contextualize the research within existing literature and support further exploration of these critical themes.

Public Health Data Surveillance

The history and significance of public health surveillance underscore its pivotal role in public health practice. Public health surveillance is crucial for continuously monitoring disease occurrence, providing essential data for informed decision-making, and public health action. (Kumar & Raut, 2014). Originating from early efforts to monitor infectious diseases in the U.S., surveillance has evolved significantly over time, with milestones such as Lemuel Shattuck's influential report in 1850 and the establishment of the Epidemic Intelligence Service (EIS) by Alexander Langmuir, CDC's first chief epidemiologist, in 1951 (Thacker et al., 2012). Thacker et al. (2012) highlighted Alexan Langmuir's leadership during the 1955 polio vaccine incident, during which polio cases were attributed to live virus present in a batch of vaccines, demonstrating the critical importance of surveillance in addressing public health crises. Langmuir's subsequent influence refined the definition and scope of surveillance, emphasizing its integral role in guiding public health action.

Despite historical advancements, ongoing challenges such as timely analysis and adaptation to emerging health threats persist, highlighting the need for continued investment and innovation in public health surveillance.

The U.S. public health surveillance is an enterprise system comprised of thousands of long-term partnerships among federal and STLT PHAs. CDC fulfills a critical national role in aggregating, analyzing, and disseminating data; developing and maintaining surveillance tools; providing technical assistance to STLT PHAs; conducting research on surveillance policy; and allocating funding to sustain the aforementioned activities. (Buehler & Centers for Disease Control and Prevention, 2012a, 2012b; Richards et al., 2014, 2017). Each jurisdiction creates data-sharing agreements with the CDC and other jurisdictions. The data CDC receives from states and jurisdictions varies, which dictates how and when the agency receives the data (Centers for Disease Control and Prevention, 2021b). CDC receives data electronically, in spreadsheets, by fax, by phone, or by hand; it demonstrates the complex landscape of public health surveillance efforts in the U.S. (Centers for Disease Control and Prevention, 2021b; Richards et al., 2014). CDC's current data systems encompass various surveillance platforms, including the National Notifiable Diseases Surveillance System (NNDSS), National Healthcare Safety Network (NHSN), and other integrated databases, enabling comprehensive monitoring and analysis of public health trends and threats. Although the exact number of CDC surveillance systems may vary over time due to updates and changes, there are typically dozens of active surveillance systems managed by the CDC across different areas, such as infectious diseases, chronic conditions, injuries, or environmental health.

Richards et al. (2014) noted that observers, external and internal to the CDC, identified some of the most important factors influencing public health surveillance in today's landscape, such as advances in technology, data security concerns, and the changing landscape in healthcare, and how these influences may affect national surveillance strategies. The authors noted that observers recognized the need for ongoing evaluation of surveillance systems, data standardization to develop sustainable and integrated systems, and system and workforce adaptability to meet current demands. They also recognized fundamental tensions between the desire for an enterprise-level surveillance approach and disease-specific programmatic needs, which require specialized surveillance data. The U.S. public health data infrastructure falls short of national needs, lacking readiness for response, incomplete standards, and inconsistent implementation across jurisdictions; while some jurisdictions have succeeded in automating and streamlining electronic data management, there is a pressing need to align and expand such successful approaches to enhance overall efficiency and effectiveness. (CDC Advisory Committee to the Director (ACD) Data and Surveillance Workgroup (DSW), 2022).

Health Information Exchange

HIE systems enable the secure and seamless sharing of health information among healthcare providers, public health agencies, and patients. Still, HIE is accountable to their state laws in what information can be shared (Dixon, Brian E. et al., 2020). The design choices in HIE architectures range from fully decentralized to fully centralized, with hybrid options in between. Decentralized models involve each organization retaining control of its

data and sharing it upon request, while centralized models consolidate data in a common repository for easier access. Hybrid models combine elements of both, with variations such as record locator services or centralized repositories for specific data types. The basic technical infrastructure that supports connectivity is similar across all models (McCarthy et al., 2014). HIOs primarily focus on improving direct patient care by enhancing providers' access to information and reducing costs. While HIOs typically serve clinical use cases, they can also support public health objectives through collaboration with public health agencies on data standards and protocol development (Shapiro et al., 2011). Through their infrastructure and expertise, HIOs can serve as vital partners to public health agencies, enabling enhanced surveillance and response to public health threats while providing the technical capabilities needed for data analytics to support informed policy decisions and public health interventions.

For HIOs to function optimally, healthcare data must meet the secondary use needs of public health agencies, and public health systems must be able to collect and leverage pertinent data. In the context of COVID-19, a cross-sectional study of almost 1,700 hospitals reported that about 61% encountered at least one difficulty reporting to a PHA, with the most common issues being the capability of the PHA; hospitals with advanced EHR systems and those participating in health information exchange were less likely to report facing challenges and more likely to report organizational challenges (Walker et al., 2021). Similarly, hospitals with public health collaboration and affiliation with Accountable Care Organizations (ACOs) in 2020 showed a notably higher likelihood of participating in local and national HIE networks. Additionally, hospitals in underserved

regions were more prone to report a lack of connections with public health entities (Maguire et al., 2024). Public health agencies must be accountable to both the government and the public. Because essential data fields like race/ethnicity or zip code are often missing in healthcare data, it is necessary to include metadata during the initial data collection process (Baseman et al., 2017). A study examining HIE participation in Indiana emphasized the importance of ongoing education and outreach efforts by public health agencies to improve reporting knowledge among clinic reporters, cautioning against complete reliance on electronic data extraction through HIOs due to potential limitations, particularly for high-impact or uncommon conditions (Revere et al., 2017).

Research shows that HIOs can help support the CDC's data needs. HEALTHeLINK, a western New York HIE initially designed for clinical care, was expanded to support public health operations, enabling the Erie County Department of Health to improve efficiency in various activities such as investigations, contact tracing, and immunization reporting (Haque & Bailey, 2023). The Maryland Department of Health collaborated with Chesapeake Regional Information System for Our Patients (CRISP), Maryland's designated health information exchange, to establish data enhancement processes crucial for the success of Maryland's contact tracing program, significantly improving contact tracing outcomes by enriching COVID-19 laboratory reports with demographic and contact information. (District of Columbia Department of Health Care Finance (DC HCF), 2025; Feldman et al., 2023). An evaluation of the District of Columbia's HIE program showcased the program's effectiveness in enhancing public health reporting and surveillance activities through enhanced data collection methods and collaboration, particularly in capturing

immunization data and electronic lab reporting for diseases like HIV/AIDS, tuberculosis, and viral hepatitis (Chesapeake Regional Information System for Our Patients (CRISP), 2025; Goldwater et al., 2014). A study found that an HIE-informed intervention led by social workers increased linkage to care among out-of-care people with HIV (PWH) who were seen in an Atlanta hospital's emergency department. The HIE created an alert for the state health department indicating the abilities of HIEs to facilitate re-engagement efforts for out-of-care PWH (Sharp et al., 2019).

HIEs have the potential to evolve to become health data utilities (HDUs); HDUs are advanced statewide models designed to integrate and exchange electronic health data across various care settings. HIEs traditionally focus on transmitting clinical data among healthcare facilities to enhance patient-centered care. HDUs go beyond the scope of HIEs by integrating health systems with public health departments, claims data, and social service providers to enable comprehensive, real-time data sharing (Bari et al., 2022; Frellick, 2023). Several states, including Maryland, Oregon, Arizona, and Michigan, are pioneering the establishment of statewide nonprofit HDUs (Frellick, 2023; Raths, 2023). In early 2022, a series of roundtable discussions brought together stakeholders – including HIOs, Regional Health Improvement Collaboratives (RHICs), and state health leaders – to deliberate on crucial considerations for implementing HDUs; topics covered included governance structures, funding strategies, policy alignment, technical infrastructure, and the importance of demonstrating value to secure support and expand participation, aiming to enhance health data exchange and interoperability for improved healthcare delivery and population health outcomes (Bari et al., 2022).

HIT Policy

Federal policy developments play a crucial role in bolstering the U.S.'s capabilities in multiple critical areas. Firstly, these policies facilitate more robust connections between the healthcare sector and public health initiatives, fostering collaboration and coordination between these traditionally separate domains (Bourdeaux et al., 2023). Secondly, they enhance data accessibility by implementing standards and protocols that streamline the sharing and exchanging of health information, ultimately improving decision-making and public health outcomes (Smith, B. M. et al., 2003). Additionally, these policy changes influence how technologies are acquired, encouraging the adoption of modern solutions that align with interoperability standards and support the evolving needs of the healthcare and public health sectors (Yogesh & Karthikeyan, 2022). These federal policy developments drive positive transformations in the healthcare landscape, promoting integration, efficiency, and innovation.

The HITECH Act

The HITECH Act played an invaluable role in accelerating the adoption of EHR throughout the country (Burde, 2011). The HITECH Act contained four sets of provisions. Subtitle A established the Assistant Secretary for Technology Policy/Office of the National Coordinator for Health Information Technology (ASTP), tasked with setting interoperability standards for health information exchange among healthcare professionals and patients (Redhead, 2009; Stark, 2010). Subtitle B tasked testing of HIT standards and support the establishment of a voluntary testing program by accredited sources, and Subtitle C

authorized funding for grant programs to support activities like electronic health records adoption, developing HIT infrastructure, disseminating best practices, telemedicine, etc. (Redhead, 2009). Lastly, Subtitle D strengthened and updated the Health Insurance Portability and Accountability Act[1] (HIPAA) (Stark, 2010).

Under the Act, the Centers for Medicare and Medicaid Services (CMS) established the Meaningful Use incentive program. The program paid providers who demonstrated they were "meaningfully using" EHRs (Thurston, 2014). To demonstrate "meaningful use[2]," providers were required to meet 15 core objectives (Thurston, 2014).

One of the chief goals of the HITECH Act was to promote the widespread adoption of interoperable EHRs. HITECH provided funding for federal leadership in setting standards and promoting interoperability through programs like the State Health Information Exchange. Still, it did not specify methods for achieving standardization or promoting data

[1] The Act clarified who could access patient data and where it could be sent without expressed permission from the patient (Stark, 2010). In the event of a breach of unsecured protected health information, providers are required to notify the patient if their data has been compromised (Redhead, 2009; Stark, 2010). If providers do not protect patient data, the Act increases financial penalties for violations under Subtitle D (Redhead, 2009).

[2] To meet the Meaningful use requirements, a provider's EHR program had to include the following: "(1) computerized provider order entry, (2) e-prescribing, (3) report ambulatory clinical quality measures to CMS/states, (4) implement one clinical decision support rule, (5) provide patients with an electronic copy of their health information upon request, (6) provide clinical summaries for patients for each office visit, (7) drug-drug and drug-allergy interaction checks, (8) record demographics, (9) maintain an up-to-date problem list of current and active diagnoses, (10) maintain an active medication list, (11) maintain an active medication allergy list, (12) record and chart changes in vital signs, (13) record smoking status for patients 13 years or older, (14) capability to exchange key clinical information among providers of care and patient-authorized entities electronically, and (15) protect electronic health information."

exchange in a predominantly private healthcare system regulated jointly at federal and state levels (Gold & McLaughlin, 2016). Centers for Medicaid and Medicare Services (CMS) set ambitious "meaningful use" requirements, which lacked specificity and guidance, and set the foundation for disjointed, incompatible EMR systems (Halamka & Tripathi, 2017; Sao et al., 2013). The incentive program assumed interoperability would occur organically through their proposed criteria.

21st Century Cures Act

Where the HITECH Act failed to deliver on its interoperability promises, the 21st Century Cures Act attempted to move the country towards a fully interoperable HIT exchange system (Lye et al., 2018). The 21st Century Cures Act, also known as the Cures Act, was signed into law in December 2016. The U.S. sought to move closer to an interoperable HIT infrastructure that serves all stakeholders with the Cures Act. The U.S. has made substantial investments in laying the groundwork for digital health with initiatives like the Cures Act. Efforts to improve interoperability are constrained by policy variation, as national and state governments apply different rules for privacy, security, and data-sharing authority that complicate the routine use of electronic health information exchange (Magnuson & Dixon, 2020).

In March 2020, The Cure's Act's "Interoperability, Information Blocking, and the ONC Health I.T. Certification Program Final Rule" was released (Anthony, 2020). The Cures Act Final Rule mandated provisions to improve access to and exchange of health information. It aimed to ensure patients have greater control over their medical records through enhanced access and interoperability. Additionally, it addressed issues such as

certification and the prevention of information blocking to facilitate smoother data sharing across the healthcare landscape. Although not directly focused on public health, the Final Rule's provisions impact public health agencies and the information systems under their purview. ONC's Final Rule illustrates the U.S.'s vision for digital health technology. The rule portrayed a future where electronic health information is easily accessible through smartphone apps. The promise of digital health technology goes beyond the EHR. Dr. Deborah Lupton, an Australian digital sociologist, described the current landscape as the digitization of as many elements of healthcare as possible (Lupton, 2014). These elements work together to create an overarching framework incorporating data from healthcare systems and actors and agencies outside this sector.

In July 2020, the CDC held a listening session on real-world testing of the 21st Century Cures Act. The listening session started with the premise that standardization and baseline capabilities will enable public health to access richer data, driving quicker decision-making and informing the public more precisely; that CDC-supported data modernization efforts can provide timely and actionable information for various levels of information sharing, addressing longstanding public health data challenges sustainably by leveraging existing and forthcoming capabilities like health information exchanges and standardized Application Programming Interfaces (APIs) (Centers for Disease Control and Prevention (U.S.) Deputy Director for Public Health Science and Surveillance, 2020). The listening session participants discussed how modern technologies, including FHIR-based standards, offer significant support for public health initiatives spanning local to national levels. These advances collectively enhance public health decision-making and

operational efficiency while maintaining strong privacy protections. By leveraging cloud-based systems and a distributed network, public health can access analytics-ready data for various purposes, facilitating collaboration across federal, state, and local levels without dependency on a single vendor or technology provider.

TEFCA

The Cures Act, ASTP adopted United States Core Data for Interoperability (USCDI) to promote interoperability by establishing common data elements for exchange from EHRs. Yet, the chief focus is patient care, not public health. (*United States Core Data for Interoperability (USCDI),* 2022). In early 2022, ASTP published TEFCA for Health Information Networks. The Common Agreement's flexibility supports multiple exchange purposes, allowing stakeholders – including public health agencies –to benefit from accessible health information (HHS Press Office, 2022).

TEFCA is a set of policies and technical specifications designed to facilitate the secure exchange of health information among healthcare providers, payers, patients, and other stakeholders. TEFCA aims to address the interoperability challenges in healthcare by creating a standardized framework for exchanging electronic health information across different health information networks. It includes a common agreement that outlines legal and technical requirements for participating organizations, such as privacy and security standards, data exchange protocols, and patient consent mechanisms. TEFCA aims to improve patient care, enhance population health outcomes, and promote greater efficiency and innovation in the healthcare system by enabling seamless and secure sharing of health information across organizational boundaries.

TEFCA is designed with three primary objectives. It aims to establish a universal governance, policy, and technical framework that enables nationwide interoperability across the healthcare ecosystem. This involves setting standardized protocols and regulations to ensure seamless communication and data exchange across health information networks. Secondly, TEFCA seeks to streamline connectivity for organizations involved in healthcare, enabling them to exchange information securely. By simplifying this process, TEFCA endeavors to enhance patient care, improve the welfare of populations, and generate greater value within the healthcare system. Finally, TEFCA is committed to empowering individuals by facilitating their access to and gathering of healthcare information. This emphasis on individual engagement reflects a broader shift towards patient-centered care. It aims to give individuals greater control over their health data for informed decision-making and improved health outcomes (Assistant Secretary for Technology Policy/Office of the National Coordinator for Health IT, 2024).

ASTP released Version 1.1 of the Common Agreement on November 7, 2023, which builds upon Version 1.0 and lays the groundwork for Version 2.0, which will incorporate enhancements requiring support for HL7® FHIR® based transactions (Assistant Secretary for Technology Policy/Office of the National Coordinator for Health IT, 2024). Health IT.gov notes that TEFCA became operational on December 12, 2023, with a celebration involving the Health and Human Services (HHS) Secretary and other senior leaders.

CDC Moving Forward and the Public Health Data Strategy

The COVID-19 pandemic intensified the structural and systemic operational challenges within the CDC. In response to the admitted major public mistakes, CDC

Director Dr. Rochelle Walensky launched a two-component review of the agency in April 2022 to better support the future of public health (Centers for Disease Control and Prevention, 2022a). The review comprised a scientific and programmatic review to identify ways to improve how the CDC develops and deploys science and a structural review to gather feedback on the agency's core capabilities: a diverse workforce, data modernization, laboratory capacity, and how the agency prepares and responds to disease threats around the world and the U.S. (Centers for Disease Control and Prevention, 2022a).

The review coined "CDC Moving Forward" as a strategic move to modernize the agency and deliver consistent real-time public health information and guidance. The findings from the review resulted in the following recommendations: implement large-scale cultural and operational changes to improve organizational accountability, utilize lessons learned from COVID-19 to improve how CDC delivers science and programs, modernize CDC to prepare for future public health challenges, and develop levers that do not exist at CDC that will allow the agency to be nimbler and work faster (Centers for Disease Control and Prevention, 2022a). "CDC Moving Forward" outlines immediate next steps, which include implementing a team to implement the vision, starting to implement structural changes at all levels, creating an executive council to determine and track agency priorities, creating a new equity office, and creating a one-stop shop for external partners (Centers for Disease Control and Prevention, 2022a).

CDC's PHDS is a comprehensive framework that delineates critical actions in data exchange, technology integration, policy implementation, and administrative coordination necessary for efficient and secure sharing of core public health data across healthcare and

public health domain (Centers for Disease Control and Prevention, 2023a). The strategy aims to equip the nation with response-ready capabilities, promote health equity, and enhance overall health outcomes for all segments of society. It is designed to bridge existing gaps in public health data infrastructure. It outlines a clear pathway to address key challenges and ensure the nation's public health system is equipped to fulfill its core missions, including detecting and monitoring health threats, investigating and responding to outbreaks, and disseminating timely information to stakeholders (Centers for Disease Control and Prevention, 2023a).

Aligned with "CDC Moving Forward," the PHDS focuses on consistently delivering public health information and guidance to Americans in near real-time to advance core public health missions (Centers for Disease Control and Prevention, 2023a). Through this strategy, decision-makers across various sectors, including the public, laboratories, healthcare providers, STLT agencies, CDC programs, and federal agencies, will benefit from a streamlined vision of near-term priorities. The four goals outlined in the PHDS aim to fortify the foundation of public health surveillance while advancing capabilities for timely response and equitable health outcomes. The first goal entails strengthening the core of public health, which involves reducing reporting burdens through electronic systems and ensuring faster access to critical data for decision-making at all levels. The second goal focuses on accelerating access to analytic and automated solutions that identify emerging threats and address gaps in public health workflow, particularly in underserved communities. The third goal relates to visualizing and sharing insights that enhance understanding and inform proactive public health action, while the fourth goal's

focus is advancing open and interoperable data to ensure efficient exchange and utilization of information across healthcare systems.

According to the CDC, the agency will pursue these goals through collaborations with diverse stakeholders. CDC will ensure accountability by establishing the Office of Public Health Data, Surveillance, and Technology (OPHDST) within its organizational framework. This office will lead in enhancing engagement, fostering collaboration, and overseeing the execution of data modernization efforts to advance public health initiatives (Centers for Disease Control and Prevention, 2023a).

CDC DMI. Before "CDC Moving Forward," CDC's Data Modernization Initiative (DMI) launched in 2020. DMI is a national effort to create "modern, integrated, and real-time public health data and surveillance that can protect Americans from any health threat" (Centers for Disease Control and Prevention, 2023b). The multi-year initiative aims to move from siloed public health data to a connected, sustainable, and adaptable system that can respond to problems before they happen. CDC's DMI is a billion-plus dollar effort to help the agency strengthen its data reporting, management, and analytics across public health. According to the CDC, the agency's shared vision for the future is to advance world-class data and analytic capabilities that are responsive to both current public health needs and the emerging challenges of tomorrow (Centers for Disease Control and Prevention, 2023b).

The initiative highlights how the COVID-19 pandemic exposed the vulnerabilities of U.S. public health data collection and how improving our data collection systems will require EHRs to automatically send real-time data, especially in public health emergencies

Centers for Disease Control and Prevention (2021a). The DMI also focuses on health equity to center equity within data systems to account for social factors that impact health, such as socioeconomic status, environment, and discrimination (Centers for Disease Control and Prevention, 2023b).

In 2022, as part of the DMI, CDC and ASTP began developing the North Star Architecture—a strategic blueprint for building an interoperable public health data system (*Centers for Disease Control and Prevention,* 2022b). In its development, the architecture incorporates input from STLT agencies, public health associations, and industry partners. It is grounded in iterative development and human-centered design to support seamless data flow across healthcare and public health systems. The North Star Architecture aims to: (1) standardize data exchange, (2) reduce reporting burden through a "common front door," and (3) boost efficiency using cloud services, open-source tools, and open standards. Pilot use cases from infectious and non-infectious disease programs are informing future implementation at scale (*Centers for Disease Control and Prevention,* 2022b).

As part of its broader DMI program, CDC announced in 2024 that they are developing the One CDC Data Platform (1CDP), a secure cloud-based infrastructure that seeks to transform how the agency manages and uses public health data (Walke, 2024). 1CDP is designed to consolidate multiple siloed systems into a unified, interoperable platform that enables the agency to collect, integrate, analyze, and share data more efficiently across programs and with STLT partners. By supporting standardized data flows, modern APIs, and real-time analytics, 1CDP will enhance the timeliness, quality,

and accessibility of public health data (Walke, 2024). This modernization effort seeks to not only improve routine surveillance and outbreak response but also strengthen the foundation for equity-focused, cross-cutting public health action. Ultimately, 1CDP positions CDC to lead with the data, supporting a faster, smarter decision-making to protect the nation's health in both every day and emergency situations (Walke, 2024).

As part of the PHDS, CDC launched the Core Data Use Agreement (DUA) Initiative, which provides a standardized legal and policy framework that helps STLTS and their partners exchange data more efficiently and securely for routine and response purposes. By creating a standard template, the initiative reduces administrative burden, promotes consistency across jurisdictions, and ensures that shared expectations around privacy, security, and compliance govern key data flows. It is designed to strengthen interoperability between state, tribal, local, and territorial public health authorities and their partners in healthcare and other sectors. Ultimately, this agreement advances CDC's broader data modernization goals by enabling the timely, coordinated, and sustainable use of critical public health data (Centers for Disease Control, 2024).

Framing the Study

The literature shows that, over time, public health data collection methods have evolved from manual record-keeping to sophisticated digital systems, revolutionizing how information is gathered, analyzed, and utilized to inform health policies and interventions. However, the COVID-19 pandemic exposed the vulnerabilities in the U.S.'s siloed, outdated, and often underfunded public health data systems. Modern policy decisions paved the way for public health to adopt new ways of collecting and using healthcare data.

HIOs are pivotal in sharing data about healthcare entities, and their utility has been understudied in modern public health surveillance efforts.

Building upon the existing body of research in the field, this dissertation seeks to deepen our understanding of the current collaboration between PHAs and HIOs. By delving into the landscape of public health surveillance and data modernization, the study aims to pinpoint areas requiring the most attention for improvement and where policy levers could advance DMI efforts. The second aim is to examine how the key components of the CDC's PHDS are currently applied in public health practice, identifying associated barriers and opportunities. The study aims to identify current opportunities and barriers hindering public health agencies from modernizing their data-sharing practices and policies. These findings hold the potential to offer valuable insights into directing limited resources for optimal use, ultimately contributing to the advancement of public health data management and surveillance practices.

CHAPTER 3: Methods

This study employed a mixed-methods design to explore the intersection of public health data modernization implementation, with a particular focus on the role of HIOs. The methods were structured around two aims: a national analysis of HIO-public health collaboration using data from a 2023 survey, and a scoping review of how key components of CDC's PHDS are reflected in the literature. This approach allowed for a qualitative study supported by quantitative insights to better support examining the public health data landscape as public health infrastructure continues to modernize.

Aim 1: Assessing HIOs Participation in Public Health Reporting

The first aim examines the collaboration between HIOs and PHAs in supporting public health surveillance by analyzing primary data collected from ASTP's joint Civitas survey of HIOs. The survey assessed the HIO in the United States and provided a comprehensive picture of health information exchange (HIE) coverage, efforts, and capabilities. The survey also solicited HIOs' perceptions of the impact of federal regulations to inform future policy efforts aimed at improving interoperability and reducing information blocking. Eligible respondents were HIOs operating in the U.S. that supported live electronic health information exchange between independent entities as of March 1, 2022. Data collection was conducted online via Qualtrics between January and July 2023, with recruitment emails sent by Civitas Networks for Health, the University of California San Francisco (UCSF) research team, and the ASTP. The study received an exempt

designation from the University of California, San Francisco institutional review board. The survey was designed collaboratively by UCSF and ASTP, with funding provided by ASTP, and data collection managed by UCSF.

This study focused on public health surveillance activities, services, and the challenges encountered by HIOs who reported that their primary public health agency was a state entity. In total, 76 organizations completed the survey or submitted sufficiently complete partial responses. The U.S.-based HIOs described their HIE coverage, capabilities, and perceived barriers. Of the 76 respondents, 37 HIOs identified a state entity as their primary PHA.

Measures

The survey instrument included a mix of question formats designed to capture organizational characteristics, public health reporting services, and barriers to data exchange. Organizational characteristics were measured using closed-ended, single-response items with predefined categories. Respondents were asked which public health reporting services they offered to their primary public health agency for participating health care providers: syndromic surveillance reporting, immunization registry reporting, electronic case reporting, electronic reportable laboratory result reporting, public health registry reporting (administered by or for public health agencies), clinical data and/or specialized registry reporting (administered by or for non-public health entities), other COVID-19–related reporting (e.g., registry), and vital record system reporting.

Respondents were asked to what extent they experienced the following barriers to public health reporting — both sending to and receiving from their primary PHA: patient

consent models hindering data exchange; state statutes or regulations limiting PHA participation with HIE; need for data use agreements; limited funding from the PHA; limited funding from HIE participants; insufficient PHA staffing; PHA's lack of technical capability to receive or process HIE messages; other technical limitations at the PHA; competing PHA priorities; and low return on investment for the HIE.

Public health reporting services were assessed through check-all-that-apply items, asking whether the HIO provided capabilities, and then measured using closed-ended, single-response items to determine HIO and PHA collaboration. Barriers to exchange were measured using Likert-type scales, with participants indicating the extent to which issues such as patient consent models, state statutes or regulations, PHA workforce capacity, and technical limitations hindered reporting. Response options for these items included not at all, very little, somewhat, and to a great extent. Although the study included open-ended questions, they were not assessed for this study.

Data Analysis Plan

The HIO dataset was cleaned and prepared by the USCF under an executed DUA and provided to me in de-identified form. I conducted descriptive analyses to characterize (a) organizational features of HIOs reporting primarily to a state PHA, (b) availability and maturity of public health reporting services (e.g., syndromic surveillance, ELR, eCR, IIS connectivity), and (c) reported barriers to public health data exchange with primary public health agencies. For categorical items, I reported counts and percentages; for ordinal Likert-type items, I summarized response distributions. All analyses were performed in Stata (v19); figures and tables were generated using Microsoft Office Suite programs.

Aim 2: The Scoping Review on CDC's Public Health Data Strategy Components

The second aim examines what has been disseminated about the key components of the CDC's Public Health Data Strategy (PHDS), employing a scoping review. The scoping review utilized the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (Tricco et al., 2018). Searches were conducted in PubMed in April 2025 and Policy Commons in May 2025.

PubMed Search Terms

In consultation with university librarians, I developed detailed search terms to identify relevant public health data modernization literature that were comprehensive and specific to select terms in the HIO survey. The PubMed search combined: ("Public health data" OR "Public health surveillance" OR "Public health informatics" OR "Public Health Data Systems") AND ("Data Modernization" OR "Data Modernization Initiative" OR "interoperability" OR "Health Information Exchange" OR "HIE" OR "Information Technology" OR "Health IT" OR "wastewater surveillance" OR "Funding" OR "Trusted Exchange Framework and Common Agreement" OR "TEFCA" OR "Electronic case reporting" OR "eCR" OR "Electronic health records" OR "Electronic Laboratory Reporting" OR "EHR" OR "Syndromic surveillance" OR "Artificial intelligence" OR "AI" OR "FHIR" OR "Fast Healthcare Interoperability Resources" OR "Workforce").

Grey Search Terms. "Data Modernization Initiative" was searched in Policy Commons.

Exclusion and Extraction Criteria. Documents were excluded if they: (a) were not conducted in the United States, (b) were published before 2009 or the data collection period was before 2009, (c) did not mention any of the search terms, (d) were not available in full text, (e) were written in a language other than English or (f) animals studies that did not involve humans. For grey literature, CDC-produced documents were excluded since I wanted to capture perspectives external to CDC rather than reproducing CDC's narrative. CDC grey literature remains important in contextualizing and framing the conversations, as cited in the first two chapters, but excluding it from the formal review preserves objectivity where CDC's policy-supporting materials are both the subject and source of evaluation.

The following items were extracted from the included documents: Author(s), year of publication, title of the study, document type (i.e., Journal Article, Editorial/Perspective/Commentary, Report, Conference Summary, White Paper, or Policy Statement), the source or publisher, focus area, and thematic category (data modernization, interoperability, public health workforce & capacity building, wastewater surveillance, syndromic surveillance, electronic case reporting, or policy & governance). I also documented key findings, the methodology approach, contributors involved, and any limitations noted by the authors. Additional notes and comments were recorded as applicable to contextualize the findings.

A standardized data extraction form (Appendix A) was designed in Excel, and I extracted the data. In synthesizing findings, I organized the evidence according to the thematic categories, highlighting key patterns, noting gaps, and policy recommendations.

CHAPTER 4: Results

Aim 1: Characterizing HIOs in Public Health Reporting

Of the 76 HIOs who completed the survey, 37 identified a state entity as their primary PHA and responded to PHA-related questions (Table 4.1) and reflected a wide range of organizational characteristics, both in terms of legal structure and governance models. The majority (73.7%) reported being organized as private nonprofit entities under section 501(c)(3), underscoring the nonprofit orientation of most HIOs. This structure highlights their role as community-based, mission-driven organizations designed to advance health information exchange in the public interest rather than for financial gain. A smaller but meaningful share (18.4%) indicated that they functioned as state government agencies, suggesting that some states have opted to formally integrate HIO operations into the public sector. Only one HIO (2.6%) was identified as a private for-profit organization, while two (5.3%) reported "other" arrangements.

The organizational structures of participating HIOs reflect a balance between different governance approaches. Among the 37 respondents, just over half (51.4%) reported using a hybrid model combining centralized and federated exchange elements. This approach allows for flexibility in balancing efficiency with stakeholder autonomy. Centralized structures were the second most common, with 14 HIOs (37.8%) operating under a model that relies on a single, centralized database. By contrast, only four HIOs

(10.8%) reported using a fully federated model, in which data remains with local participants and is exchanged only as needed.

Table 4.1: Characteristics of Participating HIOs

Characteristic	Category	N	%
Legal Organization Structure	Private Non-Profit (501c3)	27	73.7%
	State Government / Agency	7	18.4%
	Other (specified)	2	5.3%
	Private For-Profit	1	2.6%
Governance Model	Both (Hybrid)	19	51.4%
	Centralized	14	37.8%
	Federated	4	10.8%

Participating HIOs reported serving a wide range of states, highlighting their diverse reach and the variation in how health information exchange is organized across the country. States represented in the survey include Arizona, Colorado, North Dakota, Maine, New York, Utah, Massachusetts, Louisiana, Arkansas, Illinois, Kansas, Missouri, Oklahoma, Vermont, Delaware, Maryland, Pennsylvania, Connecticut, Georgia, Mississippi, New Jersey, South Carolina, Texas, Ohio, Indiana, Kentucky, Michigan, Florida, California, Montana, New Mexico, Iowa, Minnesota, Nebraska, South Dakota, Wyoming, Virginia, the District of Columbia, and West Virginia. This geographic spread demonstrates the breadth of HIO participation nationwide and illustrates how HIOs are supporting health data exchange in diverse policy and operational environments.

Reporting Services to Public Health Agencies

Respondents to the 2023 HIO survey whose primary PHA was a state entity offered a wide range of reporting services to their PHA, including syndromic surveillance,

immunization registries, eCR, ELR, public health and clinical registries, COVID-19–specific reporting, and vital records systems (Table 4.2).

The level of implementation varied considerably. Syndromic surveillance reporting was the most widely adopted, with more than two-thirds of respondents (69.70%) indicating it was already in production, while smaller proportions noted the service was still in planning (18.18%), available but not functional for the PHA (6.06%), or not available (6.06%). Similarly, immunization registry reporting was widely supported, with 61.11% reporting the service in production; the remainder described it as in planning (11.11%), available but not functional (11.11%), in testing (11.1%), or not available (5.56%).

In contrast, eCR showed more variable adoption. Only about one-third of respondents (39.39%) indicated eCR was in production, while 27.27% reported it was in planning, 12.12% said it was available but not functional, and 12.12% stated it was not available. ELR was more commonly implemented, with two-thirds (66.67%) reporting it in production. Smaller shares indicated the service was in planning (12.12%), in testing (6.06%), or not available (9.09%).

Other reporting services showed mixed uptake. Public health registry reporting, administered by or for PHAs, was in production for 43.75% of respondents; smaller shares indicated it was in planning (15.6%), available but not functional (12.5%), or unknown (6.3%), while 21.9% reported it was not available. Clinical or specialized registry reporting, typically administered by non-PHA entities, had higher adoption, with 62.50% reporting it in production and smaller proportions describing it as available but not functional (9.38%), in planning (9.38%), or not available (18.75%). COVID-19-specific reporting services showed

strong uptake, with nearly 70% in production and only a small proportion indicating they were in planning (6.06%), in testing (3.03%), or not available (12.12%).

Vital records system reporting stood out as the least developed service. Only 9.38% of respondents indicated the service was in production, while over half (46.88%) reported it was not available at all. Close to a quarter (28.12%) noted the service was still in planning, highlighting a substantial gap in adoption compared with other reporting services.

Table 4.2 Availability of Public Health Reporting Services

Public Health Reporting Service	Available N (%)	In Planning N (%)	In Production N (%)	In Testing N (%)	Not Available N (%)	Don't Know N (%)
Syndromic surveillance reporting (N=33)	2 (6.06%)	6 (18.18%)	23 (69.70%)	0 (0.0%)	2 (6.06%)	0 (0.0%)
Immunization registry reporting (N=36)	4 (11.11%)	4 (11.11%)	22 (61.11%)	4 (11.11%)	2 (5.56%)	0 (0.0%)
Electronic case reporting (N=33)	4 (12.12%)	9 (27.27%)	13 (39.39%)	2 (6.06%)	4 (12.12%)	1 (3.03%)
Electronic laboratory reporting (ELR) (N=33)	2 (6.06%)	4 (12.12%)	22 (66.67%)	2 (6.06%)	3 (9.09%)	0 (0.0%)
Public health registry reporting (PHA-administered) (N=35)	4 (12.50%)	5 (15.62%)	14 (43.75%)	0 (0.0%)	7 (21.88%)	2 (6.25%)
Clinical/ specialized registry reporting	3 (9.38%)	3 (9.38%)	20 (62.50%)	0 (0.0%)	6 (18.75%)	0 (0.0%)

(non-PHA) (N=32)						
Other COVID-19–related reporting (N=33)	3 (9.09%)	2 (6.06%)	23 (69.70%)	1 (3.03%)	4 (12.12%)	0 (0.0%)
Vital records system reporting (N=32)	3 (9.38%)	9 (28.12%)	3 (9.38%)	1 (3.12%)	15 (46.88%)	1 (3.12%)

Barriers to Public Health Reporting

Respondents reported a range of barriers that affect how they exchange data with their PHA (Table 4.3). These barriers spanned legal requirements, technical limitations, funding shortfalls, and organizational constraints. The degree to which each barrier was experienced varied, underscoring the complexity of connecting health information exchanges (HIEs) with public health systems.

One area of concern was patient consent models, which refer to the legal and technical processes that determine whether a patient's health information can be shared. Nearly half of respondents (45.7%) said these models did not hinder data exchange at all, but approximately one-third (34.3%) said they created a little hindrance, and 20% said they were a barrier somewhat or to a great extent.

State statutes and regulations were another barrier. State-level legal frameworks can create inconsistencies in how PHAs can partner with HIEs, often requiring additional agreements or limiting the scope of collaboration. About 37.1% of respondents reported that legal restrictions did not hinder data exchange, but more than half reported at least some barrier: 28.6% somewhat, 28.6% very little, and 5.7% to a great extent. Similarly,

DUAs are contracts that outline how data can be shared and for what purposes. Forty percent said DUAs were somewhat of a barrier, while 31.4% reported they were not at all. Smaller shares indicated the barrier's impact as very little (25.7%) or to a great extent (2.9%).

Constrained financial resources on both the public health and clinical sides hinder the ability to maintain and expand HIO services. Funding provided by PHAs stood out as especially significant. Nearly one-third of respondents (29.4%) reported that PHA-provided funding was a barrier to a great extent, and another 29.4% experienced it somewhat. Similarly, when asked about funding limitations from other HIE participants (e.g., hospitals or providers contributing data), 38.2% reported this was somewhat of a barrier, and 14.7% said funding was a barrier to a great extent.

Workforce and technical infrastructure also emerged as common challenges. Nearly half of respondents 90% reported that PHA staffing shortages posed at least some barrier, and only 11.4% said staffing was not at all a barrier. This means that many public health agencies simply do not have enough trained staff to handle the demands of data exchange, which can delay processing, reduce follow-up, or limit their ability to make full use of the information they receive. Similarly, PHAs' technical capability to receive or process electronic messages was uneven. In practice, this refers to whether a public health agency has the right software, servers, or data systems to accept health information from HIEs in a usable format. About one-third (34.3%) said receiving capacity was not at all a barrier, but the rest reported it somewhat (31.4%), very little (22.9%), or to a great extent (11.4%). For message processing, which means the agency's ability to clean, analyze, and

integrate the data into their systems, 41.7% reported no barrier, but 22% experienced it to a great extent. Respondents also identified other technical limitations –although undefined –it could include topics such as outdated computer systems, lack of updated or modernized standards, or poor interoperability between different software platforms. These issues were somewhat of a barrier for 48.6% of respondents, with a smaller percentage of respondents reporting experiencing this barrier to a great extent (8.6%) or very little (22.9%).

The most widely reported challenge was competing priorities at the PHA level. Over half of respondents (52.8%) said competing priorities were somewhat of a barrier, and another 25% said they were a barrier to a great extent. Only 8.3% said this was not at all a barrier. In practice, this means that PHAs often face many urgent demands at once with finite resources. When resources and staff are pulled in multiple directions, data exchange efforts may be deprioritized

Finally, respondents were asked about the return on investment (ROI) for HIEs. Unlike the other barriers, ROI was generally seen as less of a concern. About 41.2% reported it was very little of a barrier, and 29.4% said it was not a barrier at all. Only 23.5% said it was somewhat of a barrier, and just 35.9% said it was to a great extent. This suggests that while ROI is always a consideration in sustaining partnerships, most HIEs did not see it as a major obstacle to engaging in public health reporting.

Table 4.3: Barriers to Public Health Reporting

Barrier Reported	Not at All N (%)	Very Little N (%)	Somewhat N (%)	To a Great Extent N (%)
Patient consent model hinders data exchange with PHA (N=35)	16 (45.71%)	12 (34.29%)	4 (11.43%)	3 (8.57%)

State statutes/regulations limit PHA participation with HIE (N=35)	13 (37.14%)	10 (28.57%)	10 (28.57%)	2 (5.71%)
Need for data use agreements for public health data (N=35)	11 (31.43%)	9 (25.71%)	14 (40.00%)	1 (2.86%)
Limited funding from PHA (N=34)	7 (20.59%)	7 (20.59%)	10 (29.41%)	10 (29.41%)
Limited funding from HIE participants (N=34)	11 (32.35%)	5 (14.71%)	13 (38.24%)	5 (14.71%)
PHA lacks staffing (N=35)	4 (11.43%)	7 (20.00%)	16 (45.71%)	8 (22.86%)
PHA lacks technical capability to receive messages from HIE (N=35)	12 (34.29%)	8 (22.86%)	11 (31.43%)	4 (11.43%)
PHA lacks technical capability to process messages from HIE (N=36)	15 (41.67%)	6 (16.67%)	8 (22.22%)	7 (19.44%)
Other technical limitations on the part of PHA (N=35)	7 (20.00%)	8 (22.86%)	17 (48.57%)	3 (8.57%)
PHA has other priorities (N=36)	3 (8.33%)	5 (13.89%)	19 (52.78%)	9 (25.00%)
Low return on investment to HIE (N=34)	10 (29.41%)	14 (41.18%)	8 (23.53%)	2 (5.88%)

Aim 2: Scoping Review of Public Health Data Strategy Elements

The search criterion presented 1,192 journal articles from PubMed and 243 grey literature sources from Policy Commons (Figure 4.1). An initial abstract review eliminated 844 PubMed articles. A full-text review followed, with 339 PubMed articles assessed; two duplicates were removed, and exclusions were made for 112 articles not focused on the U.S., 18 without full text, and 67 off-topic. The Policy Commons search yielded 146 sources, which were thoroughly reviewed, of which 119 were excluded. Ultimately, 132 PubMed articles and 24 Policy Commons or other grey literature sources were thoroughly examined and abstracted.

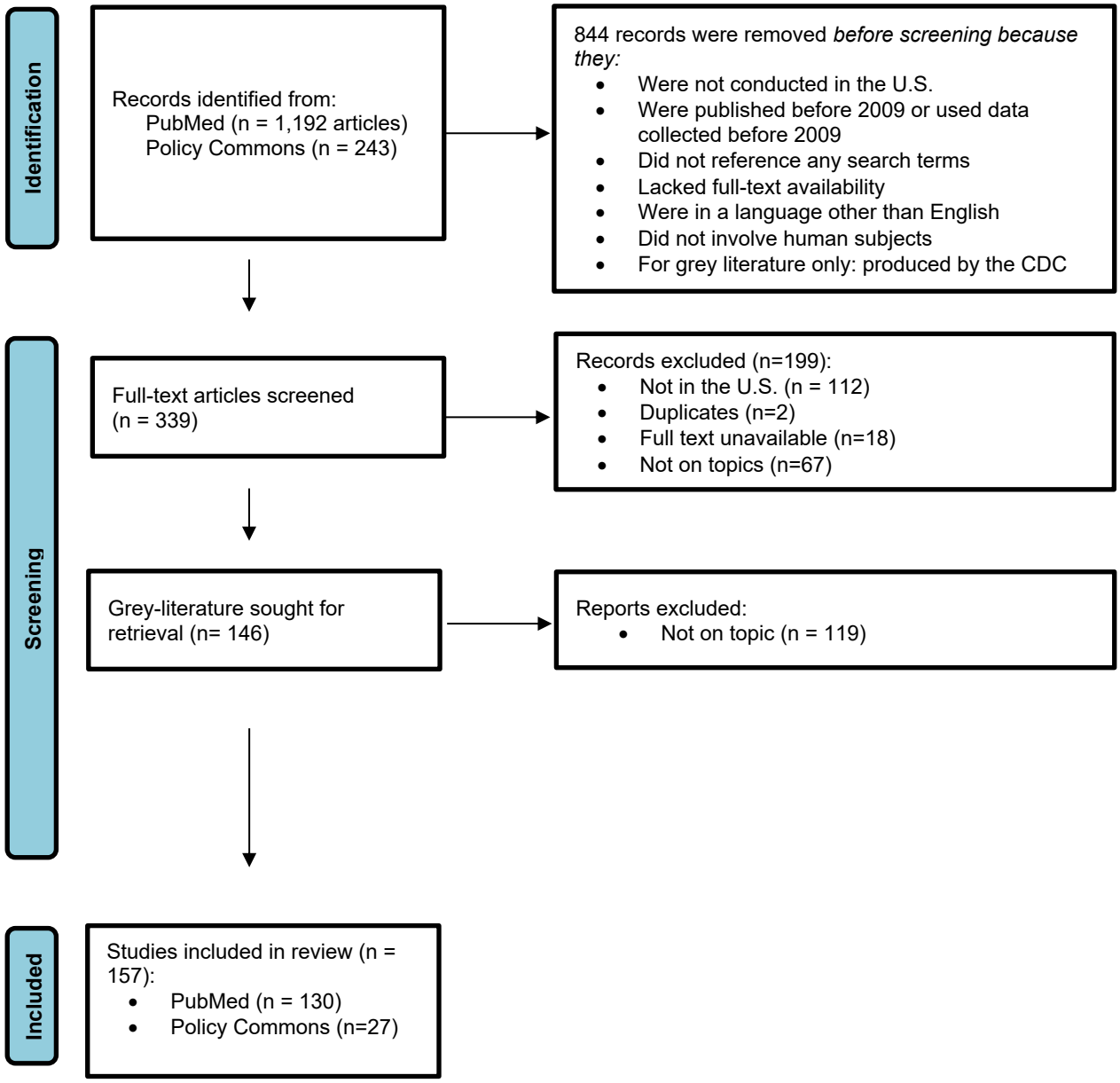

Figure 4.1: Scoping Review Process

A total of 155 documents were included in the review. The majority were journal articles (n = 114), while other document types included conference perspectives (n = 4), editorials (n = 15), policy statements from grey literature (n = 4), reports (n = 16), and white papers (n = 2) (Table 4.4). Publications spanned from 2011 to 2025, with the highest volume in 2024 (n = 34), followed by 2023 (n = 19) and 2021 (n = 23). A notable increase in

publication output was observed beginning in 2021, coinciding with greater national attention to public health data modernization initiatives.

In respect to the PHDS, the documents collectively addressed a wide range of components, with several addressing multiple areas. The most frequently represented theme was data modernization (n = 57), followed by policy and governance (n = 33), workforce (n = 28), and syndromic surveillance (n = 28). Other topics included interoperability (n = 25), wastewater surveillance (n = 23), electronic case reporting (ECR) (n = 19), and electronic laboratory reporting (ELR) (n = 7) (Table 4.4).

Table 4.4. Characteristics of Reviewed Articles and Grey Literature, N = 155.

Characteristic	n
Type of Document	
Journal Articles	114
Conference Perspectives	4
Editorials	15
Policy Statements (Grey)	4
Reports	16
White Papers	2
Year of Publication	
2011	1
2012	4
2013	7
2014	10
2015	5
2016	3
2017	9
2018	7
2019	5
2020	9
2021	23
2022	12
2023	19
2024	34
2025	7
PHDS Component(s) Covered in Content*	
Data Modernization	57

Policy and Governance	33
Workforce	28
Syndromic Surveillance	28
Interoperability	25
Wastewater Surveillance	23
Electronic Case Reporting	19
Electronic Laboratory Reporting	7

**Note: PHDS = Public Health Data Strategy categories are not mutually exclusive.*

Thematic Analysis of The Public Health Data Modernization Landscape

Data Modernization

Public health data modernization represents a strategic response to longstanding fragmentation across surveillance systems in the U.S. Rather than isolated upgrades, modernization is increasingly framed as a structural transformation that connects multiple surveillance domains—eCR, ELR, syndromic surveillance, and wastewater surveillance—into a cohesive and responsive data ecosystem (Gamache et al., 2018; Kadakia et al., 2021; LaVenture et al., 2014; Robert Wood Johnson Foundation, 2021). Collectively, these domains reflect a shift toward automated, interoperable, and adaptive infrastructures capable of supporting timely public health decision-making and equitable outcomes (Bosch, 2021; Robert Wood Johnson Foundation, 2021; Trust for America's Health, 2020).

Modernization is not solely a technical endeavor. Interoperability continues to present challenges due to inconsistent adoption of data exchange standards across jurisdictions, vendors, and healthcare systems (Dixon, B. E., Gibson et al., 2014; Lewis & RTI International, 2023; Mishra et al., 2021). These issues impede the integration of data streams and limit the ability to conduct timely, accurate surveillance. Efforts to align systems through common protocols, such as HL7 FHIR, are foundational to overcoming

these barriers and enabling data liquidity across the public health enterprise (Kadakia et al., 2021; Robert Wood Johnson Foundation, 2021).

Within this ecosystem, syndromic surveillance has evolved beyond its original use as an early-warning tool. It now operates alongside ELR and eCR systems as part of a broader strategy for situational awareness and real-time monitoring (Katz et al., 2011; Mac Kenzie et al., 2016). Wastewater surveillance contributes a population-level perspective by capturing community-level health trends in near real-time, expanding the scope of data sources available for integrated analysis (LaJoie et al., 2022; Trust for America's Health, 2024a). While each system offers distinct value, they are increasingly deployed in parallel, and their effectiveness is amplified when supported by shared infrastructure, standardized vocabularies, and coordinated governance (Adams et al., 2024; Gamache et al., 2018; Gluskin et al., 2014).

Workforce capacity is another foundational element. Investments in informatics, data science, and IT personnel are essential for deploying, maintaining, and optimizing modern systems (Adams et al., 2024; Kadakia et al., 2021; LaVenture et al., 2014). Workforce shortages and lack of technical expertise have been repeatedly cited as limiting factors in both implementation and sustainability (AcademyHealth, 2024; Robert Wood Johnson Foundation, 2021; Trust For America's Health, 2022). Ensuring that workforce development is embedded in modernization efforts is critical to long-term success (Trust for America's Health, 2024a).

Taken together, these themes point to data modernization as a unifying strategy rather than a collection of discrete programs. ELR, eCR, syndromic surveillance, and

wastewater surveillance are increasingly recognized as interconnected components of a modern public health architecture (Adams et al., 2024; Gamache et al., 2018; Trust for America's Health, 2024a). Policy statements such as the COSSA 2021 sign-on letter and the 2022 coalition letter to strengthen NCHS underscore the urgency of sustained investment, interagency collaboration, and integration of social science perspectives (Bosch, 2021; Pierson, 2022). When supported by interoperable infrastructure, equitable governance, and a skilled workforce, these systems provide the foundation for a more resilient and responsive surveillance ecosystem (Robert Wood Johnson Foundation, 2021; Trust for America's Health, 2024a).

Policy and Governance

If data modernization is the foundation of 21st-century public health, then policy and governance are the blueprint shaping how systems are built, who has access, and how data flows across sectors. The evidence reviewed on policy and governance underscores that the success of surveillance modernization efforts hinges as much on clear, equitable governance structures and supportive policies as it does on technology itself. Throughout the literature, one message resounds: modernization without governance risks amplifying fragmentation, inequities, and public mistrust (Dixon, B. E. et al., 2023; Gamache et al., 2018; Kadakia et al., 2021).

The COVID-19 pandemic was a stress test for the U.S. public health data ecosystem, exposing longstanding weaknesses in governance and highlighting the consequences of decades of underinvestment (Crowley et al., 2023; Lane et al., 2020). Surveillance systems, even when technically advanced, were constrained by fragmented

decision-making, inconsistent policies, and opaque accountability mechanisms (Knicely et al., 2024; Mac Kenzie et al., 2016). One of the clearest findings across the studies was that chronic underfunding and governance gaps left many state and local health departments ill-prepared to act on the data they were able to collect (Leider et al., 2017; Trust for America's Health, 2023a). Even as new data streams like electronic case reports, syndromic surveillance feeds, and wastewater signals became available, the lack of clear policies on how to integrate, prioritize, and act on these signals left many jurisdictions unable to fully capitalize on the information (Rigby et al., 2024; Rosenthal et al., 2024).

Governance and policy structures also shape modernization outcomes. Jurisdictions with clear data use agreements, defined roles, and cross-sector partnerships are better positioned to implement and sustain modernized systems (Bipartisan Policy Center, 2023; Lewis & RTI International, 2023). Conversely, fragmented authority and unclear accountability have led to uneven adoption and constrained capacity for response. This governance variability also contributes to disparities in modernization progress, as better-resourced jurisdictions often advance faster, while under-resourced areas remain reliant on legacy infrastructure (Gluskin et al., 2014; Mishra et al., 2021; Robert Wood Johnson Foundation, 2021; Trust For America's Health, 2022).

The findings highlight that governance challenges are multi-layered, spanning technical, legal, ethical, and organizational dimensions. At the technical level, the lack of uniform data standards and clear interoperability requirements hindered the seamless exchange of data across systems and jurisdictions (Knicely et al., 2024; Lee et al., 2018). Studies repeatedly noted that federal leadership is critical to establishing national

standards for data collection, transmission, and reporting — and to ensuring that those standards are implemented equitably (Khurshid & Sarkar IN., 2025; Lenert, L. & Sundwall DN., 2012). Without national-level consistency, jurisdictions were left to negotiate individual agreements, creating a patchwork of policies and practices that undermine the scalability and resilience of the overall system (Pathak et al., 2024; Tabano et al., 2017).

Equity at the Core of Public Health Governance

Considering legal and ethical issues, concerns about privacy, consent, and appropriate use of data were pervasive. Several studies identified public skepticism about how. surveillance data — particularly sensitive demographic information — would be used (Cochlin et al., 2024; Subbian et al., 2021). These concerns were particularly acute in historically marginalized communities, where a legacy of mistrust of government agencies and health institutions fueled reluctance to participate in surveillance initiatives (Field et al., 2024; Robert Wood Johnson Foundation, 2022a). Researchers stressed that governance frameworks must not only comply with legal privacy protections but also actively engage communities in shaping how their data is collected, shared, and used. Transparent communication, opportunities for community input, and clear accountability mechanisms were identified as essential to building trust (Dixon, B. E. et al., 2023; Gamache et al., 2018).

One of the more forward-looking aspects of the findings was the emphasis on equity-centered governance. Many researchers argued that structural racism and entrenched inequities are themselves public health crises that data systems must explicitly confront (Ho, 2022; Robert Wood Johnson Foundation, 2022a). Equity-centered

governance means going beyond simply avoiding harm to proactively designing policies that address inequities in who benefits from data modernization. For example, decisions about which jurisdictions receive funding, how data is disaggregated by race and ethnicity, and how surveillance priorities are set can either reinforce or mitigate health disparities (Cochlin et al., 2024; Dixon, B. E. et al., 2023). Studies called for governance structures that build community power, collect and report standardized disaggregated data and ensure inclusive communication practices that are accessible across language and literacy levels (Field et al., 2024; Robert Wood Johnson Foundation, 2022b).

Another key theme in the findings was the importance of resilience and adaptability in governance structures. The pandemic revealed that rigid, top-down decision-making could delay responses or stifle innovation, while overly decentralized governance led to duplication of effort and inconsistencies (Mac Kenzie et al., 2016; Rigby et al., 2024). Jurisdictions that had invested in flexible governance mechanisms — for example, pre-established advisory boards, cross-sectoral partnerships, and data-sharing agreements that allowed for rapid updates — were better able to pivot in response to evolving conditions (Bipartisan Policy Center, 2023; Lenert, L. A. et al., 2021). One study recommended appointing a White House Deputy National Security Advisor for Pandemic Preparedness and creating a National Pandemic Preparedness Board as means of improving federal-state coordination and ensuring consistent governance during crises (Crowley et al., 2023).

Building Sustainable Governance Through Policy Alignment, Workforce, and Funding

Sustainability was another recurrent concern in the governance literature. Many jurisdictions launched promising pilot projects during COVID-19, supported by temporary funding, but lacked plans or resources to sustain them once emergency funds expired (Lane et al., 2020). Researchers called for governance models that include dedicated, ongoing funding streams tied to modernization goals and workforce development (Gamache et al., 2018; Leider et al., 2017). Without such sustainability planning, gains in surveillance capacity risk being lost between crises, leaving the system vulnerable when the next emergency strikes.

The findings also illustrate how governance and policy intersect with workforce and technical capacity. Clear governance can help align the work of diverse stakeholders, from IT vendors to epidemiologists to community organizations (Lee et al., 2018; Mac Kenzie et al., 2016). Several studies highlighted how jurisdictions with robust governance structures were more successful in attracting and retaining skilled staff, building institutional knowledge, and fostering a culture of data use and continuous improvement (Dixon, B. E. et al., 2023; Trust for America's Health, 2024b). Conversely, poorly defined governance often left staff unclear about priorities, leading to burnout, turnover, and missed opportunities (Gamache et al., 2018; Leider et al., 2017).

Governance reform was described as inseparable from broader public health policy reform. Many of the barriers to modernization identified in the literature — such as underfunding, inequitable resource allocation, and inadequate workforce development — stem from policy choices (Crowley et al., 2023; Kadakia et al., 2021). Researchers argued that policymakers must recognize public health data systems as critical infrastructure and

invest accordingly. This includes codifying funding commitments, embedding equity and resilience into federal and state public health strategies, and holding institutions accountable for progress (Robert Wood Johnson Foundation, 2022b; Trust for America's Health, 2024a).

The evidence paints a clear picture: governance and policy are not peripheral to data modernization but central to its success. Technology alone cannot fix a fragmented, underfunded, and inequitable system. Modernization efforts must be guided by governance structures that are transparent, flexible, equitable, and inclusive, and by policies that prioritize sustained investment and accountability. As one researcher noted, "A modern data system without modern governance is just a faster way to repeat the mistakes of the past" (Dixon, B. E. et al., 2023). By embedding equity, resilience, and transparency at the heart of public health governance, jurisdictions can ensure that modernization fulfills its promise.

Workforce Development as a Strategic Lever for Equity and Sustainability

Workforce capacity challenges go beyond numbers; they are also about skills. Modern surveillance demands a workforce that blends traditional epidemiology with informatics, data science, and systems thinking (Gamache et al., 2018; Rajamani et al., 2024). Many jurisdictions lack staff who understand both clinical workflows and public health data needs, limiting their ability to design interoperable systems or collaborate effectively with partners such as EHR vendors, wastewater utilities, or HIEs (Dixon, B. E. et al., 2023). For example, even as electronic case reporting and EHR-based chronic disease

surveillance became technically viable, many public health agencies lacked the informatics expertise to operationalize these tools (Kraus et al., 2024; Shah et al., 2016). This uneven capacity contributes to widening disparities across the public health landscape. Larger, urban jurisdictions often have informatics-trained staff, dedicated IT teams, and experience managing complex data streams, while smaller and under-resourced health departments struggle to adopt even foundational technologies (DeVore et al., 2016; Dixon, B. E. et al., 2015; Sepúlveda MJ., 2014). Without targeted investment in workforce development for rural and underserved communities, modernization efforts risk exacerbating health inequities (Ho, 2022; Holm et al., 2023; Trust For America's Health, 2022).

Modern public health also requires soft skills—building trust with communities, communicating complex data clearly, and navigating ethical and governance issues (Edmunds et al., 2014; Trust For America's Health, 2022). Studies emphasized the need for staff who reflect their communities, advocating for multilingual hiring, cultural competency, and inclusive workplaces that support diversity at all levels (Holm et al., 2023; Rajamani et al., 2024).

Burnout and retention were also prominent themes. The relentless demands of the pandemic, combined with chronic understaffing and political pressures, led to high turnover, particularly among early-career professionals and those from marginalized communities (Ho, 2022). This churn erodes institutional memory and places added stress on remaining staff. Researchers called for more substantial investments in retention

through competitive pay, professional development, mentorship, and supportive workplace cultures (Arrazola & Auer S., 2023; Wholey et al., 2018).

Encouragingly, several studies showed that targeted workforce investments yield tangible benefits. Pilot projects such as the MENDS EHR-based surveillance network demonstrated success due in part to deliberate investments in training, trust-building, and governance (Kraus et al., 2024) Similarly, community of practice models—such as those used in syndromic surveillance—helped build local capacity through peer learning and mentorship (Fleischauer & Gaines J., 2017; Gould et al., 2019).

To meet modernization goals, workforce development must be institutionalized as a core strategic priority. Multiple studies recommend expanding public health informatics training programs, offering scholarships and loan forgiveness, creating clearer career pathways, and fostering interdisciplinary collaboration across public health, IT, engineering, and data science (Dixon, B. E. et al., 2023; Rajamani et al., 2024; Williams et al., 2019). Initiatives like the TRIUMPH consortium and PHIAT Conference offer scalable models for expanding and diversifying the workforce (Moreno Arellano et al., 2024; Rajamani et al., 2024).

Workforce expansion is also essential for equity and resilience. The pandemic showed that over-reliance on surge staffing is unsustainable, particularly in communities facing structural disadvantages (Ho, 2022). Building a stable, diverse, and highly skilled workforce ensures that public health agencies can respond to emergencies and maintain essential functions during non-crisis periods, reducing burnout and strengthening community trust (Holm et al., 2023; Trust for America's Health, 2024b). However,

workforce investments must be matched with sustainable funding and governance reform. Many agencies are reluctant to hire permanent staff with short-term grant funding, fearing layoffs once funding ends (Dixon, B. E. et al., 2023). Researchers advocate for long-term investments tied to modernization goals and policies that allow for strategic workforce planning and retention (Massoudi et al., 2012; Trust for America's Health, 2024b).

The evidence is clear: workforce and capacity building are not ancillary concerns; they are the foundation upon which public health data modernization must be built. Without a skilled, adequately resourced, diverse workforce, even the most advanced technologies will fall short of their potential. Sustained investment in people—through training, funding, equity, and supportive work environments—is essential for ensuring that modernization efforts deliver real, lasting improvements in population health (Dixon, B. E. et al., 2015; Sepúlveda MJ., 2014; Trust for America's Health, 2024b).

Syndromic Surveillance

Chronologically, syndromic surveillance has evolved as its application matured. In its formative stage, syndromic surveillance was most often described in the literature as an emerging, innovative approach aimed at providing “early detection” and “situational awareness” for bioterrorism events and novel infectious disease outbreaks (Katz et al., 2011).By the mid-2010s, as systems like the CDC’s National Syndromic Surveillance Program’s (NSSP) BioSense became more widely deployed, the literature began to frame syndromic surveillance as an operationalized, routine tool for public health (LaVenture et al., 2014). NSSP is one of the most prominent examples of syndromic surveillance in action, particularly its ESSENCE platform. ESSENCE demonstrated exceptional

adaptability during live operations, effectively integrating diverse data streams, maintaining real-time responsiveness, and enabling jurisdictions to rapidly adjust to evolving threats (Burkom et al., 2021; Lucero-Obusan et al., 2017). As the public health application evolved, syndromic surveillance, as a standard, was reinforced through discussions of building STLT PHA's capacity to conduct syndromic surveillance (Fleischauer & Gaines J., 2017; Gamache et al., 2018; Gould et al., 2019; Smith, P. F. et al., 2013; Williams et al., 2019).

Earlier syndromic surveillance use cases relied on free-text chief complaint data, but inconsistent terminology and lack of standardized vocabularies undermine its accuracy and comparability (Conway et al., 2013; Dixon, B. E., Vreeman et al., 2014; Kass-Hout et al., 2012). While various classifier approaches—keyword-based, Bayesian, hybrid, and multi-method—can effectively parse these data, no single method consistently performs best, highlighting the need for better governance and standardization (Zhou et al., 2015).

After 2020, particularly during and after the COVID-19 pandemic, the role of syndromic surveillance was solidified as a foundational element of modern public health infrastructure, and syndromic surveillance etymology continued to evolve to demonstrate its utility. Romano et al. (2022) found that some syndromic systems embedded in state and local operations offer flexible, tailorable, real-time situational awareness to support decision-making. Similarly, Burkom et al. (2021) highlighted ESSENCE, an analysis tool within the CDC's NSSP, as a scalable, adaptable platform for detecting and responding to

emerging threats. The ability of ESSENCE to accommodate new data sources and changing epidemiologic priorities in real time was cited as a critical strength.

Use Cases for Syndromic Surveillance

The reviewed literature demonstrates the breadth of conditions to which syndromic surveillance has been applied, which spans infectious diseases, injuries, chronic conditions, and maternal health. Beyond COVID-19, syndromic surveillance was also used effectively to track other pressing issues, such as the opioid epidemic (Pickens et al., 2022; Roehler et al., 2021). The literature also shows syndromic data use cases for nonfatal opioid overdoses as a reliable input for decision-making through the ability to disaggregate data by age, sex, and geography, allowing for localized, precise interventions.

Syndromic systems have been widely used to monitor influenza and influenza-like illnesses, tick-borne diseases, heat-related illnesses, as well as supporting infection control efforts in healthcare settings (Daly et al., 2017; Lin & Trick WE., 2021; Lucero-Obusan et al., 2017; Thomas et al., 2018; White et al., 2017). It has also helped track firearm injuries and unintentional injuries like falls and motor vehicle crashes (Seil et al., 2015; Zwald et al., 2025). Beyond acute conditions, syndromic surveillance has been leveraged to assess disparities in pregnancy-related ED visits and estimate hypertension prevalence using HIE data (Nazzal et al., 2023; Valvi et al., 2023). In its earlier phases, syndromic surveillance capitalized on advances in automated classifiers to enhance detection of syndromic categories such as gastrointestinal, respiratory, and fever–rash syndromes and validated the use of self-reported fever as a proxy indicator (Haas et al., 2014; Kass-Hout et al., 2012).

The research also highlighted the potential for syndromic surveillance to inform preparedness for mass gatherings and other large-scale events (Fleischauer & Gaines J., 2017; Spector et al., 2022). Platforms such as ESSENCE and BioSense have been used to monitor health threats during mass gatherings, providing real-time situational awareness and strengthening a PHA's ability to quickly detect and respond to potential outbreaks (Burkom et al., 2021; White et al., 2017). Although no studies demonstrated conclusive evidence that syndromic systems directly prevented outbreaks at these events, the tool helped decision-making (Spector et al., 2022).

The research also shows the use case of syndromic surveillance as a tool to identify health disparities. Nazzal (2023) found data from pregnancy-associated ED visits were higher than expected and increased over time, disproportionately affecting younger, Black, and rural or suburban populations. Although these visits carried higher overall odds of admission, Black patients had lower admission odds compared to White patients, suggesting potential inequities in care. Similarly, syndromic data showed firearm-related ED visits surged during 2020, particularly among youth and individuals living in areas of high social vulnerability, with elevated rates persisting in the following years. (Zwald et al., 2025). These disparities underscore the importance of considering an equity lens in designing and interpreting syndromic surveillance data.

Opportunities to Improve Syndromic Surveillance

The research shows syndromic surveillance tools offer a clear value to public health. However, experts note its implementation can raise concerns about misuse, misinterpretation, and lack of transparency. Several studies highlighted the critical role of

shared governance structures and cross-jurisdictional trust in enabling equitable, coordinated, and effective syndromic surveillance and data modernization efforts (Gamache et al., 2018; Lenert, L. & Sundwall DN., 2012; Lin & Trick WE., 2021; Schmit et al., 2023; Smith, P. F. et al., 2013).

Building and sustaining an aptly skilled public health workforce remains a critical challenge for maximizing the potential of syndromic surveillance and data modernization (Gamache et al., 2018; Williams et al., 2019). Studies highlighted persistent gaps in informatics training, technical expertise, and engagement, calling for investment in workforce development and capacity-building initiatives (Fleischauer & Gaines J., 2017; Gould et al., 2019).

Despite these achievements, findings also made clear that syndromic surveillance is not without its challenges. Addressing persistent challenges around governance, workforce capacity, and technology adoption will be essential to realizing the full potential of syndromic surveillance in protecting public health (Dixon, B. E., Vreeman et al., 2014; Gamache et al., 2018; Williams et al., 2019). Experts noted that while the systems excel at situational awareness and outbreak tracking, they have limited predictive value for truly early detection. Many events are detectable only once they have begun impacting health care systems (Thomas et al., 2018). This limitation underscores the need to integrate syndromic data into a broader, multi-stream public health surveillance ecosystem (Gamache et al., 2018).

Wastewater Surveillance

At its core, wastewater surveillance operates on the principle that pathogens shed by infected individuals — often before symptoms develop — accumulate in sewage systems, offering a composite, population-level indicator of infection trends (Gerrity et al., 2021; Kirby et al., 2021).

The COVID-19 pandemic saw the emergence of wastewater surveillance as one of the most innovative and impactful approaches to public health monitoring. The research chronicled wastewater-based epidemiology's (WBE) evolution from a niche research area to an established tool with demonstrated value for early warning, trend detection, and situational awareness (Gerrity et al., 2021; Hopkins et al., 2023; Kirby et al., 2021). Multiple studies documented its effectiveness in detecting outbreaks before clinical data (Scott et al., 2021; Yang et al., 2025). Additionally, it has utility in various community settings, including college campuses, long-term care facilities, and underserved areas (Harris-Lovett et al., 2021; Holm et al., 2023; Keck et al., 2023). LaJoie et al. (2023) report strong public support for wastewater surveillance when framed as a health-promoting tool, but emphasize the need for transparency, trust-building, and respect for privacy to ensure sustained community acceptance.

The CDC's National Wastewater Surveillance System (NWSS) was a landmark effort to scale this approach nationally. Studies revealed that NWSS data correlated strongly with clinical case data during COVID-19 waves and were faster than clinical case data by days or weeks (Hopkins et al., 2023; Kirby et al., 2021). In multiple studies, wastewater treatment plant (WWTP)-level data reflected city-wide clinical patterns, giving local health

officials a critical early warning, expediting the ability to allocate resources strategically, prioritize testing efforts, and anticipate surges (Hopkins et al., 2023; Layton et al., 2022).

The Utility of Wastewater Surveillance

WBE has proven valuable not only for monitoring known threats but also for detecting new and emerging pathogens. One of its most compelling strengths is identifying emerging SARS-CoV-2 variants before clinical reporting. For example, variants such as EG.5.1 and XBB.1.16 were detected in wastewater samples weeks before they were identified in clinical testing databases, highlighting WBE's role as a sentinel system for viral evolution and genomic surveillance; over 90 distinct viral variants across more than 200 wastewater samples, capturing both the diversity of circulating strains and shifts in variant dominance over time (Chen et al., 2024).

Wastewater surveillance proved adaptable beyond COVID-19, enabling detection of other pathogens such as norovirus, Candida auris, influenza, and antimicrobial resistance genes (Barber et al., 2023; Tierney et al., 2024; Vo et al., 2023; Yu et al., 2024). Another study piloted multiplexed assays capable of detecting and quantifying multiple pathogen targets—including SARS-CoV-2, Norovirus, and Influenza—with strong correlations to reported clinical data (Rao et al., 2023). This multi-pathogen surveillance capacity points to wastewater's long-term potential as a foundational component of routine public health monitoring, not just in pandemics but as part of a sustained infectious disease surveillance infrastructure.

Beyond large municipal systems, WBE also proved effective in smaller-scale applications. Geospatial resolution has advanced, with Tierney et al. (2024) and Layton et

al. (2022) demonstrating how high-resolution wastewater data at neighborhood or institutional levels can pinpoint hotspots and guide targeted interventions. Campus-level wastewater monitoring successfully signaled trends in SARS-CoV-2 prevalence, enabling administrators to implement targeted mitigation measures and communicate risks to students and staff (Harris-Lovett et al., 2021; Scott et al., 2021).

Opportunities for Improving Wastewater Surveillance

Operational lessons learned from the rapid deployment of the NWSS and other WBE efforts were consistent across jurisdictions. The importance of clear governance structures, transparent communication of findings, and standardized laboratory and reporting protocols emerged as key enablers of success (Harris-Lovett et al., 2021; Kirby et al., 2021). Without these, jurisdictions struggled to interpret data consistently or to act on signals in a timely manner. Some jurisdictions expressed concern over regulatory ambiguity: questions about who "owned" the data, how results could be shared, and how findings might be used in enforcement contexts remain unresolved (Harris-Lovett et al., 2021).

Despite successes in both large municipal systems, the data highlighted that smaller-scale applications face operational challenges: sample variability, delays in laboratory turnaround times, cost constraints, and regulatory uncertainty around data sharing all pose barriers to smooth implementation (Harris-Lovett et al., 2021).

WBE has limitations in sensitivity and specificity, particularly during periods of low disease prevalence. One evaluation in long-term care facilities found moderate sensitivity (~31% overall, ~48% among residents) but relatively high specificity (~80%), underscoring

the difficulty of interpreting weak signals (Keck et al., 2023). Other studies reported challenges such as sample variability, population mobility, and analytical uncertainty, particularly when viral loads were low or fluctuating (Gerrity et al., 2021; Harris-Lovett et al., 2021). Researchers emphasized that WBE data should be contextualized alongside other surveillance streams—such as syndromic surveillance, electronic case reporting, and laboratory-confirmed cases—to avoid over- or underestimating the actual disease burden (Yang et al., 2025).

Health disparities and equity considerations emerged as a critical theme. Although WBE offers a cost-effective method for monitoring entire populations, disparities in sewer access, infrastructure variability, and differences in catchment area demographics can introduce biases. Experts emphasized the importance of designing surveillance systems that intentionally include underserved and marginalized communities to advance health equity and address environmental justice concerns (Holm et al., 2023). Menchú-Maldonado et al. (2024) highlighted infrastructure gaps affecting over 500 Federally Recognized Indian Tribes, noting that many Tribal communities lack permitted wastewater treatment facilities, which limits their participation in WBE efforts. Experts across studies recommended additional research and policy support to understand and mitigate these inequities, ensuring that WBE serves as an inclusive surveillance tool rather than one that inadvertently overlooks marginalized populations (Holm et al., 2023; Menchú-Maldonado et al., 2024).

Another emerging theme was the importance of sustainability. WBE gained prominence during the COVID-19 emergency, and its long-term future depends on

securing sustained funding, building laboratory and analytic capacity, and integrating it seamlessly with other surveillance systems. Researchers called for establishing permanent WBE programs that can pivot between pathogens of interest, contributing to preparedness and resilience against future outbreaks (Barber et al., 2023; Chen et al., 2024; Harris-Lovett et al., 2021; Hill et al., 2022; Rao et al., 2023; Tierney et al., 2024; Yu et al., 2024).

As wastewater surveillance continues to evolve, the findings underscore the need for workforce development and cross-sector collaboration. Expanding WBE requires laboratory technicians, epidemiologists, engineers, wastewater utility operators, data scientists, and policy experts who can work together to interpret signals and translate them into public health action. Some studies highlighted how jurisdictions built these partnerships successfully, while others reported ongoing gaps in coordination and understanding between public health and wastewater sectors (Harris-Lovett et al., 2021; Hill et al., 2022; Keck et al., 2023; Tierney et al., 2024).

Wastewater surveillance marks a significant evolution in public health practice. It offers a scalable, cost-effective tool for monitoring population health trends. Despite ongoing implementation challenges, the evidence supports WBE's integration as a core component of modern public health surveillance systems. Its strengths—from early outbreak detection and variant tracking to neighborhood-level insights—enhance and extend traditional surveillance methods. To ensure WBE reaches its full potential, sustained attention to technical capacity, governance structures, equity considerations, and workforce development will be essential for long-term sustainability and impact.

Electronic Case Reporting

Electronic Case Reporting (eCR) is a modernized approach to public health surveillance that uses EHRs to automatically generate and transmit case reports to public health agencies when a reportable condition is detected. Unlike traditional reporting methods, which often rely on manual processes, eCR enables more timely, complete, and efficient data exchange, reducing provider burden and enhancing early detection of public health threats (Knicely et al., 2024; Mac Kenzie et al., 2016). It was developed as part of a national initiative to strengthen routine case reporting infrastructure and expand automated surveillance capabilities.

Electronic Case Reporting's Utility

Studies show that eCR provides significant advantages over existing systems. For example, pilot implementations for sexually transmitted infections such as chlamydia and gonorrhea demonstrated that eCR can match or exceed the completeness of electronic laboratory reporting (ELR), while also capturing richer clinical details including demographics and treatment information (Mishra et al., 2023; Todd et al., 2022). These improvements are especially valuable during outbreaks, where timely data is essential to deploying an effective response.

National-level implementation efforts have emphasized the importance of interoperability, data standardization, and governance to scale eCR sustainably. For example, eCR Now and related public-private collaborations have accelerated adoption across jurisdictions, demonstrating that automated reporting can support both routine disease surveillance and emergency response (Dixon, B. E. et al., 2020; Rajamani et al.,

2022). Although challenges remain — such as variation in EHR systems and legal complexities — eCR is widely recognized as a foundational component of the broader public health data modernization strategy (Blumenthal et al., 2020).

Opportunities for Improving Electronic Case Reporting

Despite the technical feasibility of eCR, persistent challenges continue to hinder its widespread and equitable adoption. Chief among these are issues with interoperability. Although the HITECH Act and subsequent federal efforts accelerated EHR adoption and enabled over 70% of hospitals to implement e-prescribing, the inconsistent application of standards like HL7 CDA and FHIR has fragmented data exchange, particularly between healthcare systems and public health agencies (Dixon, B. E. et al., 2020; Mac Kenzie et al., 2016). Health departments frequently lack the infrastructure to receive, process, and act on eCR data in a timely or usable format (Knicely et al., 2024). While automation eases the burden on providers, its public health value remains contingent on the capacity to integrate, validate, and apply that information for surveillance and response (Mishra et al., 2023; Rajamani et al., 2022).

Workforce capacity and its equity implications were another defining constraint. Under-resourced and rural jurisdictions often face compounding challenges, including funding shortfalls, outdated systems, and limited access to skilled public health informatics professionals (Blumenthal et al., 2020; Mac Kenzie et al., 2016). Recruiting and retaining public health informatics professionals pose a significant challenge for rural and under-resourced jurisdictions. These areas often lack the funding, competitive salaries, and training infrastructure to build and sustain a skilled informatics workforce. This can

hinder their ability to implement and fully benefit from systems like eCR. Without targeted investment in workforce development, informatics training, and public health data science career pathways, eCR may deepen disparities in surveillance capacity (Dixon, B. E. et al., 2020; Knicely et al., 2024).

The findings also highlighted innovations that underscore the transformative potential of eCR. Some jurisdictions integrated eCR with syndromic surveillance or laboratory reporting to enhance outbreak detection and streamline case confirmation (Mishra et al., 2023; Todd et al., 2022). Others piloted closed-loop systems enabling PHAs to send feedback to clinical providers, improving collaboration and reinforcing data quality (Rajamani et al., 2022). These examples show how eCR can serve as a reporting mechanism and as the foundation for a more integrated and responsive surveillance ecosystem.

Achieving the full potential of eCR requires more than technology; it depends on consistent case definitions, harmonized data standards, and robust governance structures. Jurisdictions that implemented eCR successfully often had formal agreements between healthcare providers, HIEs, and public health agencies to guide roles and responsibilities and mitigate legal concerns related to data sharing and patient privacy (Blumenthal et al., 2020; Mac Kenzie et al., 2016). Governance and policy reforms are ultimately critical to sustaining and scaling eCR nationally. Recommendations across studies include consistent federal funding, standardized reporting definitions, and long-term collaboration between healthcare providers, vendors, and public health agencies (Blumenthal et al., 2020; Dixon, B. E. et al., 2020; Knicely et al., 2024; Mac Kenzie et al.,

2016; Mishra et al., 2023; Todd et al., 2022). Without this support, jurisdictions may remain stuck in pilot phases or fail to transition from ad hoc innovations to fully integrated, interoperable systems capable of supporting public health in real time. Governance and policy reforms are essential to the long-term success of electronic case reporting (eCR), particularly in addressing the technical and workforce challenges that hinder widespread adoption

Electronic Laboratory Reporting

Electronic Laboratory Reporting (ELR) has emerged as a foundational component of modern public health surveillance in the U.S., offering measurable improvements in timeliness, data quality, and case detection. By automating the transmission of laboratory-confirmed results from clinical laboratories to public health agencies, ELR enhances both routine monitoring and emergency response (Centers for Disease Control and Prevention (CDC)., 2013; Gluskin et al., 2014)

By 2013, more than 60% of laboratory reports were transmitted electronically to public health agencies, reflecting a sharp increase from the previous year and marking a significant milestone in ELR adoption (Centers for Disease Control and Prevention (CDC)., 2013; Gluskin et al., 2014). This early progress, driven partly by federal initiatives like the Meaningful Use program, was most visible among state and local health departments beginning to modernize their reporting infrastructure. At the time, hospital and commercial laboratories were still navigating early implementation challenges such as building technical capacity and aligning reporting workflows—issues helped shape subsequent

national investment priorities in surveillance modernization (Centers for Disease Control and Prevention (CDC)., 2013; Gluskin et al., 2014).

Electronic Laboratory Reporting's Utility

ELR has demonstrated significant utility in strengthening public health surveillance. A national mixed-methods review found that ELR reduced average reporting delays by more than one week and increased Salmonella case notifications by 76% in certain jurisdictions (Gluskin et al., 2014). Targeted enhancements have also supported better outcomes for high-priority populations. In New York City, the inclusion of pregnancy indicators in ELRs for syphilis and hepatitis B virus (HBV) led to earlier identification of individuals with HBV, with 91% of laboratories complying within five years and marked improvement in timely case detection (Liao et al., 2020). Another study in the same jurisdiction used capture–recapture analysis to estimate that ELRs helped identify 96.5% of births to HBV-positive mothers. Missed cases were associated with delays in post-exposure prophylaxis (PEP), highlighting ELR's potential to close critical gaps in perinatal surveillance (Devinney et al., 2020). The PACER platform, piloted by Mishra et al., demonstrated the potential to enhance ELR utility by using FHIR-based queries to automatically supplement lab reports with critical clinical details, significantly improving data completeness for public health case investigations. ELR has also shown promise beyond infectious disease reporting; for instance, a California-based study demonstrated high concordance between HbA1c lab results and clinical diagnoses of type 2 diabetes, underscoring ELR's potential in chronic disease surveillance and health equity monitoring (Richardson et al., 2017).

Opportunities for Improving Electronic Laboratory Reporting

The early success of ELR in improving case detection and timeliness has also introduced new pressures on public health infrastructure. Jurisdictions have reported challenges such as data overload, elevated false positive rates, and annual operational costs ranging from $221,000 to $633,000 (Gluskin et al., 2014). These issues have underscored the need for improved data standardization, workforce development, and sustainable funding models. Planning for increased report volume has become particularly urgent. Modeling studies have projected that ELR adoption under Meaningful Use policies could increase the volume of incoming reports, with substantial variation depending on hospital type and size (Dixon, B. E., Gibson et al., 2014) These projections highlight the importance of scaling ELR capacity in line with local infrastructure, staffing, and workflow realities.

Interoperability remains a central focus in improving ELR utility and managing its growing demands. A more recent pilot project deployed a FHIR-based platform known as PACER, which automatically leveraged ELR triggers to extract additional case details from electronic health records. The platform significantly improved report completeness—capturing demographics (99%), medications (73%), symptoms (71%), and diagnoses (65%)—and was intentionally designed to be open-source and adaptable across diverse systems (Mishra et al., 2021). However, the implementation revealed familiar barriers: inconsistent code mapping, uneven FHIR adoption, and fragmented data governance across institutions.

Electronic Health Records (EHRs) and Interoperability

Interoperability, the seamless exchange and use of data across systems and organizations, is foundational to realizing the full potential of EHRs in public health. EHRS offer the potential for more complete, timely, and actionable surveillance (Gamache et al., 2018; Mac Kenzie et al., 2016). EHRs are uniquely positioned to improve public health surveillance because they contain rich, longitudinal clinical information on patients, often at a level of granularity that far exceeds what is available through traditional reporting mechanisms and can help PHA develop more nuanced public health responses (Gamache et al., 2018; Mac Kenzie et al., 2016). PHAs can identify patterns, monitor chronic disease burden, and respond to health threats with greater precision when this information can be exchanged in standardized, timely formats.

The Utility of Interoperable Electronic Health Records

Several studies documented the use of interoperable EHR data to support chronic disease surveillance, identifying distinct clusters of states with varying capacities and readiness to expand surveillance networks (Ghildayal et al., 2024; Hohman et al., 2024). This stratification informed equity-focused expansion strategies, ensuring that resources were allocated where needed most and that no community was left behind. One of the most compelling findings was the impact of targeted data remediation on EHR data quality. In one example, through a coordinated intervention, public health teams addressed persistent data quality problems, such as missing race and ethnicity fields, duplicate records, orphan observations, and mapping errors. These efforts reduced hypertension validation error rates from 14% to just 2%, and improved ZIP code completeness from around 50% to over 95% (Hohman et al., 2024).

The findings also point to the promise of integrating EHR data with other novel surveillance streams, such as wastewater monitoring and syndromic surveillance, to create a more robust, comprehensive surveillance ecosystem (Dixon, B. E. et al., 2023; Gamache et al., 2018). In one study, public health agencies piloted the use of computable phenotypes derived from HIE-sourced EHR data, achieving high sensitivity and positive predictive value in estimating hypertension prevalence (Hohman et al., 2024). This innovation illustrates how interoperable EHR data can complement and strengthen other surveillance modalities, providing a more complete picture of population health trends.

Opportunities for Improving Electronic Health Record Interoperability

Despite near-universal adoption of EHRs in clinical settings, studies consistently find that true interoperability with public health agencies is still limited, uneven, and often unreliable (Dixon et al., 2015; Knicely et al., 2024). While EHRs offer timely, detailed clinical information that far exceeds what traditional reporting systems can provide, their value for public health depends entirely on the capacity to exchange this data across sectors and systems using common standards (Gamache et al., 2018; Mac Kenzie et al., 2016).

The reviewed evidence shows that fragmented interoperability inhibits the use of EHR data for real-time, comprehensive surveillance. Although many hospitals report over 95% adoption of EHRs and widespread e-prescribing, significant gaps remain in their ability to transmit data in standardized formats like HL7 CDA and FHIR to PHAs (Barker et al., 2024; Knicely et al., 2024). This lack of alignment across vendors and jurisdictions

severely restricts the potential of EHRs to inform surveillance and emergency response efforts.

Public health agencies cannot effectively ingest, validate, or analyze clinical data at scale without interoperable systems. One study emphasized that, even with widespread EHR infrastructure, agencies struggle to obtain timely and reliable information for detecting emerging health threats and guiding equitable responses (Rosenthal et al., 2024). This disconnect increases administrative burden and perpetuates delays in critical public health action.

Strong governance was frequently cited as a foundational enabler of interoperability. Jurisdictions with formal agreements between public health agencies, healthcare providers, HIEs, and vendors were better able to set expectations for data quality, timeliness, and ethical use (Revere et al., 2017; Tabano et al., 2017). In contrast, areas lacking coordinated governance reported reluctance among stakeholders to share data or invest in interoperability solutions, perpetuating siloed systems and limiting progress.

Notably, the findings underscore that interoperability is not solely a technical issue. It is also a workforce and equity challenge. Many under-resourced jurisdictions lack the informatics staff, policy expertise, and technical infrastructure to implement and maintain interoperable systems (Dixon, B. E. et al., 2023). Still, there are promising models. For example, one study found that targeted remediation of EHR data — including fixing missing race and ethnicity fields, correcting mapping errors, and addressing duplicate records — improved data quality dramatically, reducing error rates in hypertension validation from

14% to 2% and raising ZIP code completeness from ~50% to over 95% (Hohman et al., 2024). These improvements were only possible through interoperable data flows and cross-sector coordination, demonstrating how technical fixes must be matched by governance and capacity.

Flexible interoperability also enables more adaptive surveillance systems. Public health needs differ by disease and geography, requiring systems for real-time syndromic surveillance and granular, county-level chronic disease monitoring (Calman et al., 2012; Dixon, B. E. et al., 2021). An interoperable EHR infrastructure allows public health agencies to tailor their data access needs to specific surveillance goals without sacrificing speed or accuracy.

Some of the most innovative efforts described in the literature integrated EHR data with other emerging surveillance streams, such as wastewater and syndromic surveillance. In one pilot, agencies used computable phenotypes from HIE-sourced EHR data to estimate hypertension prevalence with high sensitivity and positive predictive value (Ghildayal et al., 2024). This cross-stream integration highlights the role of interoperability in building a more comprehensive and resilient surveillance ecosystem.

The findings also point to the need for national policy leadership**.** Experts called on federal agencies to enforce common data standards, fund modernization initiatives, and incentivize vendors to support public health (Dixon, B. E. et al., 2023; Mitchell et al., 2024). Without coordinated, top-down direction and resources, interoperability efforts will progress unevenly.

Workforce & Capacity Building

Modernizing public health surveillance is as much a human challenge as it is a technical one. Across the literature, one theme is consistent: no matter how sophisticated the technology, public health systems cannot function effectively without a well-trained, adequately sized, and diverse workforce to implement, maintain, and interpret it (Dixon, B. E. et al., 2015; LaVenture et al., 2014; Williams et al., 2019). Workforce development emerged as one of the most critical—and most under-resourced—components of public health modernization (Trust for America's Health, 2020, 2023a, 2023b, 2024a, 2024b, 2024c).

The COVID-19 pandemic laid bare the consequences of decades of underinvestment in public health personnel. As agencies faced surging demands, critical gaps in staffing and expertise became apparent, particularly in epidemiology, informatics, and surveillance (Adams et al., 2024; Arrazola & Auer S., 2023). Estimates suggest the U.S. needs more than 80,000 additional public health workers just to meet basic responsibilities (Trust for America's Health, 2024a). This shortfall is particularly acute in smaller jurisdictions, where a single individual may be responsible for multiple programs, leaving little capacity for innovation or strategic data use (DeVore et al., 2016; Dixon, B. E. et al., 2015).

CHAPTER 5: Implications And Recommendations Through A Policy Lens

This dissertation assessed public health data modernization through two complementary aims: (1) a national HIO survey characterizing how HIOs are positioned to support core public health reporting activities, and (2) a scoping review mapping PHDS components across peer-reviewed and grey literature. The first aim illustrated how HIOs' collaborations with state PHAs had uneven implementation of reporting services; there was strong uptake of syndromic surveillance and ELR, mixed adoption for immunization and public/clinical registries, and limited progress on vital records. Reported barriers clustered around PHA capacity (staffing, technical readiness to receive and process messages, competing priorities), with additional constraints related to funding and state legal requirements. The scoping review reinforced the tenets of the PHDS through examining its core components. Themes illustrating the importance of considering policy/governance, workforce, and interoperability as public health data modernizes highlight that HIO utility depends on policy alignment, sustainable financing, PHA workforce/technical capacity, and practical implementation of interoperable standards and equity-centered governance.

Isolated Systems Can No Longer be the Norm

The findings of this dissertation underscore that the future of public health surveillance is as dependent on policy and governance as it is on technical capability. While substantial efforts have been made to modernize public health infrastructure

through the components of the PHDS, realizing the full value of these systems hinges on the policy frameworks that shape data access, stewardship, and collaboration (Centers for Disease Control and Prevention (CDC)., 2013; Dixon, B. E. et al., 2023). The findings also illustrate that no single surveillance tool should operate in isolation. The effectiveness of these tools depends on how well they are integrated through coordinated governance and policy infrastructure. Fragmented policies across pathogen-specific surveillance programs often result in siloed data streams that undermine the situational awareness that public health systems require. Modernization efforts must recognize that surveillance is a systems-level challenge, requiring interoperability between technologies and policy environments. Effective governance should prioritize cross-cutting data architecture and multi-stream surveillance integration as core policy objectives.

In the context of this study's aims, these findings provide critical insight into how HIO–PHA collaborations function in practice and what factors most directly influence the success of modernization initiatives. The findings illustrated that the adoption of PHDS components was generally uneven among HIOs. Syndromic surveillance was the most widely implemented, with the majority of HIOs already participating and others planning to join, suggesting that this use case is maturing and expanding in utility. ELR adoption is also relatively strong but remains uneven, while eCR lags significantly behind, with only a third of HIOs reporting systems in production. These differences underscore a broader theme: adoption of public health reporting services is highly variable, reflecting not just technical readiness but also workforce capacity, governance structures, and resource availability.

Respondents consistently pointed to challenges within state PHAs that extend beyond technology alone. Workforce capacity emerged as another area where policy decisions have direct consequences. Both literature and HIO survey data emphasized that the shortage of trained informatics and data governance professionals is not simply an operational challenge but a policy failure. Inflexible hiring rules, limited pipelines, and short-term funding structures inhibit the recruitment and retention of skilled personnel (DeSalvo et al., 2017; Dixon, B. E. et al., 2023). Modernization cannot succeed without a sustained, adequately resourced workforce, and addressing this gap requires public policy that explicitly links sustainable funding with workforce investment.

The COVID-19 pandemic served as a stress test that exposed how policy fragmentation can obstruct even the most advanced surveillance infrastructure. Despite deploying novel, or scaling up, data tools during the pandemic, many agencies were hindered by outdated laws, unclear data-sharing protocols, and gaps in trust and accountability (Crowley et al., 2023; Lane et al., 2020). These challenges underscore that critical public health surveillance is not merely a function of data collection—it depends on clearly articulated governance policies that determine how, when, and with whom data is shared and allow systems to adapt to a public health emergency.

The findings also suggest that current legal and policy frameworks are insufficiently recognizing or incentivizing the role of HIOs in public health surveillance. Survey data revealed that while HIOs are engaged in reporting services, 66.67% reported supporting ELR in production, and nearly two-thirds (62.86%) of respondents noted that state statutes limited collaboration between PHAs and HIOs to varying degrees. In addition, 68.57% cited

DUAs as at least some barrier to data exchange. These obstacles mirror themes in the literature and reinforce that modernization requires more than technical fixes; it depends on aligned governance, sustainable funding, and adequate staffing to enable meaningful, timely, and equitable public health surveillance. These findings reflect a policy gap. While HIOs offer critical technical capacity, their role in public health remains under-defined in law and under-supported in funding mechanisms.

One of the most salient implications is that policy is both an enabler and a barrier to interoperability. Although many public health agencies and HIOs have the technical readiness to exchange data, inconsistent or restrictive policies undermine these capabilities, particularly regarding DUAs, consent, and statutory authority. Governance misalignment across jurisdictions leads to fragmented access, delays in data sharing, and inequities in public health response (Gamache et al., 2018; Knicely et al., 2024). Without intentional policy harmonization, modernization efforts risk reinforcing historical silos rather than dismantling them. Funding mechanisms further compound these challenges, as short-term funding often restricts agencies to narrow implementation paths that could be misaligned with integrated data exchange goals. Long-term, more flexible funding policies tied to interoperability outcomes are critical for building durable, cross-jurisdictional data infrastructure. This shift represents a fundamental change in public health, moving from fragmented, reactive systems to a coordinated, data-driven enterprise. However, it is an essential evolution for meeting the demands of 21st-century public health. To support this transformation, federal, state, and local policies must

explicitly recognize and strengthen the legal authorities of public health agencies to access, use, and govern data across partners and systems.

Future Research Recommendations

These findings highlight areas where future research can further inform data modernization policy development. Firstly, future research should critically examine whether HIOs are the most effective pathway for modernizing public health data exchange, especially given that many have not yet demonstrated consistent or scalable use cases. Future studies are needed to assess the technical capacity of HIOs, but also their governance models and their ability to align with public health priorities. More research is needed to ascertain how HIOs can support public health's interoperability challenges. Without this evidence base, it remains uncertain whether public health-related investments in HIOs represent the best long-term strategy, or if alternative approaches may offer greater value. For example, comparative analyses of state-level governance models are needed to understand how different legal environments influence the success of HIO–PHA collaborations. Research should examine how state frameworks can be leveraged or restructured to improve public health delivery by explicitly incorporating HIOs as trusted partners in surveillance and reporting. A systematic review of statutory language, reporting mandates, and DUA frameworks could identify common legal barriers to HIO participation—such as overly narrow public health authority definitions or outdated provisions—and produce a typology of governance approaches that help federal and state actors align legal infrastructure with modernization goals. Similarly, research is needed on how governance frameworks are implemented in practice. While many jurisdictions have

adopted data sharing agreements and advisory structures, their influence on data sharing remains under-evaluated. Case studies and qualitative research could yield practical insights into what governance structures promote speed, equity, and accountability in data exchange (Kadakia et al., 2021).

Funding as a policy construct, particularly funding through the CDC's Public Health Data Strategy (PHDS) and the Data Modernization Initiative (DMI), continues to shape local infrastructure. There is a pressing need to assess how policy conditions tied to this funding affect long-term sustainability. Research should examine performance metrics and how policy affects governance capacity, equity considerations, and state-level implementation. Similarly, equity-focused research is essential. Surveillance modernization must not exacerbate existing disparities. Researchers should examine how policy decisions impact data access and participation across rural, tribal, and historically underserved communities, focusing on identifying governance structures that promote data equity (Gluskin et al., 2014; Liao et al., 2020).

Future investigators should explore how workforce-related policies—such as hiring practices, training mandates, and intergovernmental workforce coordination—contribute to or inhibit modernization; studies could assess how policy tools (e.g., fellowships, pay parity, credentialing systems) affect workforce readiness and diversity (DeSalvo et al., 2017; Mishra et al., 2021). Workforce modernization must be understood as a cross-sector effort, not limited to internal staffing within public health agencies. Future research should examine how policy can enable and sustain partnerships that span public health, HIOs, health care providers, and private-sector data entities. These partnerships are essential for

leveraging HIO expertise in data standardization, infrastructure design, and governance. Public health modernization depends on building internal capacity and establishing long-term, trusted collaborations with external partners. Research should explore how policy mechanisms can be used to structure, finance, and institutionalize these partnerships in support of a more interoperable and resilient public health data ecosystem.

The prioritization of privacy and security in public health data systems also carries significant implications for research. As modernization efforts expand data collection and integration across sectors, researchers must examine how privacy protections, legal safeguards, and ethical governance are operationalized in real-world practice. This includes studying how PHAs manage data access, apply data use policies, and navigate tensions between data utility and individual rights. Understanding how privacy and security are upheld –or where gaps persist –can inform more effective policies and highlight opportunities for strengthening public trust. Research that critically assesses the implementation of privacy-preserving practices, particularly in high-risk or resource-limited settings, is essential to ensuring that modernization efforts do not unintentionally compromise the very communities they aim to support.

Future research should also examine how different surveillance tools intersect and how policy either facilitates or obstructs this integration. Most existing studies assess ELR, eCR, or syndromic surveillance in isolation, but there is limited analysis of how policies enable these systems to work together in practice. For instance, conflicting reporting mandates, redundant data requests, or siloed funding streams can lead to inefficiencies and duplication. Research is needed to identify governance models that support multi-

stream data fusion and to develop policy frameworks that incentivize coordinated use of surveillance systems for maximal public health insight. In parallel, future investigations should explore how existing silos across surveillance systems—driven by legacy infrastructures, categorical funding, and fragmented authority—can be dismantled through policy and governance reform; this includes assessing how to align statutory requirements, standardize data flows, and consolidate reporting structures to improve cross-system interoperability. Additionally, research should evaluate how cross-sector partnerships, particularly with HIOs and health care data intermediaries, can be formally integrated into public health modernization strategies. Leveraging HIO expertise in system architecture, data exchange, and information governance will be essential to building an interconnected, sustainable, and adaptable ecosystem to future public health needs.

As the U.S. public health system modernizes, artificial intelligence (AI) and machine learning (ML) offer significant opportunities to enhance surveillance, forecasting, and decision-making by automating data processing, identifying trends in real-time, and generating predictive insights across systems (Miller, 2024; Nong et al., 2025). Nonetheless, AI and ML integration must be governed by strong legal, ethical, and technical safeguards. Future research should clarify accountability and transparency requirements through governance models that ensure AI tools are interpretable, equitable, and trusted—while also prioritizing ethical safeguards to prevent the reinforcement of structural inequities, violations of privacy, or opaque decision-making that could undermine population health outcomes (Dankwa-Mullan, 2024; McCradden et al., 2020). Policies must also address data quality and interoperability challenges, supporting shared

infrastructure across healthcare and public health sectors and jurisdictions to enable robust, real-world use of AI models (Duke-Margolis Center for, 2024; Rahimzadeh, 2024). Ultimately, AI and ML should not replace the public health workforce but should be embedded into modernization efforts through deliberate policy frameworks that consider long-term sustainability, support equitable outcomes, and strengthen public trust.

Policy Implications for Public Health Practice

The policy implications of this dissertation's findings extend directly to public health practice. Policy and governance must be embedded into system design. Health departments should adopt and institutionalize clear governance policies, such as pre-negotiated DUAs, statewide data frameworks, and cross-sector data stewardship boards. These structures are critical for ensuring that modernization efforts are scalable, secure, and aligned with public trust.

PHAs should proactively engage policymakers and HIOs to develop formalized roles for HIOs in surveillance operations, particularly as some HIOs evolve toward functioning as HDUs. These roles could be codified through statutory mandates, joint funding agreements, or shared governance structures that reflect the utility-like nature of their services. Such instruments would help normalize, sustain, and appropriately resource the contributions of HIOs/HDUs to core public health functions, including real-time data exchange, analytics, and bidirectional reporting. As HDUs, these entities can serve as neutral, infrastructure-oriented partners that support multiple stakeholders while advancing interoperability and equity-driven data modernization goals.

Public health leaders must elevate workforce development as a core policy priority across all levels of government. At the federal level, sustained investment is needed to create funding streams that support public health informatics training programs. State governments are critical in aligning training with jurisdiction-specific needs, coordinating credentialing and hiring pathways, and addressing salary disparities that often hinder recruitment and retention. Meanwhile, local health departments must be empowered—with both funding and policy flexibility—to upskill their current workforce, enabling staff to adopt new tools, interpret complex data, and contribute meaningfully to modernization efforts.

Workforce development must also extend beyond public health agencies. Embedding public health expertise within the broader health informatics ecosystem is essential to ensure that systems are technically robust and aligned with public health goals. As public health surveillance systems increasingly incorporate data from sectors such as utilities, health care, and technology, it is critical that non–public health professionals—such as wastewater engineers, IT vendors, and HIE administrators—understand the public health value of the data they manage. For example, realizing the full potential of wastewater surveillance requires that utility personnel be trained in sampling and analytics, public health interpretation, and operational use of the data.

Data modernization should be leveraged as a strategic policy instrument to align legal, technical, and social systems around a shared vision of public health equity. This effort must go beyond infrastructure upgrades to ensure data is used ethically, securely, and solely for legitimate and clearly defined public health purposes. Privacy protections,

robust data governance, and transparency must be foundational—not afterthoughts—to build and maintain public trust.

Responsible data modernization requires policy frameworks operationalizing core principles—privacy, security, ethical use, and equity at every level of the data ecosystem. This includes establishing clear guardrails on how data is collected, shared, and applied, and mechanisms to ensure that benefits are equitably distributed and risks are actively mitigated. Data modernization risks reinforcing existing inequities and eroding public trust without such intentional governance. However, with it, the U.S. can build a public health data infrastructure that is technically advanced, socially accountable, and ethically sound.

For PHAs, recognizing the interconnected nature of surveillance tools must translate into integrated operational and policy frameworks. Moving away from siloed, program-specific governance toward shared oversight structures will enable more dynamic and comprehensive data use. For example, linking syndromic trends with lab confirmations and case reports can generate more timely and actionable insights, but only if policies enable shared infrastructure, legal interoperability, and cross-program data exchange. In practice, this requires the development of unified reporting strategies, shared governance bodies, and policy frameworks that support the collective utility of all surveillance assets as part of an equitable, coordinated public health data ecosystem.

Realizing the promise of the CDC's PHDS requires more than alignment; it demands sustained action to embed its goals into policy, practice, and funding. Future public health initiatives must move beyond short-term fixes to institutionalize the lessons of COVID-19, ensure public health capitalizes on advances, especially interoperability, in the health care

sector, and close long-standing policy and infrastructure gaps. Bridging these divides is essential to building a resilient, integrated, and equitable data ecosystem; a system that empowers public health agencies to act quickly, collaborate effectively, and deliver on the full potential of modernization.

Reflexivity Statement

As a public health professional, I entered this research with a longstanding interest in surveillance and data systems. Still, I had only recently moved into a career focused on data modernization policy. This shift gave me a fresh perspective and a growing appreciation for the complexity and urgency of modernizing public health infrastructure. Throughout writing this dissertation, I was particularly drawn to emerging tools like wastewater surveillance, which are still evolving but offer exciting possibilities for real-time, population-level insights. There were many points at which I wanted to include the new and innovative developments in the findings. Still, I had to make deliberate choices to limit the scope and maintain analytical clarity. While the study was intentionally broad, I quickly realized the importance of tightening the frame and following consistent parameters to ensure focus and coherence.

This was often challenging, especially given how much innovation happens in weakly documented ways. Advances in tools, like molecular surveillance, represent important components of the public health surveillance ecosystem. Still, many fall outside the bounds of academic publishing or lack the standardization necessary for inclusion in a structured review. Their absence in my dissertation is not a reflection of their irrelevance, but instead of the limitations imposed by what is currently accessible and searchable

through traditional academic channels. Similarly, we cannot abandon things that we know work but need to be built to scale or their application broadened. For example, HIV surveillance activities capitalize on advances across health care to improve prevention and surveillance approaches.

I also had to navigate the boundary between what I know from my professional role and what the literature could support. At times, I found myself battling between practice-based knowledge and the need for documented, citable sources. It became clear that traditional journal publications are only one way knowledge is produced and shared in this field, and not always the fastest or most inclusive. There is a great deal of valuable, ongoing work that is either unpublished or communicated through informal networks, and part of the reflexive challenge was acknowledging that gap while keeping the study grounded in what could be systematically analyzed.

This experience underscored the need for more dynamic, real-time mechanisms to document and disseminate public health innovation, particularly as the field evolves faster than traditional academic publishing can keep pace. While this dissertation captures only a snapshot of that rapidly shifting landscape, it aims to contribute to the growing body of work advocating for a more interconnected, timely, and practice-informed approach to public health data modernization. By bridging research, policy, and real-world implementation, I hope this work supports ongoing efforts to reimagine how public health systems adapt, share, and respond in an increasingly data-driven environment.

Limitations and Strengths

As with any mixed-methods research effort, this study is subject to several limitations that may affect the interpretation and generalizability of its findings. While care was taken to ensure methodological rigor across the study, certain limitations should be acknowledged. Recognizing these limitations is essential for understanding the scope of the study and identifying areas where further research is needed.

A single reviewer conducted the scoping review, which may have introduced selection bias during screening and data extraction. Although efforts were made to follow the PRISMA-ScR framework rigorously, it is standard practice to use at least two independent reviewers to improve reliability, ensure consistency in applying inclusion criteria, and minimize subjectivity in data interpretation. While the scoping review aimed to provide a comprehensive view of the current environment of public health data modernization through the lens of the CDC's PHDS, the broad scope limited the ability to explore any one component of the strategy deeply. Furthermore, the PHDS component related to hospital bed capacity data was excluded from this study due to feasibility constraints associated with broadening the scope of analysis. A more narrowly focused study could have enabled deeper analysis of the most pressing challenges and distinctive issues associated with each public health surveillance tool, helping to better identify where modernization efforts should be prioritized. This study serves as a valuable first step in contextualizing progress and offers a holistic view of the current public health data modernization landscape.

This study draws on primary data from a national survey of HIOs to examine their collaboration with PHAs, focusing on surveillance-related services and barriers. The survey, collaboratively developed by UCSF and ASTP and administered via Civitas Networks for Health, aimed to provide a comprehensive snapshot of HIO capabilities, HIE coverage, and perceptions of regulatory and interoperability challenges. Among the 76 HIOs that responded, 37 identified a state entity as their primary public health partner. However, the scale and ambition of the survey effort may have come at the expense of analytic depth. By focusing on HIOs that identified a state entity as their primary PHA, the study offers insights into how HIOs currently support state-level public health surveillance and where challenges persist. Although the data offer a valuable starting point for understanding adoption trends and systemic barriers, a more narrowly scoped study focused on PHA-related issues with HIOs could have enabled deeper exploration of the unique challenges associated with specific surveillance tools or policy levers. This limitation is compounded by the small sample size, which limits generalizability, and the findings may not be generalizable given the diverse experiences of HIOs nationwide. It's important to note that some states noted working with several states in data not analyzed for this study, which could make it difficult to truly ascertain the true picture of HIO/PHA collaborations. Participation bias is also possible, as HIOs with more mature infrastructure or stronger relationships with public health may have been more likely to respond. The study relied on self-reported data, which is inherently susceptible to recall error, interpretation variance, and social desirability bias.

Additionally, because the survey captured only one response per HIO, it may not fully reflect the range of perspectives within each organization. Staff at different levels—such as technical leads, policy directors, or frontline implementation teams—may hold distinct views on collaboration with public health agencies, data sharing challenges, and modernization priorities. This limitation could result in an incomplete understanding of internal variation within HIOs. These factors suggest that while the study provides a useful landscape-level view, further research is needed to unpack specific implementation challenges in greater detail. A more narrowly focused survey or a smaller-scale qualitative inquiry might have enabled deeper exploration of the unique issues and priorities within specific public health surveillance tools, offering clearer insight into where modernization efforts should focus first. Nonetheless, this study represents a valuable first step in holistically assessing the field and informing future policy and interoperability strategies.

This research engaged with key federal policies and strategies but did not systematically examine the influence of state-specific policies or programs. These contextual factors play a critical role in shaping the feasibility and implementation of data sharing between HIOs and federal and STLT PHAs. State-level legal frameworks, resource allocations, and governance structures vary widely and may enable or obstruct collaboration and interoperability. For example, organizations such as CRISP, Maryland's state-designated HIE, and an emerging HDU, demonstrate how state- or regionally governed HIOs can strategically advance data modernization and public health integration. However, such models are not uniformly adopted across states, and a more granular,

jurisdiction-specific analysis is needed to understand how these structures support or hinder public health surveillance efforts.

Moreover, the modernization of public health data is a rapidly evolving field. New technical standards, shifts in funding priorities, and emerging governance models continue to reshape the landscape in real time. As these developments unfold—including the expansion of HDUs and the evolution of cross-sector partnerships—some of the findings presented in this study may become outdated or require reinterpretation. Compounding this challenge, there is a chance that the most innovative or operationally relevant work in this space has not yet been published or is poorly represented in peer-reviewed or grey literature. This creates blind spots in our collective understanding of what models work, at what scale, and under what conditions. To keep pace with the field, future efforts must prioritize both the publication of practice-based insights and the development of alternative mechanisms—such as public dashboards, implementation case studies, or structured interviews with state and regional actors—to capture and disseminate lessons learned in near real time.

Conclusion

The implications are clear: modernization cannot be achieved through technology alone, nor through policy divorced from state PHA's real-world implementation capacity. Policy must be rooted in practice, ensuring that governance frameworks, statutory authorities, and funding mechanisms directly address the day-to-day capacity constraints of PHAs. These practical considerations, such as staffing shortages, uneven technical

readiness, and competing priorities, are where modernization efforts often falter, highlighting the need for policy to respond to operational realities on the ground.

HIOs can play an important role in supporting modernization, but their effectiveness depends on alignment with public health priorities, interoperable infrastructure, and sustainable investment in people and systems. By bridging policy vision with practical implementation, public health can move toward a more resilient, integrated, and equitable data ecosystem; one capable of supporting both routine surveillance and rapid response to emerging threats. Looking ahead, future research will be critical to clarifying how governance models, funding structures, and technical partnerships can best be leveraged so that the CDC's PHDS and broader DMI efforts translate into sustainable, scalable improvements for public health practice.

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Appendix

Appendix A: Scoping Review of CDC's Public Health Data Strategy

Authors, Year, & Title	Document Type	PHDS Thematic Components	Objective(s)	Approach	Key Findings
Katz R; May L; Baker J; Test E (2011). Redefining syndromic surveillance	Journal Article	Syndromic Surveillance; Data Modernization	Clarify definitions and categories of syndromic surveillance systems (specific vs non-specific detection)	Literature review of publications and conference summaries	Syndromic surveillance definitions vary widely, creating confusion in implementation and evaluation; five key principles common across definitions identified; proposed typology distinguishes syndrome-specific from non-specific systems; clear definitions can improve system design, resource allocation, and adoption, particularly in low- and middle-income countries.
AMIA Public Health Informatics Conference participants (2012). Informatics agenda for public health: revisiting and updating priorities	Conference Summary	Public Health Workforce & Capacity Building	Update priorities; enhance workforce; advance interoperability and data standards; redefine research and investment strategies	Expert panels, stakeholder discussions, consensus-building at national conference	Workforce capacity remains a challenge; interoperability improvements needed; new tools emerging (social, mobile)
Calman N; Hauser D; Lurio J; Wu WY; Pichardo M (2012). Strengthening public health and primary care collaboration through electronic health records	Journal Article	Interoperability	Describe how EHRs can strengthen collaboration between primary care providers and public health through shared data and alert systems	Narrative case study across two health care networks with EHR-based alert implementation	EHR integration led to real-time clinical alerts aligned with public health goals, improving early intervention for influenza-like illness, HIV testing, etc.
Kass-Hout, T.A.; Buckeridge, D.; Brownstein, J.; Xu, Z.; McMurray, P.; Ishikawa, C.K.T.; Gunn, J.; Massoudi, B.L. (2012). Self-reported fever and measured temperature in emergency department records used for syndromic surveillance	Journal Article	Syndromic Surveillance	Compare utility of self-reported fever vs. measured temperature in ED-based syndromic surveillance	Quantitative analysis of ED records using BioSense data; kappa statistics; descriptive stats	Most patients with measured fever also reported fever, but few with self-reported fever had measured fever; measured temperature rarely recorded

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Lenert L; Sundwall DN (2012). Public Health Surveillance and Meaningful Use Regulations: A Crisis of Opportunity	Journal Article	Data Modernization; Syndromic Surveillance; Policy & Governance	Examine the readiness of public health systems for Meaningful Use data exchange under HITECH	Policy analysis with supporting survey data from 2011–2012; analysis of Healthcare IT policy requirements	Findings highlight significant gaps in public health IT systems and funding; recommend large-scale use of cloud services to enable scalable and cost-effective data exchange
Brian E. Dixon, MPA, PhD; Jason A. Siegel, MD; Tanya V. Oemig; Shaun J. Grannis, MD, MS (2013). Electronic Health Information Quality Challenges and Interventions to Improve Public Health Reporting	Journal Article	Policy & Governance	To evaluate and enhance the completeness of race and ethnicity fields in ELR data through structured interventions	Observational study with pre-post intervention design; data quality audits	Improved completeness in key demographic fields; demonstrated practical, scalable improvements in ELR data quality
CDC (2013). Progress in Increasing Electronic Reporting of Laboratory Results to Public Health Agencies — United States, 2013	Journal Article	electronic Lab Reporting	Track national progress on adoption of electronic lab reporting (ELR) to public health agencies	Descriptive summary based on CDC national ELR data collection and state/jurisdiction self-reports	As of July 2013, 62% of laboratory reports were sent electronically (up from 54% in 2012); major gaps remained among commercial and hospital labs; funding and technical capacity were key factors influencing implementation
Conway M; Dowling JN; Chapman WW (2013). Using Chief Complaints for Syndromic Surveillance: A Review of Chief Complaint Based Classifiers in North America	Journal Article	Syndromic Surveillance	Review classification systems using chief complaints at city, county, state, and federal levels in North America	Narrative review of 15 North American systems using chief complaint data	Identified variance in classifier types (keyword, Bayesian, hybrid); emphasized chief complaints as a near-ubiquitous, timely data source; noted lack of standard vocabularies and variability in performance
Dixon, B. E.; Lai, P. T. S.; Grannis, S. J. (2013). Variation in information needs and quality: implications for public health surveillance and biomedical informatics	Conference Summary	Data Modernization	Understand variation in public health data needs and quality across jurisdictions	Survey—distributed to public health professionals across multiple jurisdictions	Found variation in data needs by disease type; county data seen as essential; systems must be flexible/configurable to user needs
Friedman DJ; Parrish RG; Ross DA (2013). Electronic Health Records and US Public Health: Current Realities and Future Promise	Journal Article	Policy & Governance	Describe current use and future potential of EHRs for population health surveillance and public health practice	Narrative review of literature, policy analysis, and expert synthesis	Identified opportunities (disease tracking, population insights) and barriers (coverage gaps, data standards, legal frameworks); called for national coordination to realize EHR public health potential
Smith PF; Hadler JL; Stanbury M; Rolfs RT; Hopkins RS; CSTE Surveillance Strategy Group (2013). Blueprint version 2.0: Updating Public Health Surveillance for the 21st Century	Journal Article	Syndromic Surveillance; Data Modernization; Public Health Workforce & Capacity Building	Update surveillance strategies to reflect new information technologies, health care reform, and preparedness needs	Literature review and expert consensus during CSTE-led meeting	Public health professionals applied evaluation, tech, and training lenses to update surveillance framework

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Travers D, Haas SW, Waller AE, Schwartz TA, Mostafa J, Best NC, Crouch J. (2013). Implementation of Emergency Medical Text Classifier for Syndromic Surveillance	Journal Article	Syndromic Surveillance	To describe the development and implementation of a text classifier for emergency medical data to support syndromic surveillance.	Classifier development using natural language processing and statistical learning methods.	The classifier effectively identified relevant syndromic information from free-text emergency department chief complaints.
Dixon BE, Vreeman DJ, Grannis SJ (2014). The long road to semantic interoperability in support of public health: Experiences from two states	Journal Article	Syndromic Surveillance / Interoperability	Describe two-state experiences in implementing semantic interoperability for public health surveillance; propose strategic approaches	Narrative case study/essay with qualitative policy and technical analysis	Lack of consistent use of available standards; fragmented policies; need for collaborative national strategy
Dixon, B. E.; Gibson, P. J.; Grannis, S. J. (2014). Estimating Increased Electronic Laboratory Reporting Volumes for Meaningful Use: Implications for the Public Health Workforce	Journal Article	electronic Lab Reporting	Provide formulas to predict ELR volume increase from meaningful use	Quantitative analysis of ELR transaction data	Public health agencies may see >2× increase in notifiable disease reports; ELR volume varies by facility type and bed count; planners can estimate workload
Edmunds M; Thorpe LE; Sepulveda M; Bezold C; Ross DA (2014). The Future of Public Health Informatics: Alternative Scenarios and Recommended Strategies	Journal Article	Public Health Workforce & Capacity Building	Develop future-oriented strategic priorities to strengthen PHI systems and capacity	Scenario-based expert workshop with thematic synthesis of recommendations	Emphasized need for: intersectoral collaboration, investment in informatics infrastructure, evidence-building, effective communication with policymakers, and workforce development
Foldy S; Grannis S; Ross D; Smith T (2014). A Ride in the Time Machine: Information Management Capabilities Health Departments Will Need	Editorial/Perspective/ Commentary	Data Modernization	Identifies key trends (EHRs, cloud, interoperability, syndemics, public engagement) and proposes 10 core informatics capabilities for health departments	Commentary	Expert-informed commentary; synthesis of ACA trends, informatics literature, and informatics think tank discussions
Gluskin RT; Mavinkurve M; Varma JK (2014). Government leadership in addressing public health priorities: strides and delays in electronic laboratory reporting in the United States	Journal Article	electronic Lab Reporting	Review U.S. ELR adoption, highlight NYC DOHMH experience, identify successes/barriers in surveillance using ELRs	Mixed-methods: literature review, interviews, national survey analysis	ELRs reduced report delays by avg 8.5 days (range 4–17); increased case volume (e.g., +76% Salmonella); adoption in >80% states by 2011; challenges include data overload, false positives, infrastructure costs ($221k–633k/year), workforce skill gaps, standards and interoperability issues
Haas SW; Travers D; Waller A; Mahalingam D; Crouch J; Schwartz TA; Mostafa J (2014). Emergency Medical Text Classifier: New system improves processing and classification of triage notes	Journal Article	Syndromic Surveillance	Create and evaluate an automated triage-note classifier for ED syndromic surveillance	Vector-space model + pseudo-relevance feedback on triage note text	Improved sensitivity and specificity across syndromes: GI ≈ 90/71%, respiratory ≈ 97/73%, fever-rash ≈ 100/87% in test set 1; similar in test set 2.

Authors, Year, & Title	Document Type	PHDS Thematic Components	Objective(s)	Approach	Key Findings
Howland RE, Madsen AM, Nicaj L, Noe RS, Casey-Lockyer M, Begier E (2014). Assessing Electronic Death Registration and American Red Cross Systems for Mortality Surveillance During Hurricane Sandy, October 29–November 10, 2012, New York City	Journal Article	Policy & Governance	Evaluate and compare the utility of EDRS and Red Cross systems for identifying disaster-related mortality; assess data completeness, accuracy, and timeliness	Retrospective data analysis and case matching using decedent identifiers; review of variable completeness and concordance	EDRS provided more complete and timely records; Red Cross added contextual details on evacuation decisions; joint use improved data completeness
LaVenture M; Brand B; Ross DA; Baker EL (2014). Building an Informatics-Savvy Health Department: Part I, Vision and Core Strategies	Journal Article	Data Modernization; Public Health Workforce & Capacity Building	Establish vision, governance, and infrastructure for informatics-savvy health departments	Conceptual model; framework informed by practice experience (e.g., Minnesota Dept. of Health, PHII tools)	Presents a foundational model emphasizing leadership vision, governance, and dedicated informatics roles; calls for embedding informatics into strategic priorities
Revere, D.; Dixon, B.E.; Whipple, E.C.; Dexter, P.R. (2014). Leveraging Health Information Exchange to Improve Population Health Reporting Processes: Lessons in Using a Collaborative-Participatory Design Process	Journal Article	Interoperability	To improve population health reporting by applying collaborative, participatory design principles to health information exchange systems.	Participatory design framework; qualitative methods; iterative refinement.	Collaborative and participatory methods helped identify and address gaps in HIE utility for public health reporting.
Sepúlveda O (2014). Public health informatics and the public health workforce in an era of change	Editorial/Perspective/ Commentary	Public Health Workforce & Capacity Building	Highlight changes needed in public health informatics workforce		Editorial critique of workforce preparedness. As informatics becomes integral to public health practice, the workforce must develop new competencies through targeted training and education; cross-sector collaboration is essential to maximize the benefits of data and technology innovations.
Dixon BE; Kharrazi H; Lehmann HP (2015). Public Health and Epidemiology Informatics: Recent Research and Trends in the United States	Journal Article	Data Modernization; Interoperability; Public Health Workforce & Capacity Building	Survey recent advances in public health and epidemiology informatics and their support of Essential Public Health Services	Thematic literature review of MEDLINE-indexed articles combined with Essential Services framework	Found broad growth in PH informatics, notably in monitoring and analysis, but noted that many services lagged (e.g., use of social media, certification); identified reliance on policies, workforce training, infrastructure, research, and funding to underpin systems
Dixon BE; McFarlane TD; Dearth S; Grannis SJ; Gibson PJ (2015). Characterizing Informatics Roles and Needs of Public Health Workers: Results From the Public	Journal Article	Public Health Workforce & Capacity Building	Understand the role, training needs, and characteristics of public health informatics (PHI) workers in state health agencies	Cross-sectional analysis of 2014 PH WINS survey data from 10,246 state health agency central office employees	Only 1.3% of state health workers identified as PHI specialists; PHI workers were younger and more mission-driven, but earned less and had fewer leadership roles; significant training gaps identified across groups

Authors, Year, & Title	Document Type	PHDS Thematic Components	Objective(s)	Approach	Key Findings
Health Workforce Interests and Needs Survey					
Guthrie S. Birkhead, M. Klompas, N. R. Shah (2015). Uses of Electronic Health Records for Public Health Surveillance to Advance Public Health	Journal Article	Data Modernization	To describe the current state of EHR-based surveillance, identify barriers, and propose a research agenda for advancing public health surveillance through EHRs	Review of literature and case examples (ESPnet, MU program)	Highlights opportunities to enhance timeliness, completeness, and scope of surveillance using EHRs; identifies challenges like standardization and resource needs
Seil K, Marcum J, Lall R, Stayton C (2015). Utility of a near real-time emergency department syndromic surveillance system to track injuries in New York City	Journal Article	Syndromic Surveillance	Develop six injury syndromes based on chief complaint and compare with billing data to evaluate ED SS utility	Comparative analysis of syndromic ED chief complaint data vs administrative billing data (2008–2010), using correlation and descriptive statistics	Key findings: ED SS reliably captured temporal trends ($r > 0.65$), time-of-day, sex, age patterns; neighborhood-level agreement varied
Zhou, H.; Burkom, H.; Winston, C.A.; Dey, A.; Ajani, U. (2015). Practical comparison of aberration detection algorithms for biosurveillance systems	Journal Article	Syndromic Surveillance	To evaluate performance of different aberration detection algorithms for public health biosurveillance.	Comparative performance testing using synthetic data and real syndromic surveillance records	No single algorithm consistently outperformed others: multiple-method approaches may enhance surveillance effectiveness.
DeVore K; Chughtai S; Kan L; Streichert LC (2016). Workforce Competencies in Syndromic Surveillance Practice at Local Health Departments	Journal Article	Public Health Workforce & Capacity Building	Assess proficiency of local health department (LHD) staff in syndromic surveillance tasks to identify training needs	Cross-sectional national survey using Biosurveillance Needs Assessment Survey; weighted for representation	<50% of practitioners proficient in any task; data use strongest (~60%), system development lowest (~10–20%); proficiency correlated with experience and LHD size
Shah GH, Leider JP, Luo H, Kaur R (2016). Characteristics of Local Health Departments Associated With Implementation of Electronic Health Records and Other Informatics Capabilities	Journal Article	Public Health Workforce & Capacity Building	Identify characteristics of LHDs associated with implementation of EHRs, HIE, and other informatics capabilities	Cross-sectional study using 2013 NACCHO National Profile of Local Health Departments survey data	Implementation of EHRs and other informatics capabilities was significantly associated with governance type, jurisdiction population size, and workforce composition
William R. Mac Kenzie et al. (2016). The Promise of Electronic Case Reporting	Editorial/Perspective/ Commentary	Electronic Case Reporting, Interoperability, Policy & Governance, Data Modernization	Advance nationwide implementation of eCR; improve case reporting timeliness, completeness, and efficiency	Perspective and framework development based on agency collaborations and pilot projects	eCR promises better surveillance and disease prevention; success depends on interoperability, shared governance, and incremental implementation
Daly ER; Fredette C; Mathewson AA; Dufault K; Swenson DJ; Chan BP (2017). Tick Bite and Lyme Disease–Related Emergency Department Encounters in the United States, 2010-2014	Journal Article	Syndromic Surveillance	Characterize national patterns in emergency department (ED) encounters related to tick bites and Lyme disease to inform public health education, prevention, and resource allocation	Retrospective analysis of ICD-9-CM coded ED data from a nationally representative dataset	Tick bite ED visits were most common among children aged 0–9; Lyme disease visits peaked in adults aged 15–59 and were concentrated in high-incidence states; seasonal peaks occurred during warmer months

Authors, Year, & Title	Document Type	PHDS Thematic Components	Objective(s)	Approach	Key Findings
Fleischauer AT; Gaines J (2017). Enhancing Surveillance for Mass Gatherings: The Role of Syndromic Surveillance	Journal Article	Syndromic Surveillance; Public Health Workforce & Capacity Building	Finds that pre-existing surveillance infrastructure and trained staff are essential; new data streams (e.g., mobile apps) can enhance situational awareness	Descriptive analysis of CDC field experiences supporting syndromic surveillance during mass gatherings	Effective mass gathering surveillance relies on robust pre-existing syndromic systems, trained epidemiologists, and interagency coordination; integration of emerging data streams such as mobile applications can improve situational awareness; sustainable infrastructure and advance planning are critical for timely detection and response.
Kharrazi, H.; Lasser, E. C.; Yasnoff, W. A.; Loonsk, J.; Advani, A.; Lehmann, H. P.; Chin, D. C.; Weiner, J. P. (2017). A Proposed National Research and Development Agenda for Population Health Informatics: Summary Recommendations From a National Expert Workshop	Journal Article	Data Modernization	Develop a national Research and design agenda for population health informatics; identify research domains and priorities	Consensus-building expert workshop with a structured priority-setting approach	Identifies foundational research areas needed to advance population health informatics infrastructure and practice
Leider JP; Shah GH; Williams KS; Gupta A; Castrucci BC (2017). Data, Staff, and Money: Leadership Reflections on the Future of Public Health Informatics	Journal Article	Policy & Governance	Identify leadership perspectives on barriers to implementing informatics in public health agencies (funding, staffing, data access)	Qualitative key informant interviews and thematic analysis	Leadership cited lack of staff capacity and funding as top barriers; need for strategic informatics leadership roles (executive/translator/professional/clinical); reliance on state systems in smaller agencies
Lucero-Obusan C, Schirmer PL, McCarthy NL, Winston CA, Oda G, Holodniy M. (2017). Enhanced Influenza Surveillance Using Telephone Triage and Electronic Syndromic Surveillance in the Department of Veterans Affairs, 2011–2012	Journal Article	Syndromic Surveillance	To assess the utility of telephone triage and electronic syndromic surveillance data for influenza monitoring in the Veterans Health Administration (VHA) during the 2011–2012 season	Quantitative analysis of syndromic surveillance and call center data from the VHA	Findings demonstrated that VA syndromic surveillance and telephone triage data could effectively supplement traditional influenza surveillance, identifying ILI trends like CDC reports. Peaks in VA data often preceded CDC outpatient data.
Revere, D.; Hills, R. H.; Dixon, B. E.; Gibson, P. J.; Grannis, S. J. (2017). Notifiable condition reporting practices: implications for public health agency participation in a health information exchange	Journal Article	Interoperability	Assess current reporting practices; identify barriers and facilitators to electronic case reporting via HIEs	Descriptive survey and semi-structured interviews (mixed methods) across 7 clinics and 3 public health agencies	Clinic reporters experience reporting burden and lack feedback; incomplete/missing information leads to delays; PHAs face challenges with unstructured data
Richardson MJ; Van Den Eeden SK; Roberts E; Ferrara A; Paulukonis S; English P (2017). Evaluating the Use of Electronic	Journal Article	electronic Lab Reporting	Evaluate validity of using ELR/EHR for type 2 diabetes surveillance; assess disparities by income, race, geography	Validation study comparing lab threshold to clinical diagnosis; combined	EHR HbA1c (≥6.5%) had 87.4% sensitivity and 99.2% specificity; prevalence inversely related to income

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Health Records for Type 2 Diabetes Surveillance in 2 California Counties, 2010–2014				lab data with census-tract demographics	and higher among NH-Black and Hispanic populations
Tabano DC; Cole E; Holve E; Davidson AJ (2017). Distributed Data Networks That Support Public Health: Lessons Learned From the Beacon Communities	Journal Article	Interoperability; Policy & Governance; Data Modernization	Explore the role of distributed data	Descriptive case studies across multiple Beacon Communities, including qualitative synthesis of lessons learned	Emphasized importance of strong governance, stakeholder trust, reusable technical infrastructure, and cross-sector collaboration for scaling data sharing
White J.R.; Berisha V.; Lane K.; Ménager H.; Gettel A.; Braun C.R. (2017). Evaluation of a Novel Syndromic Surveillance Query for Heat-Related Illness Using Hospital Data From Maricopa County, Arizona, 2015	Journal Article	Syndromic Surveillance	Evaluate the CSTE Heat Syndrome Workgroup's novel query vs. standard BioSense query in identifying heat-related illness	Mixed-methods validation: chief complaint + diagnosis code against chart review to calculate PPV	CSTE query: 88% PPV (591/674); BioSense query: 74% PPV; during heat season PPVs were 92% vs. 85% respectively
Garcia MC; Garrett NY; Singletary V; Brown S; Hennessy-Burt T; Haney G; Link K; Tripp J (2018). An Assessment of Information Exchange Practices, Challenges, and Opportunities to Support US Disease Surveillance in 3 States	Journal Article	Interoperability	Understand current practices in collecting/managing/reporting and exchanging notifiable disease surveillance data in CA, WA, MA	Semi-structured assessment via site visits and interviews in three states, process mapping, descriptive comparison	All states used both paper and electronic systems; non-interoperable systems led to duplicated entry and inefficiencies; manual workarounds common
Lee B; Martin T; Khan A; Fullerton K; Duck W; Kinley T; Stoutenburg S; Hall J; Crum M; Garcia MC; Iademarco MF; Richards CL (2018). Modernizing CDC Informatics Using Surveillance Data Platform Shared Services	Journal Article	Data Modernization; Interoperability; Policy & Governance	Streamline and integrate CDC surveillance systems via a common, modular platform based on shared services	Descriptive article; internal case study of strategic planning and early implementation at CDC	Highlights the value of reusable components and standards to improve interoperability, reduce burden, and increase scalability for emergency response
Purtle J; Field RI; Hipper T; Nash-Arott J; Chernak E; Buehler JW (2018). The Impact of Law on Syndromic Disease Surveillance Implementation	Journal Article	Policy & Governance	To assess how legal and policy frameworks influence the implementation of syndromic disease surveillance across states	Qualitative legal analysis of statutes, policies, and governance documentation across jurisdictions	State-level laws vary significantly, creating inconsistency in data sharing and implementation; legal authority, mandates, and governance structures shape participation; clearer legal frameworks enhance interoperability and public health readiness
Rahurkar S; McFarlane TD; Wang J; Hoover S; Hammond F; Kean J; Dixon BE (2018). Leveraging Health Information Exchange to Construct a Registry for	Journal Article	Data Modernization	Create a comprehensive electronic registry for TBI, SCI, and stroke using HIE data	Method involved integrating claims and clinical EHR data from a regional HIE, constructing and	Data shows feasibility of HIE-based registries with high capture rates, rich clinical detail, and longitudinal follow-up

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Traumatic Brain Injury, Spinal Cord Injury and Stroke in Indiana				evaluating registry completeness and data quality	
Roland Gamache, Hadi Kharrazi, Jonathan P. Weiner (2018). Public and Population Health Informatics: The Bridging of Big Data to Benefit Communities	Journal Article	Data Modernization, Interoperability, Public Health Workforce & Capacity Building, Syndromic Surveillance, Policy & Governance	Bridge electronic data to benefit public and population health; integrate SDH with public health data systems; enhance surveillance and data sharing across sectors	Literature review (July 2016, Sept 2017) using PubMed MeSH terms, inclusion criteria focused on informatics and SDH; manual curation of relevant studies	Growing trend toward digital data integration across sectors; increasing collaboration between public health and healthcare systems; greater attention to social determinants of health and new workforce needs
Thomas MJ; Yoon PW; Collins JM; Davidson AJ; Mac Kenzie WR (2018). Evaluation of Syndromic Surveillance Systems in 6 US State and Local Health Departments	Journal Article	Syndromic Surveillance	Evaluate early adopters' use of syndromic surveillance to enhance situational awareness and outbreak detection	Qualitative interviews at 6 local/state departments using CDC's evaluation guidelines	Identified strengths in situational awareness and outbreak tracking (influenza, foodborne, disasters); low predictive value for early detection, but useful for monitoring emerging events
Wholey DR, LaVenture M, Rajamani S, Kreiger R, Hedberg C, Kenyon C (2018). Developing Workforce Capacity in Public Health Informatics: Core Competencies and Curriculum Design	Journal Article	Public Health Workforce & Capacity Building	Design a master's -level curriculum in public health informatics (PHI) to support workforce development and train professionals to lead the design and implementation of public health information systems.	Curriculum design and implementation with evaluation through course iterations and graduate tracking.	The curriculum prepared students for diverse PHI roles and contributed to their employment across public and private sectors. Emphasized the importance of procedural competencies, stakeholder partnerships, and continuous evaluation.
Bacon E, Budney G, Bondy J, Kahn MG, McCormick EV, Steiner JF, Tabano D, Waxmonsky JA, Zucker R, Davidson AJ (2019). Developing a Regional Distributed Data Network for Surveillance of Chronic Health Conditions: The Colorado Health Observation Regional Data Service	Journal Article	Interoperability	Establish a distributed EHR-based surveillance network for chronic disease at regional level	Data network implementation, descriptive case study, governance analysis	EHR-based surveillance is feasible at regional scale with flexible infrastructure; governance and partnerships are key; challenges include technical alignment and value proposition
Baer, A., Fagalde, M. S., Drake, C. D., Sohlberg, E. H., Barash, E., Glick, S., Millman, A. J., & Duchin, J. S. (2019). Design of an Enhanced Public Health Surveillance System for Hepatitis C Virus Elimination in King County, Washington	Journal Article	Data Modernization; Interoperability; Electronic Case Reporting	To eliminate HCV as a public health problem by integrating surveillance, clinical, and lab data to support identification, treatment, and cure	System redesign, database integration, mixed data sources, longitudinal analysis, descriptive epidemiology	Improved ability to track and monitor HCV diagnosis, treatment, and cure; identified gaps; facilitated linkage to care

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Gould DW; Lamb E; Dearth S; Collier K (2019). Building State and Local Public Health Capacity in Syndromic Surveillance Through an Online Community of Practice	Journal Article	Syndromic Surveillance; Public Health Workforce & Capacity Building	Capacity improved via peer mentoring, shared tools, and CoP-led training; described strategies for increasing user engagement	Program evaluation (CoP model)	Community of practice model enhanced syndromic surveillance capacity through peer mentoring, shared tools, and collaborative training; fostered user engagement and skill development across jurisdictions; aligns with NSSP objectives and supports CDC's broader workforce and data modernization goals.
Jennifer Black, Rachel Hulkower, Walter Suarez, Shreya Patel, Brandon Elliott (2019). Public Health Surveillance: Electronic Reporting as a Point of Reference	Journal Article	Electronic Case Reporting	Examine the legal and policy framework supporting electronic case reporting and highlight its value for public health surveillance	Legal analysis, case examples, and policy review	eCR can streamline disease reporting, reduce burden on providers, and improve completeness and timeliness of public health surveillance
Williams F; Oke A; Zachary I (2019). Public health delivery in the information age: the role of informatics and information technology tools	Journal Article	Data Modernization; Public Health Workforce & Capacity Building; Syndromic Surveillance	Examines how informatics and IT tools are being used to transform public health delivery	Literature organized into three domains: PHI definitions; surveillance system types; IT tool capabilities and training obstacles; reviewed studies globally	Public health informatics is increasingly essential for surveillance and decision-making. IT tools are underutilized due to technical, workforce, and policy barriers. Training gaps and inconsistent infrastructure are major constraints. Calls for systemic investment in digital tools and human capacity across public health systems. Widespread but uneven adoption of IT tools; critical need for workforce informatics capacity; improved surveillance capability tied to training and infrastructure investments.
Devinney, K., Lazaroff, J., Rosen, J. B., Zimmerman, C. M., & Zucker, J. R. (2020). Use of Capture–Recapture Analysis to Assess Reporting Completeness of Births to Hepatitis B–Positive Women in New York City, 2013–2014	Journal Article	electronic Lab Reporting	To evaluate the completeness of NYC DOHMH surveillance in identifying births to HBV-positive women	Capture–recapture analysis of matched surveillance datasets with statistical estimation	DOHMH identified 96.5% of births; infants not reported were less likely to receive timely PEP; capture–recapture improved identification by 3.5%
Dixon, B.E.; Grannis, S.J.; Lober, W.B.; Vest, J.R.; Begier, E.; Wilhoit, A.; Dixon, R.; Gibson, C.; Fields, D.; Savel, T.G.;	Journal Article	Electronic Case Reporting	To assess the feasibility and impact of electronic case reporting to public health agencies through health information exchange.	Pilot studies in multiple jurisdictions; comparative analysis	eCR implementation improves timeliness, completeness, and efficiency of case reporting.

Authors, Year, & Title	Document Type	PHDS Thematic Components	Objective(s)	Approach	Key Findings
Mostashari, F. (2020). Improving Notifiable Disease Case Reporting Through Electronic Information Exchange				with traditional methods.	
Gerrity D, Papp K, Stoker M, Sims A, Frehner W (2020). Early-pandemic wastewater surveillance of SARS-CoV-2 in Southern Nevada: Methodology, occurrence, and incidence: prevalence considerations	Journal Article	Wastewater Surveillance	Assess presence and quantification of SARS-CoV-2 RNA in untreated wastewater as an early warning tool during COVID-19 pandemic	Environmental sampling and molecular analysis using RT-qPCR	Confirmed detection of SARS-CoV-2 RNA in wastewater aligned with reported COVID-19 case trends, demonstrating surveillance feasibility
Lane JT; Smith K; Allen M; Surio P; Ruebush E (2020). COVID-19 Highlights Critical Need for Public Health Data Modernization to Remain a Priority	Editorial/Perspective/ Commentary	Data Modernization; Policy & Governance	Reflect on pandemic lessons and call for coordinated national modernization strategy		COVID-19 exposed significant gaps in data interoperability, workforce capacity, and public health infrastructure; sustained investment, coordinated federal–state strategies, and public–private partnerships are essential; modernization efforts must align with the CDC Data Modernization Initiative and integrate equity considerations.
Liao, T. S., Hashmi, A., Lazaroff, J., Hennessy, R. R., Kim, A. S., Lloyd, P. E., & Rosen, J. B. (2020). Effect of Policy Change to Require Laboratory Reporting With Pregnancy Indicated for Syphilis and Hepatitis B Virus Infection, New York City, January 2013–June 2018	Journal Article	Policy & Governance; Electronic Case Reporting; Electronic Laboratory Reporting	To evaluate the impact of requiring labs to indicate pregnancy status on ELRs for syphilis and HBV to improve timely public health response	Quasi-experimental policy evaluation comparing reporting metrics before and after policy change, descriptive statistics	ELRs with pregnancy indicated improved timeliness of identifying pregnant women with syphilis and HBV; many cases would not have been identified otherwise; 91% of labs complied by 2018
Mishra, N.K.; Duke, J.; Lenert, L.; Karki, S. (2020). Public Health Reporting and Outbreak Response: Synergies with Evolving Clinical Standards for Interoperability	Journal Article	Electronic Case Reporting	Demonstrate the utility of FHIR-based surveillance (PACER) to support outbreak response by automating case reporting and data extraction	Case study and conceptual application of PACER architecture in real-world STD surveillance scenario	FHIR-based systems like PACER enable rapid, privacy-conscious, and adaptable public health data collection; supports bidirectional reporting and minimizes burden on providers
Trust for America's Health (2020). Ready or Not 2020 Blueprint Report: Transforming Public Health in America	Report	Data Modernization	Outline comprehensive priorities to rebuild and strengthen U.S. public health systems with focus on workforce expansion, data modernization, addressing structural racism, social determinants, and health security	Comprehensive policy analysis with data review, expert input, and community focus	Highlights urgent need to combat structural racism, enhance health equity, modernize surveillance and data systems, recruit and retain a diverse workforce, and expand public health emergency capabilities

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Various National Organizations (72 signatories) (2020). FY 2021 Request Letter to House Appropriations Committee on Public Health Data Modernization	Policy statement	Data Modernization, Public Health Workforce & Capacity Building	To secure $100 million in FY21 for CDC to modernize public health data systems, build a trained workforce, and ensure secure, interoperable digital infrastructure	Advocacy-based policy recommendation via multi-organization consensus; letter format with references to past appropriations, system failures, and workforce capacity needs	Highlighted vulnerabilities exposed by COVID-19 in legacy surveillance and reporting systems; stressed urgency of transitioning to scalable, modern, secure data architecture supported by a skilled workforce
Wendy Blumenthal, Temitope O. Alimi, Sandra F. Jones, David E. Jones, Joseph D. Rogers, Vicki B. Benard, Lisa C. Richardson (2020). Using informatics to improve cancer surveillance	Journal Article	Data Modernization; Electronic Case Reporting; Policy and Governance	Enhance cancer surveillance through improved informatics and data linkages to support public health decision-making Improve, standardize, and automate cancer case reporting to public health registries; enhance interoperability; enable real-time data for better cancer surveillance and control	Case study approach using mixed methods to evaluate data integration and surveillance system enhancement Review and summary of CDC's National Program of Cancer Registries activities, pilot implementations, evaluation of electronic reporting initiatives	Pilot showed feasibility and benefits of linking disparate data sources; highlighted need for stakeholder buy-in, data governance, and legal frameworks
Arvisais-Anhalt, S.; Lehmann, C.U.; Park, J.Y.; Araj, E.; Holcomb, M.; Jamieson, A.R.; McDonald, S.; Medford, R.J.; Perl, T.M.; Toomay, S.M.; Hughes, A.E.; McPheeters, M.L.; Basit, M. (2021). What the Coronavirus Disease 2019 (COVID-19) Pandemic Has Reinforced: The Need for Accurate Data	Journal Article	Interoperability	To highlight the necessity of real-time, accurate data infrastructure for pandemic preparedness and response	Commentary with narrative synthesis of COVID-19 surveillance gaps and solutions	Underscores interoperability gaps, data fragmentation, and the value of clinical informatics collaboration
Bipartisan Policy Center (2021). Public Health Forward: A New Vision for the Future of Public Health	Report	Data Modernization	Outline a vision and framework to transform the U.S. public health system through sustainable funding, improved data systems, and equitable health outcomes	Policy analysis informed by expert panels, stakeholder input, and bipartisan consensus	Emphasizes investment in interoperable data systems, workforce diversity, local public health authority, and cross-sector collaboration
Burkom H; Loschen W; Wojcik R; Holtry R; Punjabi M; Siwek M; Lewis S (2021). Electronic	Journal Article	Syndromic Surveillance	description of User-focused ESSENCE syndromic surveillance architecture and applications	Descriptive system architecture overview with implementation	Highlights ESSENCE's adaptability in live systems with diverse data sources,

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Surveillance System for the Early Notification of Community-Based Epidemics (ESSENCE): Overview, Components, and Public Health Applications				examples in multiple jurisdictions	real-time performance, and responsiveness to emerging threats
COSSA (2021). Data Modernization FY22 Sign-On Statement	Policy statement	Data Modernization	Advocate for sustained federal investment in modernizing public health data infrastructure, emphasizing social science contributions and equity	Policy statement and advocacy document with endorsements from multiple scientific and public health organizations	Calls for at least $250 M for cross-sector collaboration, data equity, workforce capacity building, and better data interoperability to improve public health response and research
Daschle T; Frist BM; Wilensky G; Burke S; Capretta J; Crippen D; Hamburg M; Jennings C; Lavizzo-Mourey R; Roper W; Smith M; Wen L (2021). Positioning America's Public Health System for the Next Pandemic	Report	Data Modernization	Review U.S. public health system's pandemic response weaknesses; recommend federal leadership, data modernization, sustained funding, and workforce investment	Policy analysis and expert consensus supported by pandemic experience and public health governance research	Recommends appointing White House Deputy National Security Advisor for Pandemic Preparedness; creating National Pandemic Preparedness Board; improving federal-state coordination; standardizing data collection with emphasis on race/ethnicity; strengthening surveillance and interoperability; ensuring consistent funding streams
Dixon BE; Grannis SJ; McAndrews C; Broyles AA; Mikels-Carrasco W; Wiensch A; Williams JL; Tachinardi U; Embi PJ (2021). Leveraging data visualization and a statewide health information exchange to support COVID-19 surveillance and response: application of public health informatics	Journal Article	Interoperability	Develop statewide dashboards using HIE data to support real-time COVID-19 surveillance	Descriptive implementation study; informatics application in public health surveillance	Dashboards enhanced situational awareness and informed rapid public health response during COVID-19 pandemic
Firestone MJ; Rajamani S; Hedberg CW (2021). A Public Health Informatics Solution to Improving Food Safety in Restaurants: Putting the Missing Piece in the Puzzle	Journal Article	Policy & Governance	Explore integration of routine restaurant inspection data into public health surveillance systems	Narrative review and policy analysis with use-case examples	Restaurant inspection data represent valuable surveillance signals but are underutilized; interoperability barriers and governance challenges need addressing
Gupta P; Kaplovitch E; Gladden RM; Mattson CL; Hurley D; Strickland MJ (2021). Development and Validation of a Syndrome Definition for Suspected Nonfatal	Journal Article	Syndromic Surveillance	Evaluate and implement a validated surveillance definition to identify nonfatal unintentional stimulant overdoses in emergency department visits	Methodology included syndromic ED data extraction, algorithm development, and validation against manual chart review	Syndrome definition achieved ~89% sensitivity and ~72% positive predictive value; found increasing stimulant overdose trends among adults

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Unintentional Stimulant-Involved Overdose					
Harris-Lovett, S.; Nelson, K.L.; Beamer, P.; Bischel, H.N.; Bivins, A.; Bruder, A.; Butler, C.; Camenisch, T.D.; De Long, S.K.; Karthikeyan, S.; Larsen, D.A.; Meierdiercks, K.; Mouser, P.J.; Pagsuyoin, S.; Prasek, S.M.; Radniecki, T.S.; Ram, J.L.; Roper, D.K.; Safford, H.; Korfmacher, K.S. (2021). Wastewater Surveillance for SARS-CoV-2 on College Campuses: Initial Efforts, Lessons Learned, and Research Needs	Journal Article	Wastewater Surveillance	Detail initial implementation of wastewater surveillance across U.S. college campuses; identify challenges and research priorities	Case study across campuses with mixed methods: lab data + stakeholder interviews	Campus-level wastewater data effectively signaled SARS-CoV-2 trends; challenges included sample variability, turnaround time, cost, and regulatory clarity
Kadakia KT; Howell MD; DeSalvo KB (2021). Modernizing Public Health Data Systems: Lessons From the HITECH Act	Editorial/Perspective/ Commentary	Data Modernization; Policy & Governance	Reflect on the HITECH Act's successes and failures to inform modernization of public health data systems	Policy commentary and lessons learned based on federal HITECH implementation experience and COVID-19 response gaps	Highlights that successful modernization depends not just on technology, but on aligning incentives, governance, and capacity; warns against repeating pitfalls from HITECH implementation
Kirby AE; Walters MS; Jennings WC; Fugitt R; LaCross N; Mattioli M; Marsh ZA; Roberts VA; Mercante JW; Yoder J; Hill VR (2021). Using Wastewater Surveillance Data to Support the COVID-19 Response — United States, 2020–2021	Journal Article	Wastewater Surveillance; Data Modernization	Describe implementation and application of national wastewater surveillance system (NWSS) during COVID-19	NWSS program report via CDC; descriptive analysis of implementation and outcomes	Wastewater RNA concentrations predicted spikes days before clinical cases; 500+ notifications issued; community-based dashboards aided decision making
Lenert L; Ding W; Jacobs J (2021). Informatics for Public Health and Health System Collaboration: Applications for the Control of the Current COVID-19 Pandemic and the Next One	Editorial/Perspective/ Commentary	Policy & Governance	Advocate for a shift from hierarchical to ecosystem data exchange model; propose tools like national patient identifiers, Flat FHIR bulk queries, computable electronic quality measures	Perspective and policy analysis	Emphasize interoperable architecture, patient disambiguation, provider-based outreach; call for investments in adaptable, 'all hazards' public health data systems
Lin MY; Trick WE (2021). Computer Informatics for Infection Control	Journal Article	Data Modernization; Syndromic Surveillance; Policy & Governance	Improve infection prevention through informatics tools in surveillance, decision support, and public health coordination	Expert review with applied examples; observational and systems-based	Computer-based informatics can automate surveillance, improve decision support, enable cross-facility outbreak detection, and support

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				analysis of current informatics practices	electronic lab reporting and antibiotic resistance tracking
Mailepessov D; Lin S; Fang L; Iwamoto A; Kang J; WJuel MAI, Stark N, Nicolosi B, Lontai J, Lambirth K, Schlueter J, Gibas C, Munir Milliams KL; Koh Y; et al. (2021). Performance Evaluation of Virus Concentration Methods for Implementing SARS-CoV-2 Wastewater-Based Epidemiology Emphasizing Quick Data Turnaround	Journal Article	Wastewater Surveillance	Evaluate and compare virus concentration methods for SARS-CoV-2 wastewater-based epidemiology (WBE) with a focus on rapid and accurate results for public health decision-making	Experimental study with side-by-side lab testing of each method; quantification by RT-qPCR and performance benchmarking against spiked SARS-CoV-2 samples	PEG precipitation offered the highest recovery but required long processing time; electronegative membrane filtration provided a balance between speed and efficiency; findings guided national WBE strategy implementation in Singapore
Mishra N; Duke J; Karki S; Choi M; Riley M; Ilatovskiy AV; Gorges M; Lenert L (2021). A Modified Public Health Automated Case Event Reporting Platform for Enhancing Electronic Laboratory Reports With Clinical Data: Design and Implementation Study	Journal Article	Electronic Case Reporting	Analyze pilot implementation of a FHIR-based PACER system to enrich ELRs with clinical data	FHIR-triggered ELR with CQL queries to extract EHR data during an 8-week pilot	PACER created eCRs for all 117 cases; captured demographics 99.1%, medications 72.6%, symptoms 70.9%, diagnoses 65%
Mishra, N., Duke, J., Karki, S., Choi, M., Riley, M., Ilatovskiy, A. V., Gorges, M., & Lenert, L. (2021). A Modified Public Health Automated Case Event Reporting Platform for Enhancing Electronic Laboratory Reports With Clinical Data: Design and Implementation Study	Journal Article	Data Modernization; Interoperability; Electronic Case Reporting; Electronic Laboratory Reporting	To enhance electronic laboratory reports (ELRs) by integrating relevant clinical data from EHRs using a FHIR-based PACER platform	Pilot implementation of FHIR-based PACER at MUSC; simulated public health department; evaluation of data completeness metrics	PACER improved completeness of case reports (demographics: 99%, medications: 73%, symptoms: 71%, diagnoses: 65%); flexible and modular design
RWJF & RAND Corporation (2021). Transforming Public Health Data Systems: Opportunities and Paths Forward – Preamble White Paper	White paper	Data Modernization	Establish vision, principles, and framework for a modern, equity-oriented public health data system providing actionable data and insight to improve health equity and population well-being	Synthesizes expert input, literature review, and grantee project findings; provides a conceptual and policy framework to guide data system modernization	Provides framing of key milestones including defining a national data vision, building inclusive governance structures, developing interoperable data infrastructure, embedding equity throughout, and fostering cross-sector collaboration
RWJF (2021). Charting a Course for an Equity-Centered Public Health Data System	Report	Data Modernization	Recommend transforming public health data systems with equity-centered narrative change, governance, data sharing, and	Consensus-driven policy report based on expert commission, literature review, stakeholder	Highlights the need for disaggregated data, community participation, data literacy, and multisector collaboration; prioritizes structural racism and social determinants measurement

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			improved measurement of structural racism	interviews, and white papers	
Roehler DR; Olsen EO; Mustaquim D; Vivolo-Kantor AM (2021). Suspected Nonfatal Drug-Related Overdoses Among Youth in the US: 2016–2019	Journal Article	Syndromic Surveillance	Characterize trends in suspected nonfatal drug overdoses (all-drug, opioid, heroin, stimulant) among youth aged 0–24 from 2016–2019	Retrospective descriptive trend analysis using ED syndromic surveillance data over 59 jurisdictions in 47 states	Suspected all-drug overdoses rose ~2.0–2.3% quarterly for ages 0–14; heroin overdoses declined ~3.3% quarterly in ages 15–24; stimulant overdoses increased across all age groups (~2.3–4.0% quarterly)
Scott L.C.; Aubee A.; Babahaji L.; Vigil K.; Tims S.; Aw T.G. (2021). Targeted wastewater surveillance of SARS-CoV-2 on a university campus for COVID-19 outbreak detection and mitigation	Journal Article	Wastewater Surveillance	Evaluate efficacy of building-level wastewater surveillance in detecting and mitigating SARS-CoV-2 outbreaks on campus	RT-qPCR analysis of composite wastewater samples, normalization approach, correlation with clinical data, outbreak response actions	Wastewater SARS-CoV-2 trends mirrored campus cases; normalization improved predictive performance; enabled proactive outbreak control via targeted testing
Subbian V; Solomonides A; Clarkson M; Rahimzadeh VN; Petersen C; Schreiber R; Demuro PR; Dua P; Goodman KW; Kaplan B; Koppel R; Lehmann CU; Pan E; Senathirajah Y (2021). Ethics and Informatics in the Age of COVID-19: Challenges and Recommendations for Public Health Organization and Public Policy	Journal Article	Data Modernization, Policy & Governance	Analyze ethical gaps in public health reporting, contact tracing, clinical scoring; Offer actionable and long-term policy recommendations	Literature synthesis and consensus process among informatics and ethics experts	– Identified ethical concerns around privacy, surveillance, state authority, interoperability; – Recommended transparent, ethically informed policy mechanisms
Todd JV; Collins NV; Oakley J; Menza T; Barber M; Kasarskis I; Weresch A; Morgan S; Jellison J; Mishra N; Pérez A; Karki S (2021). Automating Case Reporting of Chlamydia and Gonorrhea to Public Health Authorities in Oregon Clinics	Journal Article	Electronic Case Reporting	pilot eCR for CT/GC at three Oregon health centers	pilot implementation & retrospective comparison; data analysis of case counts, triggers, and completeness	365 eCRs from 206 patients; eCR completeness ≥ ELR; 95% CT cases and 97% GC cases detected; eCR provided richer clinical info like demographics and treatment
Trust for America's Health (2021). 2021 Annual Report	Report	Data Modernization, Public Health Workforce & Capacity Building, Policy & Governance	Advance equitable health policy, strengthen public health infrastructure, improve emergency preparedness, promote health equity, and modernize data and workforce systems	Policy analysis, congressional advocacy, multi-sector convenings, report publication, media outreach,	Chronic underfunding hampers public health, equity must guide data modernization, need for sustained infrastructure funding, importance of SDOH in shaping health outcomes, ACEs as critical to mental health

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				stakeholder engagement	
Hill DT, Cousins H, Dandaraw B, Faruolo C, Godinez A, Run S, Smith S, Willkens M, Zirath S, Larsen DA (2022). Wastewater treatment plant operators report high capacity to support wastewater surveillance for COVID-19 across New York State, USA	Journal Article	Wastewater Surveillance	Assess wastewater treatment plant (WWTP) operators' capacity and willingness to support public health surveillance during the COVID-19 pandemic	Cross-sectional survey	Most operators reported having capacity and interest in supporting wastewater surveillance; barriers included staffing constraints and unclear guidance
Hota, B.; Casey, P.; McIntyre, A. F.; Khan, J.; Rab, S.; Chopra, A.; Lateef, O.; Layden, J. E. (2022). A Standard-Based Citywide Health Information Exchange for Public Health in Response to COVID-19: Development Study	Journal Article	Interoperability	Describe development of a citywide data hub leveraging CCDA & ELR feeds for jurisdictional COVID-19 surveillance	Technical implementation with data completeness evaluation across 88k CCDA & 408k ELR records	Measured data completeness and matching; integration yielded richer demographic/comorbidity/hospitalizati on data; 90% match rate between feeds
Layton BA; Kaya D; Kelly C; Williamson KJ; Alegre D; Bachhuber SM; Banwarth PG; Bethel JW; Carter K; Dalziel BD; Dasenko M; Geniza M; George A; Girard AM; Haggerty R; Higley KA; Hynes DM; Lubchenco J; McLaughlin KR; Nieto FJ; Noakes A; Peterson M; Piemonti AD; Sanders JL; Tyler BM; Radniecki TS (2022). Evaluation of a Wastewater-Based Epidemiological Approach to Estimate the Prevalence of SARS-CoV-2 Infections and the Detection of Viral Variants in Disparate Oregon Communities at City and Neighborhood Scales	Journal Article	Wastewater Surveillance	Assess wastewater SARS-CoV-2 concentrations to estimate community prevalence and detect viral variants at city and neighborhood levels in diverse Oregon communities	Multi-method epidemiological study combining environmental sampling, random nasal swab testing, molecular analysis (RT-ddPCR), and viral genome sequencing	Strong correlation (r=0.96) between wastewater SARS-CoV-2 concentrations and estimated prevalence, outperforming reported cases; detected neighborhood COVID-19 hotspots and viral variants consistent with individual-level sequencing
Multiple organizations (signatories) (2022). Organizational Sign-On Letter to Dr. Mary Wakefield Regarding Strengthening NCHS	Policy statement	Data Modernization, Policy & Governance, Public Health Workforce & Capacity Building	Urge increased federal investment and commitment to strengthening the National Center for Health Statistics (NCHS) as a core national data resource	Policy advocacy letter; not a research study	NCHS must be empowered with staffing, technology, and flexible funding to support national data needs during crises and routine operations

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Rajamani S; Kayser A; Ruprecht A; Cassman J; Polzer M; Homan T; Reid A; Hanson M; Emerson E; Dahlberg Schmit A; Solarz S (2022). Electronic case reporting (eCR) of COVID-19 to public health: implementation perspectives from the Minnesota Department of Health	Journal Article	Electronic Case Reporting	Assess real-world implementation of eCR for COVID-19 across health systems and public health	Quantitative evaluation using eCR data flows, timestamps, and comparisons with manual reports	Found significant improvements in timeliness and completeness; adoption challenges around workflow and EHR integration
Robert Wood Johnson Foundation (2022). Centering Equity in the Nation's Public Health System: Considerations for the CDC and Its Public Health Partners	Report	Policy & Governance	Highlight critical equity considerations for transforming the U.S. public health system, focusing on leadership, partnerships, data accountability, communication, and culture	Policy brief synthesizing expert opinion, case studies, and equity frameworks	Emphasizes systemic racism and structural inequities as fundamental health determinants; calls for CDC leadership in equity, community power-building, standardized disaggregated data, inclusive communication, and workforce diversity and training
Romano S; Yusuf H; Davis C; Thomas MJ; Grigorescu V (2022). An Evaluation of Syndromic Surveillance–Related Practices Among Selected State and Local Health Agencies	Journal Article	Syndromic Surveillance; Data Modernization	Assess current practices and capacities in syndromic surveillance among 31 state/local health departments	Methodology: standardized OMB-reviewed survey via telephone with syndromic staff in 31 jurisdictions	daily or faster ED and additional data; universal data quality monitoring; ILI and drug syndromes top priorities; flexible use of system in situational awareness
Spector E; Zhang Y; Guo Y; Bost S; Yang X; Prosperi M; Wu Y; Shao H; Bian J (2022). Syndromic Surveillance Systems for Mass Gatherings: A Scoping Review	Journal Article	Syndromic Surveillance; Public Health Workforce & Capacity Building	Analyzes 19 studies on surveillance at events like the Olympics, focusing on EDs, first aid clinics, and custom reporting; methods vary widely	scoping review	No studies demonstrated direct evidence that syndromic surveillance systems successfully detected or mitigated outbreaks during events.
Trust for America's Health (2022). 2022 Annual Report	Report	Data Modernization, Public Health Workforce & Capacity Building, Policy & Governance	Promote a modern, resilient, and equitable public health system through sustainable funding, workforce expansion, data system upgrades, and evidence-based policies addressing climate change, health equity, and chronic conditions	Policy analysis, stakeholder convenings, legislative advocacy, media engagement, report development, coalition leadership	Sustained underfunding and fragmentation continue to challenge public health effectiveness; cross-sector collaboration, climate adaptation, and equity-centered design are essential for progress
Trust for America's Health (2022). FY22 Appropriations Letter: Funding and Support for CDC and Public Health Infrastructure	Policy statement	Data Modernization	Advocate for full-year FY22 appropriations with robust funding for CDC and public health to rebuild neglected infrastructure, address workforce shortages, and modernize data systems	Federal advocacy letter to Congressional appropriations committees	Calls for increased CDC funding ($10.5B), sustained investment in public health infrastructure, data modernization, and addressing social determinants of health
Trust for America's Health (2022). Ready or Not 2022: Protecting the	Report	Data Modernization	Assess U.S. public health preparedness and capacity, with	Comprehensive national assessment	Finds critical shortages in public health workforce (over 80,000 needed); data

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Public's Health from Diseases, Disasters, and Bioterrorism			emphasis on workforce, data systems, and equity	combining surveys, quantitative data, expert interviews, and policy review	modernization uneven and underfunded; public health labs need expansion; equity remains a key challenge in preparedness
Trust for America's Health (2022). Ready or Not 2022: Protecting the Public's Health from Diseases, Disasters, and Bioterrorism	Report	Data Modernization	Assess U.S. public health preparedness and capacity across states, highlighting strengths and gaps in workforce, data modernization, laboratory capacity, and health equity	Comprehensive policy review with state surveys, data analysis, and expert interviews	Calls for sustained funding, expanded workforce development, and accelerated data modernization efforts to enhance surveillance, response, and equity
Arrazola J; Auer S (2023). Transforming the Applied Epidemiology Workforce to Support Modernized Public Health Data Systems	Editorial/Perspective/ Commentary	Public Health Workforce & Capacity Building	Mobilize applied epidemiology workforce for data modernization		Urges development of workforce strategies, including competency frameworks and community of practice models
Barber C; Crank K; Papp K; Innes G; Schmitz B; Chavez J; Rossi A; Gerrity D (2023). Community-Scale Wastewater Surveillance of Candida auris during an Ongoing Outbreak in Southern Nevada	Journal Article	Wastewater Surveillance	Assess feasibility of using wastewater surveillance to detect Candida auris at community scale during outbreak	Retrospective observational study using environmental sampling and qPCR analysis, correlated with known outbreak locations	Wastewater detected C. auris in 79% of samples; higher positivity in outbreak-affected sewersheds (94% vs 20%); demonstrated viral load quantification (2.8–5.7 $\log_{10}$ gc/L); primary clarification reduced load by ~1.2 log
Bipartisan Policy Center (2023). Current Regulatory Landscape of AI in Public Health & Health Care: A Brief Overview	Report	Policy & Governance	Overview of current federal statutes, regulations, and initiatives shaping AI regulation and governance in health care and public health	Policy and legal analysis compiling multi-agency federal actions and regulations	Details agency-specific activities: White House AI Bill of Rights, NIST AI Risk Framework, FDA SaMD guidance, FTC enforcement, CMS reimbursement rules, ONC health IT certification, VA AI initiatives, and more
Crowley R, Mathew S, Hilden D (2023). Modernizing the United States' Public Health Infrastructure	Editorial/Perspective/ Commentary	Policy & Governance	Provides updated recommendations on funding, workforce, data systems, and emergency preparedness	ACP; federal public health agencies; health care providers	Policy analysis and expert consensus
Dixon, Staes, Acharya, Allen, et al. (2023). Enhancing the nation's public health information infrastructure: a report from the ACMI symposium	Editorial/Perspective/ Commentary	Data Modernization, Interoperability, Public Health Workforce & Capacity Building, Policy & Governance	Strengthen PH information infrastructure; secure health data; promote health data utilities; expand workforce training in informatics	Expert symposium with invited speakers and structured SWOT analysis	US PHIS is fragmented and underfunded; public health informatics workforce is insufficient; health data must be treated as critical infrastructure; funding and federal/state coordination are essential
Hohman KH; Martinez AK; Klompas M; Kraus EM; Li W; Carton TW; Cocoros NM; Jackson SL; Karras BT; Wiltz JL; Wall HK (2023). Leveraging Electronic	Journal Article	Data Modernization	Launched MENDS across five partner networks, aggregating EHRs from 91 systems covering ~10 million patients; implemented	Distributed network (MENDS) using ESP, PopMedNet, RiskScape; governance framework	Distributed network implementation with governance, EHR-based algorithms, statistical/geospatial methods for prevalence estimation, and public health visualization tools

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Health Record Data for Timely Chronic Disease Surveillance: The Multi-State EHR-Based Network for Disease Surveillance			governance, algorithms, weighting, and education	with data-sharing agreements and policies; EHR data extraction/mapping into MENDS schema; chronic disease algorithms; statistical/geospatial modeling for prevalence estimation; multi-stage validation for data quality/completeness/ plausibility; workforce training and technical assistance for public health agencies.	
Holm RH; Osborne Jelks NT; Schneider R; Smith T (2023). Beyond COVID-19: Designing Inclusive Public Health Surveillance by Including Wastewater Monitoring	Editorial/Perspective/ Commentary	Wastewater Surveillance; Public Health Workforce & Capacity Building	Promote inclusive, community-level wastewater surveillance to address health equity gaps	Literature synthesis and call to action in a perspective format involving case examples and policy reflection	Finds wastewater monitoring is a valuable early warning tool in areas with limited clinical testing; stresses need for intentional outreach to underserved communities to ensure equitable surveillance coverage
Hopkins L; Persse D; Caton K; Ensor K; Schneider R; McCall C; Stadler LB (2023). Citywide wastewater SARS-CoV-2 levels strongly correlated with multiple disease surveillance indicators and outcomes over three COVID-19 waves	Journal Article	Wastewater Surveillance	Validate wastewater SARS-CoV-2 as a routine surveillance indicator by comparing it to established metrics (positivity rate, ED visits, hospital bed use) across three COVID-19 waves in Houston	Correlation and time-lag analysis of wastewater viral loads vs case/hospital indicators using 86 weeks of surveillance data	Strong correlations found across all three waves; wastewater led or coincided with clinical indicators; individual WWTP data reflected city-wide patterns; informed public health resource allocation
Keck J W; Lindner J; Liversedge M; Mijatovic B; Olsson C; Strike W; Noble A; Adatorwovor R; Lacy P; Smith T; Berry S M (2023). Wastewater Surveillance for SARS-CoV-2 at Long-Term Care Facilities: Mixed Methods Evaluation	Journal Article	Wastewater Surveillance	Evaluate performance of SARS-CoV-2 wastewater surveillance at 6 LTCFs following CDC guidelines	Mixed methods using wastewater lab data and stakeholder interviews following CDC evaluation framework	Wastewater surveillance showed mixed performance—moderate sensitivity (~31% overall, 48% among residents), ~80% specificity; feasible and acceptable, with challenges in interpretation/timeliness
Kirkcaldy, R.D.; Biggers, B.; Bonney, W.; Gordon, J.; Yassine, B.; Crawford, B.; Papagari	Journal Article	Data Modernization; Workforce	Implementation of modernized data infrastructure, workforce capacity	Commentary and synthesis based on public health	Sustained investment is required; cross-sector collaboration is vital; data

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Sangareddy, S.; Franzke, L.; Bernstein, K.T. (2023). Modernizing Public Health Data Systems and Infrastructure to Advance Public Health Practice			building, and cross-sector partnerships	modernization initiatives	systems must prioritize equity, security, and utility.
LaJoie AS; Holm RH; Anderson LB; Ness HD; Smith T (2023). Nationwide Public Perceptions Regarding the Acceptance of Using Wastewater for Community Health Monitoring in the United States	Journal Article	Wastewater Surveillance	To assess the U.S. public's awareness, acceptance, and preferences regarding the use of wastewater-based epidemiology (WBE) for monitoring community health, including specific uses such as tracking infectious diseases, environmental toxins, and drug use.	Probability-based quantitative survey; data weighted to be nationally representative; analyzed via descriptive and regression analysis	High support for WBE to monitor diseases (76%) and environmental toxins (84%); moderate support for monitoring drug use (54%); greater acceptance at larger geographic levels (e.g., city-wide vs. household); public trust and transparency were key factors
Mishra N, Grant R, Patel MT, Guntupalli S, Hamilton A, Carr J, McKnight E, Wise W, deRoode D, Jellison J, Collins NV, Pérez A, Karki S (2023). Automating Case Reporting of Chlamydia and Gonorrhea to Public Health Authorities in Illinois Clinics: Implementation and Evaluation of Findings	Journal Article	Electronic Case Reporting	Pilot standards-based eCR for chlamydia/gonorrhea; compare completeness/timeliness with ELR; evaluate implementation in Illinois clinics	Standards-based implementation using HL7 eICR; comparison of eCR vs ELR metrics; data completeness analysis	eCR detected 95% chlamydia & 97% gonorrhea cases; identified additional gonorrhea cases missed by ELR; eCR provided richer clinical data; reduced provider burden
Nasuti L, Andrews B, Li W, Wiltz J, Hohman KH, Patanian M (2023). Using latent class analysis to inform the design of an EHR-based national chronic disease surveillance model	Journal Article	Data Modernization	Identify latent classes of U.S. states to strategically recruit surveillance sites for MENDS	Retrospective latent class analysis using national state-level data	MENDS identified 3 distinct state clusters to guide network expansion, aligning site selection with capacity and equity
Nazzal EM; Waller AE; Meyer ML; Ising AI; Jones-Vessey K; Urrutia E; Urrutia RP (2023). Pregnancy and Emergency Department Utilization in North Carolina, 2016–2021: A Population-Based Surveillance Study	Journal Article	Syndromic Surveillance	Describe emergency department (ED) utilization patterns for pregnancy-associated visits among women of reproductive age in North Carolina; assess demographic disparities and admission outcomes	Population-based syndromic surveillance analysis using administrative ED data with multivariable logistic regression to assess associations	Pregnancy-associated visits comprised 10.1% of ED visits, higher than expected based on pregnancy rates; rates increased over time; younger age groups, Black race, and rural/suburban residence were overrepresented; pregnancy-associated visits had higher admission odds but Black patients had lower admission odds compared to White patients
RTI International (2023). Easing the Path to Data Modernization Initiative Engagement:	White paper	Data Modernization	Summarize legal and governance barriers to public health data exchange under CDC's Data Modernization Initiative (DMI) and	White paper based on policy and legal analysis with practical recommendations	Proposes solutions such as data landscape assessments, data asset inventories, streamlined data sharing tools, and trusted governance

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Approaches to Address Legal and Governance Challenges			recommend approaches to facilitate agile, interoperable data sharing	from RTI's public health collaborations	frameworks to improve STLT engagement with DMI
Schmit CD; Willis B; McCall H; Altabbaa A; Washburn D (2023). Views on increased federal access to state and local National Syndromic Surveillance Program data: a nominal group technique study	Journal Article	Syndromic Surveillance	Evaluate perspectives on federal access to NSSP data and identify policy opportunities for data modernization	Virtual Nominal Group Technique NGT workshops + web-based ranking survey across geographically diverse leadership	Identified 5 key benefits (top: cross-jurisdiction collaboration) and 9 concerns (top: misuse & misinterpretation); recommended 11 policy actions emphasizing collaborative governance and communication protocols
Trust for America's Health (2023). Legislative Priorities for the 118th Congress	Report	Data Modernization	Outline critical legislative actions needed to strengthen public health funding, data modernization, workforce capacity, and emergency preparedness	Policy analysis with evidence-based recommendations targeting Congress and federal agencies	Highlights underfunding issues, data system fragmentation, workforce shortages, and the need for comprehensive, equitable public health policies
Valvi N; McFarlane T; Allen KS; Gibson PJ; Dixon BE (2023). Identification of Hypertension in Electronic Health Records Through Computable Phenotype Development and Validation for Use in Public Health Surveillance: Retrospective Study	Journal Article	Syndromic Surveillance	Developed 6 computable phenotypes (CPs); conducted chart review for validation; applied best-performing CP (CP6) to local HIE data	Retrospective observational study; chart review validation; phenotype algorithm development and testing	CP6 achieved F1=0.91, PPV=83.5%, sensitivity=99.9%; estimated hypertension prevalence of 38.4% in the population
Van Vo 1 , Anthony Harrington 2 , Ching-Lan Chang 2 , Hayley Baker 2 , Michael A Moshi 2 , Nabih Ghani 2 , Jose Yani Itorralba 2 , Richard L Tillett 3 , Elizabeth Dahlmann 2 , Natnael Basazinew 2 , Richard Gu 2 , Tiffany D Familara 2 , Sage Boss 2 , Fritz Vanderford 2 , Moonis Ghani 2 , Austin J Tang 2 , Alice Matthews 2 , Katerina Papp 4 , Eakalak Khan 5 , Carolina Koutras 6 , Horng-Yuan Kan 7 , Cassius Lockett 7 , Daniel Gerrity 4 , Edwin C Oh 8 (2023). Identification and genome sequencing of an H3N2 variant influenza A in wastewater from elementary schools during a surge of influenza H3N2 variant	Journal Article	Wastewater Surveillance	Detect and characterize influenza A virus in wastewater during a school outbreak; demonstrate utility of wastewater surveillance in detecting variant strains	Environmental sampling, RT-qPCR, metagenomic sequencing	Wastewater surveillance was able to detect and genetically characterize an influenza A variant during a school outbreak, indicating value of WBE beyond SARS-CoV-2

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influenza A cases in Las Vegas, Nevada					
AcademyHealth (2024). A Research Agenda for an Evolving Public Health System: Directions for the Field of Public Health Services and Systems Research	Editorial/Perspective/ Commentary	Data Modernization	Develop a research agenda to guide investment in public health services and systems research (PHSSR) addressing emerging system needs and equity	Mixed methods including literature review, key informant interviews, deliberative dialogues, crowdsourced research questions, and multi-stakeholder prioritization	Highlights critical evidence gaps in workforce capacity, data modernization barriers, financing strategies, governance challenges, communication, and equity integration; advocates for sustainable federal support and community engagement
Adams, Arrazola, Daly, Tompkins (2024). Threat Agnostic Epidemiology and Surveillance in US Public Health Agencies: Future Potential and Needs	Editorial/Perspective/ Commentary	Data Modernization, Public Health Workforce & Capacity Building	Support threat agnostic surveillance; invest in workforce, diagnostics, and interoperable systems	Commentary and review of practices, policies, and strategic needs	Need for flexible, cross-trained workforce and sustained funding; diagnostic innovations like home testing and wastewater surveillance have promise but face challenges
Allen KS; Valvi N; Gibson PJ; McFarlane T; Dixon BE (2024). Electronic Health Records for Population Health Management: Comparison of Electronic Health Record–Derived Hypertension Prevalence Measures Against Established Survey Data	Journal Article	Data Modernization	Assess comparability of six EHR-derived computable phenotypes against BRFSS survey estimates for Marion County (2014–2015)	Methods: Retrospective EHR/HIE data extraction; phenotype development; statistical equivalence testing (TOST); demographic stratification	Phenotypes P2, P3, P5 achieved equivalence overall; P2 & P5 equivalent in nine demographic subsets; highlights importance of including vitals Measures in phenotypes
Barker W, Chang W, Everson J, Gabriel M, Patel V, Richwine C, Strawley C (2024). The Evolution of Health Information Technology for Enhanced Patient-Centric Care in the United States: Data-Driven Descriptive Study	Journal Article	Electronic Case Reporting / Interoperability	Assess trends in health IT adoption and exchange capacity across US hospitals and physicians from 2008–2023	Descriptive time-series analysis of US national survey and administrative datasets (AHA, Surescripts, HINTS, NCHS)	Significant increases in EHR adoption, interoperability, e-prescribing (70% of hospitals), electronic public health reporting, and patient portal access; persistent interoperability, usability, equity issues
Barth O.; Anderson B.; Jones K.; Nickles A.; Dawkins K.; Burnett A.; Quartermus K. (2024). An Innovative Approach to Using Electronic Health Records Through Health Information Exchange to Build a Chronic Disease Registry in Michigan	Journal Article	Data Modernization	Describe the development of CHRONICLE, a near–real-time chronic disease registry for hypertension and stroke using EHR-HIE linkage	Descriptive system development and implementation evaluation in real-world HIE environment	Demonstrated ability to capture timely EHR data via HIE; identified challenges with data completeness, governance; system shows promise for scalable surveillance
Chen X, Balliew J, Bauer CX, Deegan J, Gitter A, Hanson BM, Maresso AW, Tisza MJ, Troisi CL,	Journal Article	Wastewater; Data Modernization	Use wastewater receptor-binding domain (RBD) amplicon sequencing to track SARS-CoV-2 variants and	Method: Weekly composite sampling, RT-qPCR	Identified 91 variants across 216 samples; detected variant waves correlating with clinical data; early

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Rios J, Mena KD, Boerwinkle E, Wu F (2024). RBD amplicon sequencing of wastewater reveals patterns of variant emergence and evolution			detect unreported outbreaks; assess temporal and geospatial dynamics across three WWTPs in El Paso, TX (Mar 2022–Aug 2023)	normalization, RBD amplicon sequencing, ASV analysis via DADA2, variant calling via BLAST, diversity indices, comparison with GISAID–clinical sequencing	detection of EG.5.1, XBB.1.16, EF.1.1, GD.1 before clinical reporting; higher diversity in lag/low-transmission periods
Cochlin, F.J.; Curran, C.D.; Schmit, C.D. (2024). Unlocking Public Health Data: Navigating New Legal Guardrails and Emerging AI Challenges	Journal Article	Policy and Governance	Examine impacts of new privacy laws and AI governance on public health data access and informatics	Legal and policy analysis with review of legislation, public health practice, and governance models	Privacy legislation may restrict access to non-HIPAA data; AI governance lacks public health focus; streamlining DUAs is critical; DMI is key to future informatics capacity
Essaid, S.; Andre, J.; Brooks, I. M.; Hohman, K. H.; Hull, M.; Jackson, S. L.; Kahn, M. G.; Kraus, E. M.; Mandadi, N.; Martinez, A. K.; Mui, J. Y.; Zambarano, B.; Soares, A. (2024). MENDS-on-FHIR: Leveraging the OMOP Common Data Model and HL7 FHIR to Enable National Chronic Disease Surveillance	Journal Article	Interoperability	Enable a national chronic disease surveillance platform using OMOP and FHIR standards to ensure interoperability and scalability	Case study and technical implementation report	Established a pipeline using OMOP CDM and FHIR to standardize chronic disease data for scalable, interoperable use
Field C; Price S; Locklear AC (2024). Barriers and Opportunities for Tribal Access to Public Health Data to Advance Health Equity	Journal Article	Policy & Governance	Identify barriers to Tribal access to public health data and propose legal, policy, and practice-based solutions to support health equity.	Legal and policy analysis; review of statutes, regulations, and published reports.	Tribal public health efforts are hindered by limited data access and insufficient federal policy support; current frameworks do not adequately ensure Tribal data sovereignty.
Ghildayal N; Nagavedu K; Wiltz JL; Back S; Boehmer TK; Draper C; Gundlapalli AV; Horgan C; Marsolo KA; Mazumder NR; Reynolds J; Ritchey M; Saydah S; Tedla YG; Carton TW; Block JP (2024). Public Health Surveillance in Electronic Health Records: Lessons From PCORnet	Journal Article	Electronic Case Reporting; Interoperability	To evaluate how PCORnet's distributed data model can support public health surveillance and case identification	Case study leveraging PCORnet Common Data Model and collaboration between public health and clinical networks	Demonstrates feasibility of using distributed EHR networks for timely public health surveillance; noted need for consistent data definitions and close coordination
Hartsell J; Wilson FA; Shoaf K; Dunn A; Samore MH; Staes CJ (2024). An economic evaluation of the expansion of electronic case reporting in an academic healthcare setting	Journal Article	Electronic Case Reporting	Quantify 5-year ROI of expanding eCR from COVID-19 to 29 reportable conditions at an academic health center	ROI framework, cost-benefit modeling, sensitivity analysis over 5-year horizon	Calculated total implementation cost (~$5,031) with 5-year ROI of 142% (NPV ≈ $7,166); breakeven in ~4.8 years; all sensitivity analyses positive

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Hohman KH, Klompas M, Zambarano B, Wall HK, Jackson SL, Kraus EM (2024). Validation of Multi-State EHR-Based Network for Disease Surveillance (MENDS) Data and Implications for Improving Data Quality and Representativeness	Journal Article	Data Modernization; interoperability	Validate stages 0–3 of data validation process across 5 organizations (Dec 2020–Aug 2023)	Multi-site (MENDS)validation case study with mixed methods (ETL audits, algorithmic review, patient-level sample checks)	Identified key EHR data issues—missing race, duplicates, orphan observations, mapping errors—with remediation reducing error rates from 14% to 2% for hypertension validation, increasing zip completeness from ~50% to 96%
Knicely K; Loonsk JW; Hamilton JJ; Fine A; Conn LA (2024). Electronic Case Reporting Development, Implementation, and Expansion in the United States	Journal Article	Electronic Case Reporting; Interoperability; Policy & Governance	Document the development, implementation, and scale-up of eCR infrastructure in the U.S.	Descriptive implementation summary; cross-sectional narrative from national programs and jurisdictions	Found improved timeliness, automation, and coverage of case reporting; emphasized foundational governance and standards-based approach for sustainability
Kraus E; Saintus L; Martinez AK; Brand B; Begley E; Merritt RK; Hamilton A; Rubin R; Sullivan A; Karras BT; Grannis S; Brooks IM; Mui J; Carton TW; Hohman KH; Klompas M; Dixon BE (2024). Fostering Governance and Information Partnerships for Chronic Disease Surveillance: The Multi-State EHR-Based Network for Disease Surveillance	Journal Article	Public Health Workforce & Capacity Building	Co-created MENDS governance framework (2020–2022); convened multi-state governance committee; executed data-sharing agreements; codified master governance document	Qualitative description of governance development; implementation timeline and procedural evolution	Piloted distributed EHR-based chronic disease surveillance network across Texas, LA, Chicago, Washington, Indiana; built trust and transparency via governance
Lipsitch M et al. (2024). Infectious Disease Surveillance Needs for the United States: Lessons from COVID-19	Conference Summary	Data Modernization	Define key data needs for infectious disease surveillance; summarize lessons from COVID-19; identify surveillance activities to support timely decisions	Expert consensus and policy analysis; review of surveillance data types and modeling needs	Multiple data streams required; data completeness, linkage, and accessibility critical; wastewater and population sampling valuable; modernized frameworks needed
Menchú-Maldonado M; Novoa DE; Joseph CN; Driver EM; Muenich RL; Conroy-Ben O (2024). Determining the connectivity of tribal communities to wastewater treatment facilities for use in environmental contamination and exposure assessments by wastewater-based surveillance	Journal Article	Wastewater Surveillance	Assess connectivity of 574 Federally Recognized Indian Tribes (FRITs) in the U.S. to wastewater treatment facilities to evaluate sanitation infrastructure adequacy and feasibility for wastewater-based epidemiology (WBE)	Spatial data analysis combining EPA permit databases, U.S. Census Bureau shapefiles, and demographic overlays	94 FRITs have NPDES permits within tribal boundaries; 210 Tribal-serving facilities serve ~135,000 American Indian individuals (~36% of Tribal members); 523 FRITs lack permitted discharging facilities suggesting infrastructure gaps; findings highlight opportunities and environmental justice concerns for WBE and sanitation investment

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Mitchell CS, Callahan T, Flynn E (2024). A messaging standard for environmental inspections: is it time?	Editorial/Perspective/ Commentary	Interoperability	Argues for the development of a standardized messaging framework for environmental inspections to support public health and healthcare integration	Policy analysis and perspective article; use case development	Calls for adoption of standardized data messaging for EH inspections to enable linkage with public health and healthcare data systems, improving response to outbreaks and environmental exposures
Moreno Arellano et al. (2024). Bringing the Public Health Informatics and Technology Workforce Together: The PHIAT Conference	Conference Summary	Public Health Workforce & Capacity Building	To create a forum for public health informatics professionals and foster innovation in workforce and tech collaboration	Pre-conference survey, keynote presentations, workshops, post-conference evaluation	Strong interest in workforce training, interdisciplinary learning, and bridging informatics and tech in public health; hybrid conferences improve access
Pathak A; Serrer L; Zapata D; King R; Mirel LB; Sukalac T; Srinivasan A; Baier P; Bhalla M; David-Ferdon C; Luxenberg S; Gundlapalli AV (2024). Privacy Preserving Record Linkage for Public Health Action: Opportunities and Challenges	Editorial/Perspective/ Commentary	Policy & Governance	Describe the benefits, challenges, and implementation considerations for using privacy-preserving record linkage (PPRL) to support public health data use and action	Practice-based commentary informed by federal pilot implementations and interagency collaboration across CDC and public health partners	PPRL allows linking across datasets without sharing personally identifiable information; it can enhance outbreak response, program evaluation, and surveillance, but requires investment in infrastructure, legal clarity, and trusted frameworks
RTI International (2024). Center for Data Modernization Solutions (CDMS)	Report	Data Modernization	Provide integrated expertise in technology, science, and public health to improve data access, interoperability, analytics, and compliance	Large multidisciplinary team (500+ experts) across multiple global offices; extensive experience in health data modernization and technology solutions	Key projects: CONNECTS (NIH COVID-19 research coordination), MENDS (chronic disease surveillance), ECHO (child health longitudinal study), LitCoin (NLP knowledge graphs), BioData Catalyst (precision medicine data sharing)
Rainey JJ; Lin XM; Murphy S; Velazquez-Kronen R; Do T; Hughes C; Harris AM; Maitland A; Gundlapalli AV (2024). Deployment of the National Notifiable Diseases Surveillance System during the 2022–23 mpox outbreak in the United States—Opportunities and challenges with case notifications during public health emergencies	Journal Article	Electronic Case Reporting	Improve case notifications during the mpox emergency	Descriptive case study of surveillance system deployment during outbreak response; process mapping and data workflow analysis	Interim approaches enabled daily mpox tracking, vaccine/funding allocation, and outbreak situational awareness; revealed delays from regulatory approvals and duplicate-case challenges
Rajamani S; Waterfield KC; Austin R; Singletary V; Odowa Y; Miles-Richardson S; Winters T; Powers B; LaRoche F; Trachet S; Fritz J; Leider JP; Wurtz R; Shah	Journal Article	Public Health Workforce & Capacity Building	Describe TRIUMPH consortium training model, experiential learning framework, recruitment and curricula	Lawrence experiential cohort model, curriculum tracking, diversity metrics evaluation	Trained 692/879 students to date (79%); high diversity (32% Black, 2% AI/AN); multiple internships completed across agencies; partnership leverage effective

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GH (2024). Training in Public Health Informatics and Technology Leveraging a Multi-institutional Partnership Model and Emphasizing Experiential Learning					
Rao G, Capone D, Zhu K, Knoble A, Linden Y, Clark R, Lai A, Kim J, Huang CH, Bivins A, Brown J (2024). Simultaneous detection and quantification of multiple pathogen targets in wastewater	Journal Article	Wastewater Surveillance	Develop and demonstrate a multiplexed assay to simultaneously detect and quantify multiple pathogen targets in wastewater	Laboratory validation, field sample testing	The assay successfully quantified 10 targets including SARS-CoV-2, Norovirus, and Influenza with strong correlation to case data
Rigby RC; Ferdinand AO; Kum HC; Schmit C (2024). Data Sharing in a Decentralized Public Health System: Lessons From COVID-19 Syndromic Surveillance	Editorial/Perspective/ Commentary	Policy & Governance	Highlight policy and relational challenges of syndromic data sharing under U.S. federalism; propose governance framework with state/local involvement	Qualitative policy analysis using literature review and interviews with public health practitioners and stakeholders	Gaps in federal access due to DUAs; trust-based frameworks and guardrails needed to enable equitable, secure syndromic data sharing across jurisdictions
Rosenthal S; Adler-Milstein J; Patel V (2024). Public Health Data Exchange Through Health Information Exchange Organizations: National Survey Study	Journal Article	Interoperability; Policy & Governance; Data Modernization	Assess how HIOs support public health data exchange and identify barriers and challenges to PHA connectivity	National survey study via structured responses from 77 of 90 invited HIOs	Found 86% of HIOs connected to ≥1 PHA; immunization, lab results, and syndromic surveillance were most common services; dashboards and analytic support provided by 64%; major barriers include limited funding and competing priorities for PHAs
Shehab N; Alschuler L; McIlvenna S; Gonzaga Z; Laing A; deRoode D; Dantes R.B.; Betz K; Zheng S; Abner S; Stutler E; Geimer R; Benin A.L. (2024). The National Healthcare Safety Network's digital quality measures: CDC's automated measures for surveillance of patient safety	Journal Article	Interoperability	Develop & pilot NHSNLink tool using FHIR APIs to automate dQM reporting (hypoglycemia, CDI, VTE); launch NHSNCoLab	Implementation of FHIR dQM via NHSNLink in collaborative site pilots	NHSNLink reduced reporting burden, improved data accuracy, timeliness, and quality compared to manual reports
Stevens A, Karki S, Shivers E, Pérez A, Choi M, Berro A, Riley M, Yang J, Tassev P, Jackson DA, Kim I, Duke JD (2024). SmartChart Suite: a Fast Healthcare Interoperability Resources-based framework for longitudinal syphilis surveillance using structured and unstructured data	Journal Article	Electronic Case Reporting	Develop a FHIR-based framework to enhance syphilis surveillance by integrating structured and unstructured EHR data	Mixed-methods approach using FHIR, NLP, and EHR integration	SmartChart Suite improved surveillance capabilities by linking EHRs to public health reporting and supporting longitudinal case tracking

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Tierney BT; Foox J; Ryon KA; Butler D; Damle N; Young BG; Mozsary C; Babler KM; Yin X; Carattini Y; Andrews D; Lucaci AG; Schaefer Solle N; Kumar N; Shukla B; Vidović D; Currall B; Williams SL; Schürer SC; Stevenson M; Amirali A; Beaver CC; Kobetz E; Boone MM; Reding B; Laine J; Comerford S; Lamar WE; Tallon JJ Jr; Hirschberg JW; Proszynski J; Al Ghalith G; Kurt KC; Sharkey ME; Church GM; Grills GS; Solo-Gabriele HM; Mason CE (2024). Towards geospatially-resolved public-health surveillance via wastewater sequencing	Journal Article	Wastewater Surveillance	Develop and apply integrated targeted and bulk RNA sequencing to characterize viral, bacterial, and functional microbial profiles in wastewater at geospatially distinct sites in Miami-Dade County	Comprehensive longitudinal observational study combining targeted qPCR, ARTIC sequencing, bulk RNA sequencing, and advanced bioinformatics including taxonomic classifiers and de novo assembly	Detected SARS-CoV-2 variants correlating closely with clinical data; identified microbial taxa linked to human health and diet; revealed spatial variation in viral and antimicrobial resistance gene abundance; established protocols for continuous high-resolution wastewater-based public health surveillance
Trust for America's Health (2024). Priority 1: Invest in Infrastructure and Workforce to Ensure Our Public Health System Can Meet the Challenges and Opportunities of the 21st Century	Report	Data Modernization	Highlight the urgent need for consistent, sustained investment in public health infrastructure, workforce expansion, and data modernization to improve prevention and emergency response	Comprehensive policy analysis with evidence from workforce studies, program data, and funding trends	Profiles key programs like CDC's Data Modernization Initiative (e.g., electronic case reporting expansion), Public Health AmeriCorps workforce pipeline, Public Health Infrastructure Grants, and forecasting centers; warns of impending funding cliffs threatening progress
Trust for America's Health (2024). Ready or Not 2024 Blueprint Report: Strengthening Public Health for the Next Administration and Congress	Report	Data Modernization	Strengthen foundational public health infrastructure at the federal, state, and local levels. Expand and sustain the public health workforce to meet current and emerging public health challenges. Accelerate data modernization efforts to enable timely, interoperable, and actionable health data systems. Advance health equity by investing in targeted programs and addressing systemic inequities. Enhance public health emergency preparedness and response capabilities.	Comprehensive policy analysis incorporating surveys, program data, expert interviews, and case studies	Details recent progress and key milestones such as launching Public Health Infrastructure Grants ($5B over 5 years), CDC Data Modernization Initiative achievements (eCR expansion to 41,000 facilities), establishment of CDC Center for Forecasting and Outbreak Analytics, and creation of Public Health AmeriCorps

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			Promote innovation in forecasting, analytics, and outbreak detection to support proactive health interventions.		
Trust for America's Health (2024). Ready or Not 2024 Blueprint Report: Strengthening Public Health, Prevention, and Health Security	Report	Data Modernization	Assess the current state and priorities of the U.S. public health system, emphasizing investments in workforce, data modernization, equity, and emergency preparedness	Comprehensive national policy analysis and expert consensus; includes survey data, case studies, and evidence-based recommendations	Calls for increased CDC funding, continuous data modernization efforts, workforce recruitment and retention, stronger public health infrastructure, and addressing structural inequities in health
Trust for America's Health (TFAH) (2024). The Blueprint: Executive Summary	Report	Data Modernization, Public Health Workforce & Capacity Building, Policy & Governance	Provide a concise, actionable roadmap to guide the next U.S. administration and Congress in strengthening the public health system through sustainable investments in infrastructure, workforce, equity, and data systems.	Policy synthesis drawing on expert convenings, existing recommendations, stakeholder feedback, and prior TFAH reports.	Calls out longstanding underfunding, workforce gaps, and siloed data systems; emphasizes cross-sector collaboration, equity-centered approaches, and resilience for health emergencies.
Vo, V.; Harrington, A.; Afzal, S.; Papp, K.; Chang, C.-L.; Baker, H.; Aguilar, P.; Buttery, E.; Picker, M. A.; Lockett, C.; Gerrity, D.; Kan, H.-Y.; Oh, E. C. (2024). Identification of a rare SARS-CoV-2 XL hybrid variant in wastewater and the subsequent discovery of two infected individuals in Nevada	Journal Article	Wastewater Surveillance	Track SARS-CoV-2 variants and their prevalence using wastewater data across a two-year period	Longitudinal wastewater sample collection and sequencing; comparison with clinical case data	Wastewater genomic sequencing provides critical insights into variant dynamics and local transmission trends
Yu, A.T.; Burnor, E.; Rabe, A.; Rutschmann, S.; Wolfe, M.K.; Burmester, J.; Pan, C.-Y.; Chen, A.; Guevara, H.; Morales, C.; Wadford, D.A.; Boehm, A.B.; Vugia, D.J. (2024). Wastewater Surveillance for Norovirus, California, USA	Journal Article	Wastewater Surveillance	Evaluate wastewater-based surveillance (WBS) for norovirus GII as a supplement to traditional public health reporting in California	Observational ecological study comparing wastewater data with surveillance systems over Dec 2022–Dec 2023	Wastewater norovirus GII concentrations correlated with clinical surveillance; WBS provided timely, localized, and actionable data for public health authorities
Bruno JF, Williams SL, Knuth MA, Lentz JH, Cardona A, Miller JM, Vukotich CJ, Davies-Cole JD, Thomas DL. (2025). Epidemiology of Lyme Disease as Identified	Journal Article	Electronic Case Reporting	To evaluate the utility of EHR data in identifying and characterizing Lyme disease cases across a large Midwestern health system.	Retrospective EHR-based cohort analysis across multiple clinical sites within a health system.	EHRs captured over 2,000 probable cases, with geographic clustering in endemic areas and consistent seasonal trends. EHR-based

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Through Electronic Health Records in a Large Midwestern Health System, 2016,2019					surveillance can complement traditional methods.
Khurshid A; Sarkar IN (2025). The health data utility and the resurgence of health information exchanges as a national resource	Editorial/Perspective/ Commentary	Policy & Governance	Advocate for investment in HDUs as a critical national infrastructure for health data exchange	Commentary and policy analysis	HDUs can unify fragmented health data, support real-time surveillance, and enable AI applications in health
Li W.; Zhang M.; Cheng J.; Jackson SL.; Vaughan AS.; Klompas M.; Carton TW.; Nauman E.; Mendoza L.; Adhikari A.; Donovan J.; Hohman KH. (2025). Weighted EHR-based prevalence estimates for hypertension at the state and local levels in Louisiana	Journal Article	Data Modernization	Estimate prevalence and control of hypertension using weighted EHR data at state, parish, and city levels	Retrospective analysis using MENDS EHR network data, statistical weighting (post-stratification), and external comparison to BRFSS/PLACES	Weighted MENDS estimates were ~10% lower than crude and ~13% higher than BRFSS awareness; geographic and demographic stratifications aligned; identified disparities by sex, race, payer, geography
Mechikoff, M.A.; Collins, J.P.; Golder, P.; Ingersoll, C.M.; McGarry, R.E.; Lu, X.-J.; Gokden, A.; Cuff, A.; Webber, B.J.; Wallace, A.B.; Steel, J.J.; Wickiser, J.K.; Balboni, A.L. (2025). Application of Pan-Viral Metagenomic Sequencing on United States Air Force Academy Wastewater to Uncover Potential Causes of Acute Gastroenteritis	Journal Article	Wastewater Surveillance	Assess utility of VirCapSeq-VERT in wastewater surveillance for detecting viral pathogens at a military installation	Pan-viral sequencing (VirCapSeq-VERT) with Illumina NextSeq; phylogenetic analysis and custom bioinformatics pipelines	Detected 68 viral families including human adenovirus, astrovirus, rotavirus, and norovirus (acute gastroenteritis). Adenovirus serotype 41 predominated early; astrovirus surged after cadets returned from winter break.
Williams KS, Rahurkar S, Grannis SJ, Schleyer TK, Dixon BE (2025). Evolution of clinical Health Information Exchanges to population health resources: a case study of the Indiana network for patient care	Journal Article	Data Modernization / Interoperability	Describe the evolution of the Indiana Network for Patient Care (INPC) into a population health resource; highlight key innovations supporting population and clinical applications	Descriptive analytical case study with literature review and operational data abstraction	By Dec 2023, INPC included nearly 25 million patients; expanded uses include ELR, cancer registry linkage (89% match), Patient-Centered Data Homes, COVID-19 data commons, ACO support; HIE uniquely positioned to support population health
Yang W, Omoregie E, Olsen A, Watts E. A., Parton H, Lee E (2025). The use of wastewater surveillance to estimate SARS-CoV-2 fecal viral shedding pattern and identify time periods with intensified transmission	Journal Article	Wastewater Surveillance	Characterize SARS-CoV-2 shedding via wastewater in NYC (2020–2023) and detect periods of increased transmission	Retrospective epidemiological modeling combining wastewater viral load and inferred infection prevalence (SEIRSV model; bootstrapping for anomalies)	Estimated variant-specific fecal shedding durations and rates; identified ~200 intensified transmission periods; demonstrated wastewater+modeling for surveillance

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Zwald ML; Holland KM; Sumner SA; Sheppard M; Chen Y; Wallace A; Friar NW; Simon TR (2025). Trends in Firearm Injuries Treated in Emergency Departments by Individual- and County-Level Characteristics, 2019 to 2023	Journal Article	Syndromic Surveillance	Examine recent trends in emergency department visits for firearm injuries by demographic, geographic, and social vulnerability factors using near real-time surveillance data	Observational study using syndromic surveillance administrative data with statistical analysis of temporal trends and social determinants	Firearm injury ED visits increased substantially in 2020 compared to 2019, especially among youth and in high social vulnerability counties; increases sustained through 2023 with disparities by age, sex, and urbanicity