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Monitoring and Reporting the US COVID-19 Vaccination Effort

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Abstract

Immunizations are an important tool to reduce the burden of vaccine preventable diseases and improve population health.[1] High-quality immunization data is essential to inform clinical and public health interventions and respond to outbreaks of vaccine-preventable diseases. To track COVID-19 vaccines and vaccinations, CDC established an integrated network that included vaccination provider systems, health information exchange systems, immunization information systems, pharmacy and dialysis systems, vaccine ordering systems, electronic health records, and tools to support mass vaccination clinics. All these systems reported data to CDC's COVID-19 response system (either directly or indirectly) where it was processed, analyzed, and disseminated. This unprecedented vaccine tracking effort provided essential information for public health officials that was used to monitor the COVID-19 response and guide decisions. This paper will describe systems, processes, and policies that enabled monitoring and reporting of COVID-19

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vaccination efforts and share challenges and lessons learned for future public health emergency responses.

Keywords

COVID-19; vaccine administration; public health surveillance; immunization; informatics; public health emergency response

Introduction

Immunizations are an important tool to reduce the burden of vaccine preventable diseases and improve population health.[1] High-quality immunization data is essential to inform clinical and public health interventions and respond to outbreaks of vaccine-preventable diseases. However, the de-centralized approach to public health service delivery, disparate state and local public health authorities, and multiple parties responsible for providing vaccination services, make high quality data collection challenging. Vaccine administration data is collected by systems at the point of care including electronic health records and pharmacy systems. For most vaccination providers, these data are then consolidated by jurisdiction public health authorities in Immunization Information Systems (IIS). IIS are confidential, population-based, computerized databases that record all immunization doses administered by participating providers to persons residing within a given geopolitical area.[2] IIS exist within Immunization Programs and play a critical role in providing data related to vaccine ordering and inventory management, clinical decision support (evaluation and forecasting), reminder/recall capabilities for patient follow-up, consolidated immunization histories, proof of immunity, and vaccination coverage estimates for specific geographic areas and population groups.[3]

IIS are governed by a complex array of state, territorial, and local laws and policies for patient consent and provider reporting; these specify which providers must report to an IIS, the types of data that can be collected, and what data may be shared for public health purposes[4]. IIS played a critical role in the COVID-19 pandemic response but by themselves were not sufficient to provide timely and complete information for public health decision making at the national level.

Although the Centers for Disease Control and Prevention (CDC) has historically provided funding for IIS via the 317 and Vaccines for Children Program Immunization Cooperative Agreement and has established the standards for IIS functionality and data exchange, it has not broadly collected data from IIS and did not have all the necessary infrastructure in place to do so. However, the COVID-19 pandemic required unprecedented access to vaccine ordering systems and vaccination data to inform rapid response, identify areas of need, track vaccine inventory, and enable efficient and timely vaccine distribution. To support the CDC COVID-19 Response, Vaccine Task Force, IIS functionality[5] and data standards for interoperability[6], standard vocabulary/vaccine code sets[7], providers' and partners' systems, and CDC infrastructure were leveraged to develop a complex data and technology ecosystem (Table 1). This ecosystem enabled a streamlined process for vaccine ordering, distribution, administration, and vaccine data monitoring across the public health systems, including the

ability to track provider enrollment, vaccine orders, inventory, distribution, wastage, and administration.

CDC established an integrated network of information systems to track COVID-19 vaccines and vaccinations. The network included entities that were participating in the COVID-19 federal vaccination program such as health care provider systems, health information exchange systems, IIS, pharmacy and dialysis systems, vaccine ordering systems, electronic health records (EHRs), and tools to support mass vaccination clinics. Data from all of these systems were reported either directly by the participating entity or indirectly via IIS to CDC's COVID-19 data collection ecosystem, where it was processed, analyzed, and disseminated. In some cases, entities reported data directly to CDC (e.g., federal agencies) because they were unable to onboard to multiple IIS within the required timeframe, or they reported to both their IIS and to CDC to provide additional insight into distribution through different channels (e.g., pharmacy specific distribution). Establishing this complex ecosystem required both traditional and non-traditional partnerships, including vaccine manufacturers, data publishers, vendors (e.g., IIS, EHRs, and payers), providers (e.g., federal agencies, pharmacies, and dialysis centers), and data exchange partners (e.g., third-party entities that facilitate data exchange between partners such as between pharmacy chains and IIS, see Table 2).

As of May 11, 2023, which was the end of the COVID-19 public health emergency declaration, these systems have tracked:

- Enrollment data for approximately 125,000 jurisdiction provider sites, 54,000 individual pharmacy sites, and 5,600 dialysis center sites participating in the COVID-19 vaccine program
- Distribution of 984,444,295 doses of COVID-vaccines
- Administration of 676,728,782 doses of COVID-vaccines

This paper explores the systems, processes, and policies that enabled monitoring and reporting of COVID-19 vaccination efforts nationally and shares challenges and lessons learned for future public health emergency responses.

Preparing to Monitor COVID-19 Vaccine Distribution and Administration

To address the scope and complexity of the pandemic response, public health technology infrastructure needed enhancement to support COVID-19 vaccination efforts across the country and ensure that data were available to drive public health decisions, such as equitable vaccine distribution. CDC assessed data requirements and conducted an analysis of existing capabilities in spring 2020. The analysis identified both CDC-owned systems and external systems that would have a role in implementing the COVID-19 Vaccine Program.

In anticipation of vaccine availability, CDC identified data requirements in areas including:

- Manufacturing
- Ordering, distribution, inventory tracking and disposition (i.e., wastage, transfer)

- Administration
- Post-administration patient follow-up
- Vaccine safety monitoring

By comparing the data requirements and the analysis of existing capabilities (see Table 1), CDC developed a coordinated strategy to link and enhance existing systems and to develop new systems to fill gaps such as collecting, processing, and analyzing data at the national level and monitoring ordering, distribution, and inventory. The IT ecosystem was developed and deployed in December 2020 (Table 1). This strategy ensured coordination among multiple system types. The ecosystem accommodates numerous data flows and related processes, different system languages, differing approaches to implementing the same specification standards, multiple data transport mechanisms, integration of new partners to support their COVID-19 response, and varying resource challenges.

Tracking COVID-19 vaccines and administration was possible because decades of work resulted in a strong foundation for immunization data capture and exchange.[8] This included jurisdiction IIS; CDC's ordering and inventory management system, Vaccine Tracking System (VTrckS); FluFinder/VaccineFinder, a publicly available system for determining the availability of specific vaccines in communities; Vaccine Adverse Event Reporting System (VAERS); and data and technology standards. In addition, CDC developed multi-tiered emergency response policy requirements to support data collection for every dose of vaccine, new and expanded partnerships, and deployment of a multi-disciplinary team with the ability to design, build, and launch systems and services rapidly and iteratively.

Policy Requirements for Data Collection, Exchange, and Use

Data collection at the national level was essential to ensure effective use of federally purchased vaccine, monitor vaccine uptake and inventory, make informed decisions about vaccine allocation, and inform public health interventions. Data collection was governed by clear reporting requirements for all providers involved in the response. The reporting requirements were specified in COVID-19 Vaccine Program provider agreements. The universal reporting requirement for all providers participating in the COVID-19 vaccine program enabled standardized, complete, and timely data collection for every dose of COVID-19 vaccine, which was not possible pre-response due to the constraints posed by disparate state and local laws. The implementation of the universal provider agreement facilitated the reporting of every dose of vaccine administered to the jurisdiction's IIS or a system designated by CDC (e.g., COVID-19 Data Clearinghouse or the Immunization Data Lake). The provider agreement closed reporting gaps for jurisdictions with limited or no requirements for providers to report data to the jurisdictional IIS. Without this requirement, gaps may have existed in data from specific provider types or for specific age groups (e.g., children only) in some jurisdictions. The provider agreement required providers to report COVID-19 vaccinations to the IIS within 72 hours of administration. This requirement was critical to ensuring accurate, timely state-based assessment of COVID-19 vaccine uptake and timely information at the national level.

Data submission by jurisdictional IIS and other partners to the CDC, and how it was used, were facilitated through detailed legal agreements between the CDC and each participating entity. Jurisdictions signed data use agreements (DUA)[9], and federal agency, pharmacy, and dialysis partners signed memoranda of agreement (MOA), that described data reporting requirements, data privacy and security, data usage, and aligned business processes with appropriate information systems, which formed the CDC COVID-19 technology ecosystem.[10] Jurisdictions engaged with CDC to adjust DUA language when state laws required more limited data sharing. Changes to the standard DUA were identified as redlined agreements. In some cases, redlined agreements resulted in specific data elements being redacted or adjusted within line level records, for example, submitting month and year of birth instead of month, day and year of birth. In a few cases, these redlined agreements resulted in the submission of aggregate data (counts of vaccinations) for various demographic characteristics by the jurisdiction rather than de-identified record level data. Entities signing MOAs with the CDC in some cases also redlined the MOAs to limit the data submitted to reflect the sensitive nature of information related to personnel or locations. Data submitted to CDC by jurisdictions and other partners were a subset of the data received from participating providers. The data set excluded personally identifiable information and represented the minimum data set necessary to monitor efforts to intervene in a pandemic and ensure accountability for federally purchased vaccine.

CDC developed the COVID-19 Vaccine Reporting Specifications (CVRS) that defined data reporting requirements and the format for COVID-19 vaccination data submissions.[10] The CVRS contained a limited subset of the data elements collected by providers during a vaccination event, including demographic and vaccination information. IIS and response partners submitted redacted (i.e., de-identified) vaccine administration data daily to CDC through a new system, the COVID-19 Data Clearinghouse (DCH) according to the CVRS. Providers were also required to place orders and report on-hand inventory using designated systems and specifications. Reporting specifications and supporting systems were updated as new vaccines became available throughout the response.

Partnerships

New and expanded partnerships were critical to mount an effective nationwide vaccine campaign, resulting in more complete and timely data, rapid development and publication of required vaccine codes, and improved data exchange for all vaccine administration data. CDC established a dedicated team to work directly with the Biomedical Advanced Research and Development Authority (BARDA) and the Food and Drug Administration (FDA) to assure rapid confirmation of new National Drug Codes (NDCs). Vaccine administration codes (CVX) and vaccine manufacturer codes (MVX) were documented and made available to all partners throughout the response effort to standardize data collection and reporting.

The CDC developed unprecedented partnerships with large chain and independent pharmacy organizations, dialysis centers, and federal agencies to expand the community-level reach and accessibility for COVID-19 vaccine administration and establish reporting of vaccination data to CDC for the first time. Early release and publication of vaccine code sets were critical in assuring that the data management systems used by electronic health record

vendors, pharmacies, provider offices, jurisdictional IIS, and federal partners were prepared in advance of emergency use authorizations (EUA) to schedule appointments, administer COVID-19 vaccines, document the correct clinical information for each administration, and report the information to the IIS and CDC. The CDC worked closely with the American Medical Association (AMA) to assure the most current procedural terminology (CPT) was available upon authorization to complete billing workflows for vaccine administration. CDC also worked with the National Council for Prescription Drug Programs (NCPDP) to share information as quickly as possible and support NCPDP in releasing and updating guidance to pharmacies on COVID-19 vaccine billing and reimbursement claims for vaccine administrations. The rapid developments and updates to COVID-19 vaccines required constant engagement with these partners, and continuous communication to all partners to assure current, correct coding was used to document COVID-19 vaccines and vaccinations.

CDC's COVID-19 Data Monitoring and Reporting team was highly engaged with the Advisory Committee on Immunization Practices (ACIP) COVID-19 workgroup. This partnership included providing data to support ACIP decision making for vaccine recommendations and translating ACIP recommendations into Clinical Decision Support for Immunization (CDSi) resources. The CDC publishes CDSi resources to support the evaluation and proper forecasting of vaccinations for individuals receiving COVID-19 vaccines. Partners use CDSi to update their vaccine forecasting algorithms, manage vaccination reminder and recall efforts, and ensure patients received the right vaccine at the right time, including completing the vaccination series and booster doses as appropriate.

In addition, CDC established a data management and governance structure that:

- Identified CDC data stewards for each submitting entity,
- Aligned with the data reporting requirements, and
- Assured CDC partner policy requirements for proper data use and governance throughout the response.

Implementing the COVID-19 Data and Technology Ecosystem

A multi-disciplinary team comprised of public health practitioners, informaticians, analysts, and epidemiologists worked collaboratively to design, build, and launch the COVID-19 vaccine data, technology ecosystem and business processes within a six-month period prior to vaccine availability. The ecosystem leveraged existing public health and health information technology systems and services whenever possible, but, in some cases, new tools were developed by the CDC and technology partners to address gaps. The highly integrated ecosystem includes systems and data flows for provider enrollment, vaccine ordering, distribution, administration, and vaccine and data disposition. These systems include:

- Jurisdiction Immunization Information Systems (IIS): consolidate immunization information into one reliable source for providers, families, and public health officials. Each of the 64 jurisdictions funded by the 317 and Vaccines for Children cooperative agreement uses an IIS that was enhanced to support the

response. Examples of enhancements include increased data transfer capability, cloud hosting, and integration with scheduling/mass vaccination tools.

- Vaccine Tracking System (VTrckS): secure, web-based system that integrates the supply chain for publicly funded vaccine from purchasing and ordering through distribution to participating state, local, and territorial health departments, and health care providers. VTrckS was enhanced to support the response. Examples of enhancements include addition of a COVID-19 provider identifier and the addition of numerous new vaccine products.
- VTrckS Partner Order Portal (VPoP)/Health Partner Order Portal (HPoP): manages provider data, ordering, inventory, wastage, transfers, and other reporting functionality for participating federal agencies, pharmacy partners, and dialysis partners. VPoP was a new system that interfaced with VTrckS and was implemented leveraging established VTrckS file specifications specifically to support quick and safe access to the supply chain of COVID-19 vaccine for newly onboarded partners such as pharmacies, federal agencies, and dialysis centers. VPoP allowed rapid onboarding of a large number of providers in a short timeframe, which was not possible leveraging existing systems. The accelerated time frame of the pandemic response prohibited leveraging existing platforms (i.e., VTrckS) due to the large-scale onboarding and the required development changes.
- Vaccines.gov (previously known as VaccineFinder): information system that provides a public-facing portal to assist people in finding providers that offer select vaccines. Vaccines.gov also allows healthcare providers to list their vaccination locations in a centralized, searchable database and to track vaccine supply. Vaccines.gov was enhanced to support the response. Examples of enhancements include capability for provider-level tracking of on-hand inventory, usability improvements, and addition of new vaccine products
- V-safe: safety monitoring system that uses personalized and confidential health check-ins via text messages and web surveys to allow people to share their post vaccination experience with CDC. V-safe was a new system that was implemented specifically for the COVID-19 response to allow rapid data collection on post-vaccination concerns.
- Vaccine Administration Management System (VAMS): secure, online system to support management and operations of vaccination clinics including tracking inventory, clinic setup, appointment schedules, patient registration, vaccine administration, and post-administration follow up. VAMS was a new system that was implemented specifically for the COVID-19 response and served as a safety net for vaccinating entities without an electronic system to capture information and to support temporary, satellite, mobile, and mass vaccination clinics. VAMS was made available free of charge to jurisdictions that did not have existing capability, as well as federal partners, and vaccinating providers.

- CDC Immunization (IZ) Gateway: secure, message routing service that streamlines connections needed between partners for data exchange. The IZ Gateway facilitates data exchange between IIS, provider electronic health record systems and IIS, IIS and consumer applications, and IIS to CDC. IZ Gateway was enhanced to support the response.
- COVID-19 Data Clearinghouse (DCH): cloud-hosted data repository that receives, deduplicates, and deidentifies COVID-19 vaccination data that populate the IZ Data Lake with deidentified data for analytics. DCH was a new system that was implemented specifically for the COVID-19 response in order to rapidly onboard and operationalize reporting of vaccine administration data from data partners. DCH enabled Jurisdictional IIS, federal agency, and pharmacy partners to electronically submit COVID-19 vaccination data to the CDC. In addition, DCH allowed partners to validate submissions, update and delete COVID-19 administrations reported previously to ensure CDC had more accurate count of COVID-19 vaccination events. These capabilities did not previously exist.
- Tiberius: secure web-based system configured to collect, integrate, analyze, and visualize information from multiple data sources to provide decision-makers timely supply chain insight to guide deployment of medical countermeasures. Tiberius was a new system that was implemented specifically for the COVID-19 response and allowed data partners to access metrics and leverage the visual analytics and dashboards for public health decisions including jurisdiction planning.
- CDC COVID-19 Data Tracker (CDT): dynamic, web-based dashboard used to display vaccination, hospitalization, death, and emergency room visit data associated with COVID-19. CDT was a new system that was implemented specifically for the COVID-19 response to provide information to the general public on the COVID-19 pandemic including cases, deaths, hospitalizations, and vaccinations.
- IZ Data Lake (IZDL): cloud-hosted data repository that receives, stores, and analyzes deidentified COVID-19 vaccination data including vaccine administration, enrollment, logistics, inventory, ordering, distribution, and provider data from CDC systems, jurisdictions, federal agencies, pharmacy partners, and dialysis partners. The IZDL is the data storefront responsible for sending data to the HHS Protect data hub, HHS Tiberius, the CDC COVID-19 Data Tracker (CDT), and CDC public datasets (data.cdc.gov). IZDL was a new system that was implemented specifically for the COVID-19 response. Prior to implementation of IZDL, there was no one big data platform for immunization data at CDC that had the required capabilities to handle the volume, velocity and variability of data reported for COVID-19.

Figure 1 shows the interactions between the COVID-19 vaccination reporting data systems and the different system users and Table 1 describes how each system was used to support the CDC COVID-19 response.

Partner IT and Data Support

To operationalize the CDC COVID-19 Response, Vaccine Task Force monitoring effort, CDC dedicated teams to work with each partner in the response to assure the information systems and processes they used were technically ready to meet vaccination data reporting requirements. In addition, CDC assisted each partner with initiating accounts and establishing system access to complete the necessary business processes associated with the response. This work included verifying the identity of users for each partner, establishing two-factor authentication, processing account requests, and defining terms of agreement as needed for each system. Ongoing support for users was provided by a complement of help desk and technical assistance staff that system users could contact for assistance in troubleshooting system issues. For the 64 jurisdictional IIS, the first line of assistance was often a team of IIS subject matter experts who could direct users to the appropriate help desk, coordinate across teams supporting the response, and pursue information the jurisdiction needed to successfully partner in the response. Similarly, technical assistance was provided to federal agency, pharmacy, and dialysis partners by a dedicated team of subject matter experts.

Throughout the response, technical assistance was provided to participating entities to assure the highest quality vaccination data were reported and available for decision making. CDC developed data quality reports for federal agency, pharmacy, dialysis, and jurisdictional IIS partners. Each partner received weekly data quality reports that reflected missing, invalid, or illogical values submitted for the previous week's data submissions and recommendations for approaches to address the identified issues. These reports were then used to determine the need to update previously submitted data. The DCH was enhanced to allow for both updates for incorrect or invalid values and deletion of duplicate records to improve data quality. The process for using updates and deletes to improve data quality included a pre-submission validation check by the organization, notification to response leaderships of the impact of the changes at the state level, and notification to impacted states of the pending change the week prior to the updates or deletes being processed in the production environment. Federal agency, pharmacy, dialysis, and jurisdictional IIS partners used this functionality beginning in July 2021 as a mechanism for data quality improvement. These efforts required close coordination between the jurisdiction, IIS subject matter experts, federal agency, pharmacy, dialysis centers, DCH, and IZDL teams for completion. Additional coordination was required with the Tiberius and CDT teams to manage updates to outward-facing systems, assure proper footnoting, and support responses to internal and external queries. The high-quality data resulting from this effort supported confidence for the use of vaccine administration data to enhance survey data collected through the COVID modules of the National Immunization Survey (NIS).

The unprecedented collection and visibility of vaccination data from multiple partners, complexities of data gathering, and data sharing guided by DUAs and MOAs resulted in many opportunities to identify and address concerns about discrepancies between data presented on state dashboards and data presented on CDT. The high visibility resulted in engagement with the media, state and local government officials, jurisdiction leadership, and other stakeholders. Outcomes of these inquiries included the development of resources to

add clarity to the data displayed on CDT and the contribution of each group of participating providers. In addition, to support jurisdiction planning efforts, increased data visibility was added in the Tiberius platform that allowed jurisdictions to see federal agency data impacts at the county level, with detail that supported health equity and series completion goals. In-depth data reviews and follow-up were also provided to jurisdictions if specific concerns about data discrepancies arose. CDC used in-depth data reviews to work with jurisdictions to identify and resolve IIS related data discrepancies as well.

Challenges and Lessons Learned

The policy framework to secure reporting from the diverse stakeholders participating in the COVID-19 vaccine response required several data sharing agreements and MOAs for each component of the COVID-19 vaccine response, including vaccine administration, distribution, and vaccination provider reporting to jurisdictions. The level of effort required to process multiple agreements, negotiate them with 64 jurisdictions and other participating partners, and complete the signatory process was time-consuming, confusing for participants, and required involvement of a significant number of staff within and across agencies. In addition, pursuit of the response related reporting agreements came amid requirements for agreements supporting data exchange between various partners of the response. This process identified a need for consolidating the data sharing and data exchange agreements. The result was the creation of the consolidated data use agreement between the CDC and each jurisdiction that included COVID-19 vaccines but also covered the submission of routine vaccination data, seasonal influenza vaccination data, and reporting requirements for outbreaks and pandemic events. In addition, CDC, in collaboration with partners, streamlined legal agreements required for participation in the IZ Gateway. The IZ Gateway consolidated data exchange agreement allows multi-jurisdiction vaccination providers and jurisdictional IIS to sign one time to allow data exchange to occur with all jurisdictions and multi-jurisdictional providers who also signed the agreement. The establishment of consolidated agreements and expansion of the IZ Gateway functionality has positioned the CDC to be proactive in allowing rapid implementation of vaccination data submission and reporting now and in the future.

After legal agreements were negotiated and data submission began, it was essential to have processes in place to reflect data quality back to jurisdictions, federal agencies, pharmacies, and dialysis partners, as well as to have a way to improve data quality. The use of the DCH update and delete process became a routine aspect of improving data quality for many partners. Overall, during the response, 55 entities utilized the update and delete functionality 263 times. About 260 million records were submitted through this process for update or deletion over the course of the response, leading to a more complete and accurate depiction of the data associated with the national COVID-19 response effort.

Existing standards for immunization data exchange[12] are broadly used by IIS but flexibility within the existing standards and variations in how the standards are implemented across systems inhibit the scope of data exchange needed to support a global pandemic response. CDC's IZ Gateway provides the technical capability to exchange data between jurisdictions, from multi-state providers to jurisdictions, and from jurisdictions to consumers, but more

work is needed to broaden its use and leverage the efficiencies it offers. CDC, federal partners, and jurisdictions have made significant strides in data exchange using the IZ Gateway as a result of COVID-19 investments. However, barriers persist. The allowable variances in the current data exchange standards add complexity to establishing connections between exchange partners. This complexity requires significant resources, time and sometimes development work by one or both exchange partners. There is significant variance in the technical capability and standardization of IIS. Not all systems meet the CDC's IIS Functional Standards or operate using the national HL7 Implementation Guide.[11] There is not currently a certification process for IIS technology.[4] Connecting to the IZ Gateway requires compliance with standards and the IZ Gateway onboarding process has accelerated improvements in IIS. However, this process has also highlighted additional efforts needed to achieve better alignment.

Some jurisdictions have legacy IIS that need replacement or modernization. Without critical modernization, not only will IIS be unable to fully leverage the efficiencies the IZ Gateway connection offers, but they will also not be able to leverage emerging standards and technology that accelerate interoperability. Federal providers have some unique challenges. Not all federal agencies use certified health IT, in part due to some of their unique use cases. As a result, some federal agency immunization systems lack the technical capability needed to exchange data using existing standards and/or to onboard the IZ Gateway and share data with jurisdiction IIS and other federal partners. The IZ Gateway has and continues to identify and implement process and technical improvements to gain efficiencies. However, to achieve efficient, seamless, and scalable interoperability, more consistency in the application of immunization exchange standards, standardization of IIS technology, and modernization of connecting systems is needed.

The collection and processing of daily COVID-19 vaccination data was only made possible by the expansion of IZDL. The IZDL is a cloud-based data processing repository capable of ingesting and processing an array of vaccine response-related data, including vaccine administration data from jurisdictions, pharmacies, dialysis centers, and federal agencies. Vaccine administration data processing included the transformation of information obtained from the CVRS data files into vaccination coverage and doses administered data for the externally facing CDT. The public and other government entities (including the White House) used CDT to monitor COVID-19 vaccination coverage. It was also integrated with other critical vaccine response data sources (e.g., cases, hospitalizations, deaths, and vaccine safety) to inform critical public health communications. In addition, IZDL fed data to response systems such as Tiberius, which was used by jurisdictions and federal agencies to monitor key metrics related to orders, distribution, inventory, and administration.

Vaccination data collection is de-centralized through provider and public health systems and historically very little routine vaccination data flowed to the national level. Data that is shared with CDC is de-identified, which poses challenges for patient matching, de-duplication, and linkage with other data sets to develop a more complete picture of population health. Due to policy restrictions at the state level, some jurisdictions were restricted to sharing aggregate counts of COVID-19 vaccination events rather than more detailed data on each administration. Submitting aggregate data was a time-consuming

process for both the impacted jurisdictions and CDC staff who had to extract the data, use algorithms to process the data consistent with other data being processed by CDC, and integrate it with other data submissions, often using manual processes. The COVID-19 pandemic highlighted opportunities to improve access to and usefulness of vaccination data by implementing technology such as Privacy Preserving Record Linkage (PPRL) that results in higher quality linked data without identifying individuals[13,14]. PPRL technology has broader applicability than immunization data and would enable linkage of deidentified data sets across data domains to inform public health decision making such as combining nationally notifiable disease surveillance data with immunization data to understand areas where there may be increased risk of a vaccine preventable disease outbreak and populations at greater risk.

The unprecedented tracking of the COVID-19 response was only possible because of the foundation laid by years of work by local, state, territorial public health agencies federal agencies, and their partners. Continued investment in the infrastructure that supported the COVID-19 response is critical for future public health emergencies and to support routine immunization activities to prevent vaccine preventable diseases. Many routine immunization activities can leverage the same technology resources and can benefit from the same data requirements and policies that were used for the COVID-19 response so that data can be collected in a consistent, timely manner and be used to inform public health decision making (Figure 2). This would ensure that knowledge and expertise are available to prepare for the next public health emergency. Investments in technology and immunization processes made prior to 2019 (e.g., IIS, VTrckS, IZ Gateway) were leveraged to support the response. Use of existing technology and processes allowed jurisdictions to focus on scaling systems and processes to meet response needs. Post-response systems established to fill gaps are being reviewed to determine if they are still needed, and if so, make the appropriate investments to incorporate them into infrastructure that supports routine immunizations across the lifespan and prepare for the next pandemic response. Ongoing investment in systems used to support business processes, data exchange, and data management needed to operationalize immunization programs and monitor vaccine distribution, uptake, and coverage are necessary to ensure public health’s ability to rapidly scale up for the future public health emergencies.

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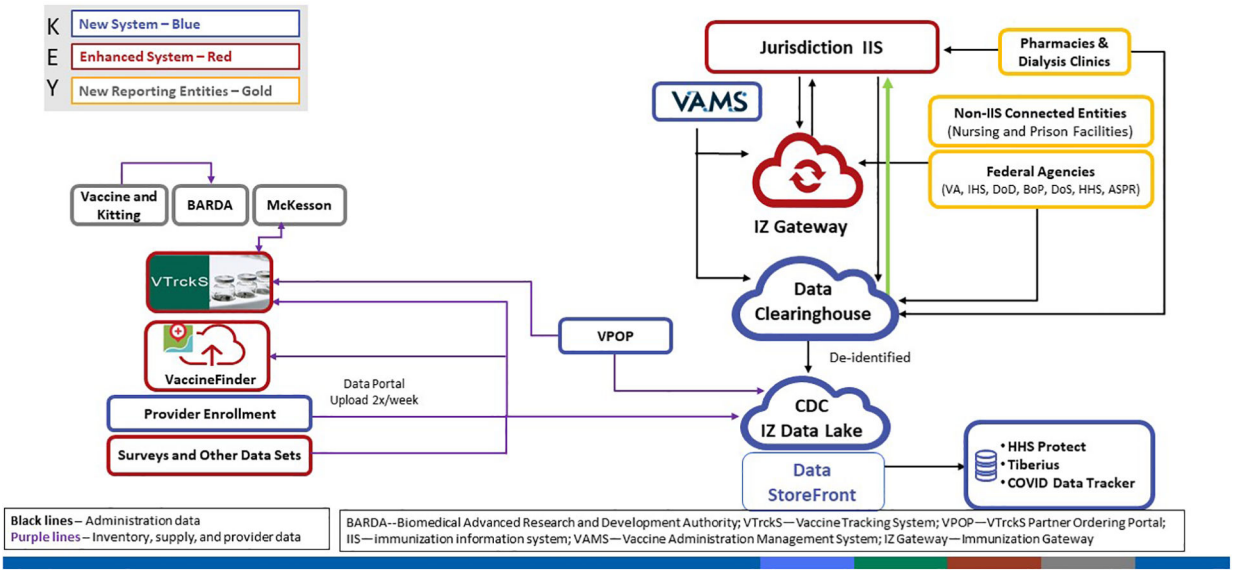

Figure 1:
COVID-19 Vaccine Information Architecture

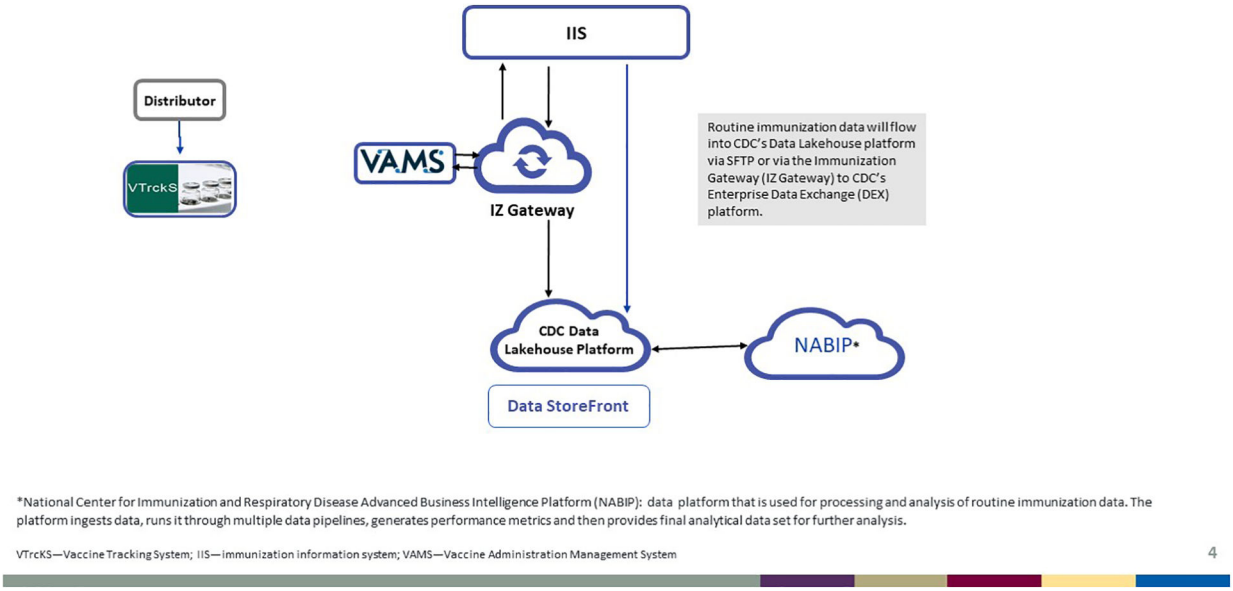

Figure 2:
Routine Immunization Information Architecture

Table 1:

Role of Systems in the COVID-19 Vaccine Response

System Name	System Type	COVID-19 Function
Jurisdiction Immunization Information Systems (IIS)	Enhanced	Jurisdictions used their IIS for provider enrollment, vaccine ordering, inventory management, collection of vaccine administration data, vaccine accountability, and reporting vaccination data to CDC.
Vaccine Tracking System (VTrckS)	Enhanced	Provided the master record of providers enrolled to receive vaccine. Tracked orders, shipments, and wastage aspects of the supply chain.
Vaccine Tracking System (VTrckS) Partner Order Portal (VPoP)	New	In conjunction with the existing VTrckS system the VTrckS Partner Order Portal enabled 30 commercial and 7 federal agency partners with more than 60,000 provider locations (pharmacies, dialysis clinics, mobile mass vaccination clinics, federal clinics) to place and receive COVID-19 vaccine orders.
Vaccines.gov (aka VaccineFinder)	Enhanced	Vaccines.gov serves two roles in the COVID-19 vaccination program: 1) inventory reporting for all COVID-19 vaccine providers and 2) supporting peoples' ability to find locations offering COVID-19 vaccines.
Vaccine Administration Management System (VAMS)	New	Twelve jurisdictions, 4 federal vaccine provider organizations, and 4 non-federal vaccine provider organizations used VAMS to support their vaccination clinics and to document and report COVID-19 vaccine administration.
CDC Immunization Gateway (IZ Gateway)	Enhanced	The IZ Gateway automated reporting COVID-19 vaccine administration data documented in VAMS to the IZDL and/or appropriate jurisdiction IIS.
Data Clearinghouse (DCH)	New	Jurisdictional IIS, federal agency, and pharmacy partners submitted COVID-19 vaccination data to the CDC via the DCH throughout the response effort.
Tiberius	New	Provided jurisdictions and federal agencies with dashboards on key metrics related to orders, inventory, shipping and distribution, and administration. Also provided tools to support jurisdiction planning.
CDC COVID-19 Data Tracker (CDT)	New	The dashboard includes detailed information about vaccination coverage by geographic area and various demographic characteristics.
Immunization Data Lake (IZDL)	New	The IZDL processes and stores vaccine administration, enrollment coverage, logistics, inventory, ordering, distribution, and provider data from CDC systems, jurisdictions, federal agencies, pharmacy partners, and dialysis partners. The IZDL is responsible for sending data to the HHS Protect data hub, the HHS Tiberius system, CDC COVID-19 Data Tracker (CDT), and the CDC public datasets (data.cdc.gov).
v-safe	New	Post-vaccination safety monitoring tool that allowed vaccine recipients to sign up to report any post-vaccination concerns to CDC.

Table 2:

Primary CDC COVID-19 Vaccine Data Partners

Entity	Count
Federal Agencies *Health Resources and Services Administration, Indian Health Service, Department of Veterans Affairs, Federal Bureau of Prisons, Department of Defense, National Institutes of Health, and Department of State*	7
Data Publishers *American Medical Association, Cerner Multum, Elsevier, First Databank, IBM Micromedex, National Council for Prescription Drug Programs, National Library of Medicine, Walters Kluwer*	**8**
Jurisdictions *50 States, District of Columbia, 5 large cities, 3 freely associated states and 5 US territories*	**64**
Commercial Providers	**23**
Pharmacies (21) *Albertson's Companies, Inc., Amerisource-Bergen Drug Corp, Cardinal Health, Costco Wholesale Corp., CPESN USA, CVS Health, GeriMed, Inc., Health Mart Systems, Inc., H-E-B Pharmacy, Hy-Vee, Inc., Innovatix, Inc., Managed Healthcare Associates, Meijer, Publix Supermarkets, Retail Business Services LLC, Rite Aid, Southeastern Grocers, The Kroger Company, Topco, Walgreens, Walmart*	
Dialysis Centers (2) *DaVita, Inc., Fresenius Kidney Care*	
Payers	**5**
COVID-19 Manufacturers	**6**
IIS Data Exchange & Systems Vendors	**3**