The 2019 novel coronavirus is on pace to overtake the 1918 influenza as the deadliest pandemic in U.S. history. A highly efficient strategy for vaccination is crucial to curbing the public health crisis. In January 2021, UCHealth — an innovative nonprofit health system serving Colorado, southern Wyoming, and western Nebraska — brought together key stakeholders to develop a new drive-through vaccination model with the goal of providing immunizations to 10,000 individuals over a 2-day period, which would be the largest vaccination effort in the United States at that time. Health care innovators, operational leaders, and information technology experts used iterative process improvement and real-time data collection to create the model. Their standards for efficiency in handling high-volume events are published in a playbook available to any entity hoping to utilize drive-through mass vaccination. From arrival to departure, median time spent in the vaccination clinic was 24 minutes, including 15 minutes of observation.

As the Covid-19 pandemic continues to cause widespread death and suffering, even vaccine distribution has been a source of friction and consternation. Early on, news media outlets reported on lengthy wait times and lack of clarity around eligibility and how to get a vaccine. Photographs depicted elderly citizens camped out in front of vaccination sites like pre-pandemic technophiles awaiting the newest generation of iPhone. In late January 2021, the U.S. Centers for Disease Control and Prevention (CDC) estimated that 41.4 million Covid-19 vaccine doses had been distributed across the country, but only 22.7 million vaccine doses had been administered.1 (Even as of late March 2021, when 77% of 195 million delivered doses had been administered, the CDC reported that only 16.4% of the U.S. population had been fully vaccinated.2)
In December 2021, after vaccinating Phase 1A staff in hospital-based clinics, UCHHealth (an integrated community and academic health system with 12 hospitals and more than 150 owned and affiliated clinics) utilized multiple models to provide vaccinations to elderly and at-risk community members. Vaccination delivery models used included brick-and-mortar clinics, community-based pop-up clinics, and, most recently, a drive-through mass-vaccination clinic. Drive-through vaccination clinics have been successful in previous public health events, including influenza immunizations. This approach does not require hospital or clinic space to operate, enforces social distancing by default, and utilizes otherwise empty large venue sites, including sports stadiums or large parking lots. Covid-19 drive-through testing centers have been shown to be superior to traditional models around the world. Despite some skepticism about the feasibility of efficient drive-through mass-vaccination clinics, UCHHealth’s design process produced a highly efficient model. As of March 31, 2021, we have held five drive-through vaccination events: a pilot event for 1,000 on January 24, with a follow-up second dose event for those 1,000 on February 14 (which we converted to an indoor walk-up event due to inclement weather); a 2-day first-dose mass-vaccination drive-through event with 5,000 shots each day, January 30 and 31; and a 2-day second-dose drive-through event, again with 5,000 shots each day, February 20 and 21. Here, we describe how the effort began.

For our mass-vaccination events, we were able to immunize 834 patients per hour with an average time in the clinic of 22.4 minutes per car for first doses, which includes the 15-minute observation period; that comes to about 5,000 patients over 6 hours. Our success was built by designing a model that relied on strong community partnerships, developing multiple redundancies for potential critical failure points, utilizing rapid process improvement, establishing a strong information technology network, and maintaining nimble clinic operations management.

**Assembling a Team**

The delivery of vaccinations in an outdoor environment requires complex interdependent interactions that touch every corner of health care operations infrastructure. Our team included experts in information technology, logistics and materials support, emergency medical services, emergency department and ambulatory operations, facilities management, traffic control, and parking. Adept project management leadership from UCHHealth’s CARE Innovation Center organized daily team calls; facilitated information sharing, collaboration, and consensus; and ushered the team toward success. We began our work on January 8, 2021, with a site walk-through for the first event that occurred 16 days afterwards, on January 24, 2021.

For our mass-vaccination events, we were able to immunize 834 patients per hour with an average time in the clinic of 22.4 minutes per car for first doses, which includes the 15-minute observation period; that comes to about 5,000 patients over 6 hours.

Strong partnerships with community stakeholders were essential in making this clinic successful. We worked closely with Major League Baseball’s Colorado Rockies, which provided its Coors Field...
site, as well as the State of Colorado, Colorado Department of Public Health and Environment (CDPHE), the City and County of Denver, and the Denver Police Department (DPD). Our DPD resources kept the location safe for staff and patients and provided way-finding during clinic hours. The Colorado Rockies also provided site maintenance, including snow removal, 24-7 site security, information technology (IT) infrastructure support, and meals and snacks for staff throughout the event. The State of Colorado and CDPHE provided the vaccine doses and additional health care volunteers to support the observation area. Additionally, the City and County of Denver supported the event with city street signage and message boards as well as permitting support to ensure code compliance. In the 2 weeks leading up to the event, we held daily internal leadership and community partner calls, during which feedback on plans was exchanged and integrated into the planning process. A formal go/no-go meeting was held the Wednesday before each event weekend to check each team’s preparedness to support the mass vaccination, confirm that the weather forecast was acceptable, verify that vaccine had been received, and ensure that staffing needs had been met.

Finding a Suitable Location

UCHealth and the Colorado Rockies organization have historically been community partners, and this endeavor was a natural progression of the relationship. We registered, vaccinated, and observed patients at two large parking lots (more than 4,300 total spaces) at Coors Field, the team’s baseball stadium. Initial planning sessions included a walk-through of the parking lots with a group of stakeholders including UCHealth, Colorado Department of Public Health and Environment, and Colorado Rockies staff.

Our proposed site had attractive qualities. Namely, the length of the primary parking lot was roughly 2,600 feet, with adequate width to support 22 vehicles parked side by side and access roads to the east and west of these parking stalls (Figure 1).
Ingress Vaccination Schematic

This figure incorporates an aerial photograph of the parking lot at Coors Field with the design of the ingress phase of the drive-through. Vehicles enter, are divided into six queueing lanes, and patients are registered under a large tent, which would be positioned over the areas where the vehicles (1–18), three deep, pause in the six lanes. If all set, vehicles proceed to designated cabanas (numbered white rectangles) where patients are vaccinated. Vehicles with any registration issues or those arriving without appointments are directed to snafu tents to avoid delaying the cars queued behind them.

Cabanas: 1 laptop and 2 high-top tables in each tent, power strips, generators, 2 Rover devices (point-of-care tool/scanner) in each tent

Snafu: 2 Rover devices (point-of-care tool/scanner) and 2 laptops and carts in each tent; need to have IT capability to administer vaccine here

Registration: Laptops on carts, power strips, and extension cords to each cart

Key:
1. Vaccine team shelter with heat source (cabana)
2. Area – redirect cars here if problematic registration
3. Flagger to direct queued cars to specific vaccination stations
4. Pharmacy located on ground floor of garage
5. Greeters to help steer traffic to the correct lanes
6. Incident Command
7. Variable message board
8. Start break area
9. Bailout traffic. There are two bailouts, Bailout A exits on Blake and Bailout B exits on Park Ave.
10. IT Equipment

Source: The authors
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A separate lot to the south could accommodate up to 500 vehicles undergoing observation after their vaccination, which we separated into two larger lots for standard 15-minute observation, and one smaller lot for 30-minute observation (Figure 2).
Located in downtown Denver, Colorado, the site was familiar and accessible to many patients and community members. One of the exits fed quickly onto an interstate highway, which could facilitate rapid egress. A four-story parking garage sits in the middle of the site, affording an elevated position for a command post to, quite literally, oversee the entire operation (Figure 3).
Despite these advantages, some physical constraints of the parking lot threatened our ability to streamline flow. The site is designed to facilitate simultaneous mass ingress or egress to accommodate large-event attendance, but not to perform both functions concurrently. A narrow roadway that connects the two lots is only two lanes wide, and our proposed entrance was from a two-way city street, with only two lanes for ingress. To avoid backing up traffic onto a city street, patients were brought into the lot and rapidly fanned into six queueing lanes using a combination of flaggers, signage, and cones. Greeters walking the lines provided information to patients including consent forms and copies of the FDA emergency use authorization. They instructed patients to expose their arms and complete electronic check-in on their mobile device if not already done. Registration occurred under a large 18-meter by 40-meter tent spanning all six lanes and simultaneously accommodated three cars, bumper to bumper, in each lane.
After patients were checked in via the electronic medical record (EHR), they were directed to one of 16 vaccination cabanas. Each cabana was staffed by two vaccinators who performed vaccination and documented vaccine administration in the EHR in real time; they were free to determine how they would handle the division of tasks. After vaccination, individuals were directed to an adjacent parking lot to wait the recommended 15-minute observation time. They were observed by a team of medical observers, with two medical response teams available for emergencies. If a patient reported a history of anaphylaxis, a pink placard was placed on the car’s windshield at vaccination and the vehicle was directed to a distinct location for 30-minute observation. Signs, cones, and flaggers were utilized for the safety of patients and staff. At every stage, drivers were instructed to place their car in park before staff approached the vehicle.

"Four scenarios were conducted at separate tents using two experienced vaccinators, two newer vaccinators, one vaccinator/one documenter, or one medical student in addition to the vaccination team, respectively. Data on these specific tents reflected the addition of a volunteer could hasten vaccination by a full minute through preparing the patient or supplies for the next vaccination."

The observation parking lot is divided by a promenade, creating East and West lots. At the initial 1,000-dose pilot event, we tested a plan of loading cars in 15-minute cohorts into each lot, discharging the contralateral lot while filling the other. This created a bottleneck as vehicles leaving the vaccination area had to merge down into a single lane. This bottleneck threatened our ability to maximize clinic throughput — during the pilot. Vehicles were backed up to the vaccination stations. We subsequently reworked the observation lot traffic flow, creating arrival lanes that straddle the promenade. Traffic flowed in along these inside lanes and was directed into parking spaces in a serpentine fashion. When the observation time was up, flaggers directed the cars to leave by exiting toward the bordering access roads. This allowed constant ingress and egress from both sides of the parking lot, but also necessitated clear direction from our flag volunteers and careful coordination of this component of staff.

**Scheduling Appointments**

Experience from other states has clearly demonstrated a first-come, first-served model for vaccination is ineffective and dangerous. To ensure an individual’s ability to receive a Covid-19 vaccination in the correct phase, avoid clinic crowding, and to ensure minimal waiting, all patients are required to have scheduled appointments to receive a vaccination. Any residents of Colorado can add themselves to the UCHealth vaccination registry, without regard to their past engagement as a patient with the health system, insurance, or immigration status. UCHealth adhered to the vaccination phases selected based on current state guidelines outlined by the state of Colorado’s website. Patients can utilize UCHealth’s smartphone app, the UCHealth website, or the UCHealth Covid-19 vaccination hotline to place their name on the vaccination registry. The 1,000 pilot patients and 10,000 mass-vaccination patients were randomly selected from the pool of Phase 1B.
on the registry list. In Colorado, this essentially limited our pool to community members 70 and older. We used automated phone calls to reach those patients on the vaccine registry who did not have an active app or Web-based account with which to schedule their appointment. The schedule was filled within 72 hours of opening the appointments for booking.

Across our health system and regardless of vaccination phase, a first-dose appointment cannot be scheduled without simultaneously scheduling the second dose. This ensures appropriate vaccine allocation and avoids missed second doses by compelling the patient to confirm their availability to receive the second dose at the time the first appointment is made. UCHealth decided not to collect payment for any of our vaccines administered in any of our clinics. We felt it was important that cost not be a barrier, and the decision not to bill patients or their health insurance for vaccination was not unique to the mass-vaccination clinic.

**Utilizing Process Improvement**

As initial workflows and process maps were conceptualized and iteratively improved upon, one of our guiding principles was to eliminate unproductive waiting. We operated on the theory that getting patients into and out of the clinic quickly would reduce staffing costs by enabling us to operate the clinic for fewer hours and would eliminate the need for an army of flaggers to corral cars through various stages of waiting. To approximate time spent at individual points in the process, we timed registration and vaccinations in our brick-and-mortar clinics, which were utilizing the same electronic medical record registration and vaccination documentation process.

We piloted our processes the week before our mass-vaccination clinic, inoculating 1,000 patients over a 4-hour period. An initial group of 30 patients was scheduled for appointments during the first 30 minutes of opening, with a 90-minute break in scheduling pre-planned to address any issues, followed by a group of 970 patients during the subsequent 2 hours. During this pilot, time studies were collected at each step of the process from a sample of randomly selected cars. Upon arrival at the parking lot, a numbered placard was placed on the car. As each car progressed through the process, volunteers positioned throughout the venue tracked their arrival and departure at various waypoints. This data was reviewed in real time to identify and rectify any bottlenecks in the process. Individual vaccination stations that were noted to have slower throughput times received coaching and feedback. Subsequently, the information collected was analyzed and utilized to inform throughput calculations for mass-vaccination events the following weekend. During the pilot, cars spent a median 23 minutes and 33 seconds at the clinic, including 15 minutes of observation (interquartile range 21:19, 29:06).

Those planning future mass vaccinations might consider decreasing the density of appointments scheduled in the early hours, while teams are still identifying their optimal workflows.

Intentional experimentation was used during the pilot mass-vaccination clinic to better determine how to utilize staffing resources. Four scenarios were conducted at separate tents using two
experienced vaccinators, two newer vaccinators, one vaccinator/one documenter, or one medical student in addition to the vaccination team, respectively. Data on these specific tents reflected the addition of a volunteer could hasten vaccination by a full minute through preparing the patient or supplies for the next vaccination (Figure 4).

FIGURE 4

Comparison of Vaccination Models

Experimentation and time trials demonstrated a benefit to adding a volunteer — a third, non-clinical team member — whose only instruction was to do whatever was necessary to accelerate vaccination and yielded a median time of less than 1 minute. Typically, the volunteer was involved in preparing supplies such as adhesive bandages and alcohol swabs. The split role model, which instructed one vaccinator to document while the other administered vaccines, seemed to slow the process, with a median time exceeding 2 minutes.

Close Collaboration with IT Team

There was a clear understanding by the planning team that the IT infrastructure would be essential to maximizing our throughput and, thereby, the clinic’s success. The technology team partnered with Verizon to provide a reliable network for the vast number of laptop computers and mobile devices needed. A total of 39 laptop computers and 22 handheld Epic Rover devices were in
use simultaneously in both mass-vaccination event days. Each registration station had a laptop computer placed on a mobile workstation. The vaccination cabanas had one laptop computer and two handheld iPhone devices with the Epic mobile app, Rover, downloaded, which allowed clinicians to record documentation and conduct barcode validation at the point of care. Two registration snafu tents were located on either side of the vaccination lanes and were dedicated to deal with prolonged registration issues or other matters that needed additional time and resources (Figure 1). Each snafu tent had two laptops and Rover devices so registration and vaccination could be done simultaneously.

The IT team instituted a triple-connectivity contingency plan for network redundancy. The primary means of data access was through a wireless connection to the UCHealth Network with Wireless LAN (local area network) and mesh antennas provided by Cisco Meraki devices. Backup connection was available through Jetpacks, which are wireless devices that function as mobile hot spots on the Verizon Public Safety Network, and handheld Epic Rover devices with SIM cards to enable cellular data connection to the Verizon Public Safety Network. IT experts were able to provide on-site training and rapidly troubleshoot issues resulting in technology functioning as an asset and not a liability/hindrance.

Contingency Planning

As we started to discuss in detail the logistics of this massive undertaking, contingency planning became a priority. For example, backup plans were developed in the event of severe weather that would prohibit an outdoor vaccination, for snow removal for a milder storm, and for a backlog of cars that could impede city traffic. We created reserve registration and vaccination tents (registration snafu tents) where cars that arrived without appointments or with registration errors were directed to avoid creating a bottleneck at the registration station. On January 19, 2012, prior to the pilot, UCHealth disaster management experts hosted a tabletop exercise with all partner organizations to discuss possible scenarios that might inhibit our ability to vaccinate patients safely.

During the pilot, we utilized the EHR for registration, but paper documentation at the time of vaccination, which we thought would be more efficient than using multiple laptops. We were concerned that vaccinating a patient seated on the passenger side of the vehicle would necessitate rolling a workstation on wheels around the car, significantly slowing the process. The paper forms were quickly collected and entered into the EHR by a separate team. However, this required staff redundancy, created opportunity for documentation error, and ultimately was not the best practice. For the mass-vaccination event, we acquired and introduced handheld Epic Rover technology at the point of vaccination.

“We suspect that patient familiarity with the process also helped expedite second doses, but we did make substantial changes to how we executed registration and vaccination. Ultimately, patients spent an average of just 14.5 minutes in the clinic for their second doses.”

“
An IT downtime event had the potential to threaten our ability to provide vaccinations, and this seemed possible given the complexity of establishing wireless networks in an outdoor environment across 16 vaccination cabanas. A paper downtime system was created as a backup for vaccination stations, with a hard copy of the day’s schedule downloaded onto each registrar’s computer for registration. Connectivity issues did trigger a short partial downtime on the first mass-vaccination day (which was resolved by 9:30 a.m.), but, thanks to redundancy, vaccines were still given in a timely manner and throughput recovered quickly once network issues were resolved (Figure 5).

FIGURE 5

Heat Map Illustrating Throughput Time and Clinic Arrival
A combination of early arrivals — patients arrived more than 45 minutes before the 8 a.m. first scheduled appointment — and internet connectivity issues caused slower throughput until about 9:30 a.m. of the clinic day on January 30, 2021. Over time, however, we were able to handle greater densities while reducing throughput time until the last scheduled appointment time of 1:40 p.m. Those planning future mass vaccinations might consider decreasing the density of appointments scheduled in the early hours, while teams are still identifying their optimal workflows.

Source: The authors
NEJM Catalyst (catalyst.nejm.org) © Massachusetts Medical Society
**Instituting Incident Command System**

On the day of the events, we established a unified incident command utilizing the Federal Emergency Management Agency’s National Incident Management System’s Incident Command System. It was essential that all teams shared an understanding that ultimate decision-making authority for activating contingency plans, changing operations, or summoning additional resources rested with the incident commander. (The UCHealth Director of Emergency Medical Services served in that role; he was intimately involved with planning and logistics and oversaw the events, day-of.) Vaccination, pharmacy, registration, logistics, and IT support unit leaders reported up to the incident commander through the medical branch director or operations section chief. During our mass-vaccination days, patients arrived remarkably early for their appointments, on average arriving 30 minutes ahead of schedule. At the time operations started on our first mass-vaccination day, we had more than 130 cars queued waiting for registration, with around 200 cars amassing by 20 minutes after our 8:00 a.m. scheduled start. This occurred contemporaneously with the previously described IT downtime. As a throng of queued cars began to back up toward Denver city streets, the team utilized the reporting structure to allow the incident commander to respond nimbly, shifting to paper downtime procedures where necessary and deploying more resources for registration.

We utilized 15% overstaffing to account for breaks, sick calls, and contingencies, and found that to be a good practice. The incident command system also made information easy to disseminate quickly. During our second day of mass vaccination, the team pivoted to an earlier start time to accommodate the surge of early arrivals, and we never experienced a similar backlog. We held debriefings after each vaccination event for command staff and all section chiefs to discuss lessons learned, issues of concern, and preparation and planning for the next event.

**Lessons Learned**

Operating a drive-through mass-vaccination clinic at scale quickly exposes vulnerabilities of the planned system. While scheduled appointments defray the risk of bedlam associated with first-come, first-served sites, we were surprised by just how early patients arrived, and would recommend decreasing the density of appointments earlier in the day as teams are still identifying optimal workflows. Commencing operations at least 45 minutes prior to the first scheduled appointment also allows teams time to find their stride as volume starts to build.

Careful contingency planning and tabletop exercises to discuss options to confront possible pain points or systems failures on the day-of will allow teams to be successful in the face of the inevitable problems that are bound to occur during an event of this size. A clear command and reporting structure with a reliable communication network is imperative to be able to execute on these contingency plans.

Continuous improvement and design iteration are important to find ways to enhance efficiency. While the data presented in this paper are based on the first-dose events, by the time we deployed our second-dose events, we were comfortable shortening observation time to 10 minutes from 15 minutes and communicated to patients that if they had not had an adverse reaction to the first
dose, observation was optional. We suspect that patient familiarity with the process also helped expedite second doses, but we did make substantial changes to how we executed registration and vaccination. Ultimately, patients spent an average of just 14.5 minutes in the clinic for their second doses.

Finally, after a grueling year for health care workers, our team learned that conducting an efficient mass-vaccination event brought true joy to staff and patients alike — a pervasive air of hope almost forgotten in the era of masks, distance, and isolation.

**The Future of Mass-Vaccination Efforts**

As of March 31, 2021, estimates indicate the United States has fully vaccinated 15.5% of the current population with another 13.9% partially vaccinated. The nation has a considerable way to go to achieve herd immunity, if that is even possible given disparities in distribution and development of new variants, among other factors. Our drive-through vaccination clinic, although rapidly planned, was remarkably efficient and provided vaccination to 11,000 Colorado residents. Our standards for efficiency in handling high-volume events have been produced as a publicly accessible playbook available to any organization hoping to utilize drive-through mass vaccination. This model provides an opportunity for rapid inoculation of a large number of patients while maintaining social distancing and should be replicated across the United States and around the world. As of late March 2021, the playbook has been downloaded by 664 health care entities, and more than 100 systems have sought out further assistance.

"Finally, after a grueling year for health care workers, our team learned that conducting an efficient mass-vaccination event brought true joy to staff and patients alike — a pervasive air of hope almost forgotten in the era of masks, distance, and isolation."

UCHealth has administered more than 270,000 vaccine doses through the multiple platforms, including brick-and-mortar clinics and community-based pop-up clinics. As of late March 2021, vaccine supply remains our rate-limiting step in conducting further mass-vaccination events. We believe that by applying the lessons learned from our successful drive-through mass vaccination, we can further optimize the process and increase the number of doses we can administer per day while decreasing costs.

Of course, there is some downside to the mass-vaccination approach. Drive-through vaccination does necessitate that patients have access to a car or a ride to attend and it may not optimally target underserved communities. Opportunities to partner with app-based ride-sharing platforms, public transportation agencies, and taxi companies should be considered. Additionally, drive-through vaccination centers in many areas of the country are susceptible to inclement weather, which might complicate timely delivery of second doses.
The cost of our clinic was substantial: UCHealth alone contributed $27.50 per dose of vaccine before costs absorbed by the Colorado Rockies and Denver Police Department. Including the contributions of our partners, the total cost per dose was $29. This UCHealth-specific price tag is about $10 more per dose than our brick-and-mortar vaccination clinics. We continue to work to find more efficient models in our drive-through site, targeting higher throughput and decreased staffing costs as we anticipate that this vaccine distribution will be a highly important mission of the health system well through the spring and summer months. Our success shows that mass vaccination by drive-through can and should be used as one arm of a broader vaccination strategy that uses multiple avenues to reach the populace.

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