A SARS-CoV-2 Outbreak Investigation: Two Rehabilitation Units in a Pennsylvania Tertiary Care Facility

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Abstract

Background: Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the agent responsible for coronavirus disease 2019 (COVID-19) pandemic, created surges in hospitals around the United States. Infection prevention surveillance in a tertiary care facility detected clusters of healthcare workers (HCWs) and inpatients testing positive for COVID-19 on two separate rehabilitation units, named Unit 1 and Unit 2. As a result of the rehabilitation population requiring extended close-contact care from medical professionals, there is an increased risk of transmission of the highly contagious SARS-CoV-2 virus. Whole genome sequencing (WGS) was used to analyze the relationship between the cases within both units.

Methods: Infection preventionists (IPs) contact traced COVID-19 positive HCWs and patients on the afflicted rehabilitation units. Positive HCWs were isolated at home and positive patients were isolated to private rooms to prevent further transmission on the units. Intervention measures included staff education on proper personal protective equipment (PPE) donning and doffing techniques, implementing universal contact/droplet precautions, second staff screening, enhanced unit cleaning, closing staff lunch areas on the units, lowering symptom-threshold testing for the patients, and closing new patient admissions onto the units. Viral samples from the outbreaks were sent to the University of Pittsburgh's School of Medicine's Microbial Genomic Epidemiology Laboratory (MiGEL) to analyze the relationship between the cases on each unit.

Results: Between both rehabilitation units, a total of 24 HCWs and 12 inpatients tested positive for COVID-19 within a 3.5-week timeframe. Based on the data from the MiGEL lab, there were distinct outbreaks of SARS-CoV-2 on each unit that were not related to each other in any way.

Conclusion and Discussion: The COVID-19 pandemic has strained healthcare systems globally and created a new challenge for IP teams to manage. Individuals in hospitals are susceptible to infections and the contagious nature of SARS-CoV-2 creates a highly transmissible environment in rehabilitation settings even with preventative measures in place. The infection preventionist, along with a multidisciplinary team was utilized to disrupt the chain of transmission.

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1.0 Introduction

1.1 Novel Coronavirus

On December 31, 2019, a cluster of 41 novel infections in Wuhan, China were first reported to the China County Office of the World Health Organization (WHO)[1]. The causative agent was a newly discovered coronavirus that has since been named Severe Acute Respiratory Syndrome coronavirus 2, abbreviated SARS-CoV-2, that causes coronavirus disease (COVID-19)[1-3]. SARS-CoV-2 was declared a pandemic on March 12, 2020 by the WHO and has since infected more than 139 million people and caused more than 3 million deaths globally[1,2].

1.2 COVID-19 Clinical Characteristics

Transmission of SARS-CoV-2 occurs by respiratory droplets and/or direct close contact with an infected individual, which is consistent with the characteristic transmission of SARS-CoV and MERS-CoV.[3] Reported symptoms include fever/chills, sore throat, cough, dyspnea, fatigue, muscle/body aches, congestion/runny nose, nausea/vomiting, and diarrhea[4]. A notable differentiating symptom between the common cold and a SARS-CoV-2 infection is the loss of taste and/or smell.[3] Severe outcomes from COVID-19 include acute respiratory distress syndrome (ARDS), acute kidney injury (AKI) with other complications including lung infiltrates, respiratory failure, sepsis, and multi-organ dysfunction or failure[3,4] As severe as symptoms can be in certain cases, there is significant evidence that there are many SARS-CoV-2 asymptomatic individuals that have no indication of being infected with the virus.[5] The numerical impact that these asymptomatic individuals have for spreading SARS-CoV-2 is estimated, but not entirely accounted for. It is thought that presymptomatic individuals have a better ability to transmit SARS-CoV-2 than asymptomatic spread.[5]

1.3 Hospital Infection Prevention and Control

Hospital systems in the United States became overwhelmed with the increasing capacity of COVID-19 infections while balancing non-COVID-19 related infections and emergencies. The Infection Prevention and Control (IPC) departments were tasked with maintaining that balance. The Infection Preventionists' (IPs) provide education on evidence-based public health measures for prevention of infectious diseases, and maintain positive engagement with healthcare workers (HCWs) and other hospital staff to create a constructive environment for teaching and enforcing these measures to ensure the best quality of care is being given.[6] The IP's over-arching goal is to create a multidisciplinary teamwork environment with inclusive approaches to infection prevention that protects patients, protects employees, and protects the hospital's environment.[6]

The IPC department is responsible for conducting and coordinating case investigations and contact tracing of positive HCWs and patients – specifically the patients who test positive after spending a period of time at the facility. IPs follow the CDC methodologies for HCW investigations and perform chart reviews of patients to determine when their symptom-onset began to notify HCWs who interacted with the patient during their communicable about the possible exposure.

Early in the COVID-19 pandemic, screening processes for HCWs, patients, and patient support persons for COVID-19 was established at the hospital entrances with the goal of preventing individuals who were displaying COVID-19 symptoms, such as a new onset cough or shortness of breath, and/or fever, from entering the facility. Screening also included asking if there was any recent exposure to a person who was suspected to have COVID-19 or confirmed COVID-19 positive. Universal masking of HCWs, patients, and support individuals was added as a requirement to enter the hospital. If the screen were negative, the individual would be asked to sanitize their hands, get their temperature checked, and maintain appropriate masking throughout their time on the premises. If the screen were positive, the individual would be asked to leave the facility unless they were being seen by a physician or Employee Health in the case of a HCW.

1.4 Inpatient Rehabilitation (IPR) Population

The rehabilitation patient population have specialized needs that differ from the populations on acute care units due to a type of physical or functional deficit. Individuals on the inpatient rehabilitation (IPR) units typically require prolonged close contact from the registered nurses (RNs), patient care technicians (PCTs), physical therapists (PTs), occupational therapists (OTs), and speech therapists (STs) to assist with activities of daily living (ADLs). As a result of the extended close contact, our facility requires patients to test negative for COVID-19 before admittance to an IPR unit. Depending on the type of IPR required for completion of physician-set ADL goals - these patients can spend many weeks or months on the rehabilitation unit. Family members or care-takers are often required to attend in-person trainings to ensure proper care continues when the patient is ready for discharge. The necessity of family member or care-taker involvement of rehabilitation training increases the risk of introducing community-acquired COVID-19 to the unit. Rehabilitation takes place in a communal therapy gym where multiple patients undergo their specified treatment at the same time. During the COVID-19 pandemic, this community environment created the potential for easier transmission of the already contagious SARS-CoV-2. To follow the CDC recommended social distancing guidelines, limited occupancy counts within the gym were put into place to mitigate the threat of transmission and tape was secured on the floor to show where individuals could be at using the six-foot distancing rule.

Depending on the physical or functional deficit, some patients on IPR units have difficulties maintaining proper masking due to their injury that they are rehabilitating. An example from this analysis includes spinal-cord injury patients that had difficulty masking due to trouble moving their arms and hands to their face. These deficits are the reason why extended close interactions occur between IPR patients and health professionals. HCWs helping the patient put on the mask, feeding the patient, lifting/moving, and showering the patient are all contributing factors to the outbreaks on rehabilitation Unit 1 and Unit 2.

1.5 Centers for Disease Control and Prevention Outbreak Investigation

The CDC has outlined methodologies for performing outbreak investigations which have been tailored to assist public health professionals with fighting the COVID-19 pandemic[7-9]. **Figure 1** highlights the steps from the CDC. The first step in case identification is confirming a positive test result with the facility that ordered the testing or contacting the local health department. If the area where the patient resides does not have a local health department, the state's department of health would be the next contact to confirm test results. Case investigations and contact tracing of positive individuals are performed by interviewing the positive case to inquire about their date of symptom onset, symptom experience, and interactions during their communicable period. This information can help determine which individuals in their concentric circle should be considered an exposure and followed-up with for quarantine. Clear instructions for timeframe of isolation should be given, but this is dependent on the state or local public health jurisdictions. Following-up with COVID-19 cases is helpful to learn about the symptomology throughout an individual's course of infection. Discontinuation of isolation precautions for the individual can be given once they are past fourteen days of symptom onset and no longer have symptoms.

1.6 Whole Genome Sequencing (WGS)

Whole genome sequencing (WGS) is a next-generation sequencing technology that provides insights to the genetic component of pathogens[10]. WGS has been used for outbreak investigations of clinically significant pathogens such as multidrug-resistant organisms (MDROs) or viral pathogens such as influenza or now SARS-CoV-2[10,11]. WGS is a rapid and cost-effective method that enhances the understanding of the evolution of pathogens as they transmit from one host to another. WGS was used on samples from both HCWs and patients on both Unit 1 and Unit 2 as soon as IP surveillance detected a cluster on each unit. Some of the earlier samples from the investigation were recovered from storage, while those from the very beginning were not able to be found.

1.7 Essay Aims

The aims of this essay include describing an outbreak investigation of the novel SARS-CoV-2 virus at a tertiary care facility on two separate rehabilitation units using traditional epidemiological investigation techniques, describing infection prevention intervention measures that were implemented to break the chain of transmission, and discussing how genomic epidemiology provided insight on some transmission routes.

2.0 Methods

Over the course of a three-week time frame a cluster of COVID-19 positive cases were detected on two acute rehabilitation units at a tertiary care facility in December of 2020. A positive case is defined as a PCR positive result regardless of symptoms.

Rehabilitation Unit 1 has twelve private rooms and four semi-private rooms for a total of twenty beds on the unit. Seven out of a possible twenty patients tested positive for COVID-19 on Unit 1. Rehabilitation Unit 2 has ten private rooms and two semi-private rooms for a total of fourteen beds on the unit. Five out of a possible fourteen patients tested positive for COVID-19 one Unit 2.

2.1 Contact Tracing

Contact tracing is a part of an outbreak investigation strategy that is a process of identifying positive cases to isolate and quarantine the close contacts of the infected people.[7]

2.1.1 Healthcare Workers

HCWs and hospital staff that test positive for COVID-19 are instructed to notify their unit directors and Employee Health, which in turn alerts IP to initiate a case investigation. IP's perform the contact tracing by calling the individual and asking questions that are outlined by the CDC to gather information on the individual's concentric circle within the hospital. Examples of questions include what date their symptom onset began, what their symptom experience has been like, and who would be a close contact that should be considered an exposure. A close contact of a positive HCW is defined as someone that the HCW interacted with at work for greater than fifteen minutes at less than six feet apart and unmasked. Under the COVID-19 pandemic hospital protocol, HCW must maintain universal masking throughout the encounter with their patients. HCWs were also asked if their patients were able to properly mask.

The subclinical communicable period, also known as the presymptomatic period, is defined as roughly 48 hours prior to symptom onset. This information was explained to the HCW. IP asked if the HCW worked any of the days within their subclinical communicable period, or any days after their symptom onset. This establishes a clear timeline to identify staff and patient concentric circles to determine who meets exposure criteria within the facility. The HCW is then told to isolate from work based on the CDC criteria of ten-fourteen days, and then follow-up with Employee Health before returning to work. IP also recommends that the individuals within the positive HCW's household should quarantine from them. The HCW was asked to identify and contact anyone from their personal concentric circles to notify those individuals of their exposure to a positive individual for their need to quarantine.

The case investigation information is written in a formal email report, adhering to all Health Insurance Portability and Accountability Act (HIPAA) guidelines and protections, and sent to the rest of the IPC department along with the employee's unit director and clinical director so they can proceed with contact tracing the positive HCW's interactions and exposures directly on the unit.

2.1.2 Patients

IPs receive notification about a patient’s positive SARS-CoV-2 PCR result through the TheraDoc™ Clinical Surveillance Software System. Once the positive result is confirmed with the microbiology documentation, IP performs an electronic medical record review using Cerner PowerChart to determine the onset of the patient’s symptoms as documented. The subclinical communicable period is defined as 48-hours prior to symptom onset, and from there IP can determine any exposures during that timeframe. Similar to the HCWs case investigation adhering to all HIPPA guidelines and protections, IPs write a formal email report with identified departments that had HCWs exposed to the patient during their communicable period. This information gets sent to the unit director and clinical director that the patient resides on and the supervisors of the identified departments that could have potential HCW exposures.

2.2 Quarantining Exposures

2.2.1 HCW Exposures

There are multiple scenarios of HCW exposures that require different isolation precautions. If a positive HCW reported being unmasked around a coworker that was also unmasked for greater than fifteen minutes at less than six feet apart then that exposure is considered high-risk, and that identified coworker was mandated to quarantine for fourteen days. If a positive HCW reported being unmasked around a coworker that was masked for greater than fifteen minutes at less than six feet apart then that exposure is considered moderate-risk, and that identified coworker was asked to self-monitor for symptoms. These scenarios often occurred during lunch periods where one or both individuals were unmasked and eating together. Other scenarios with the positive HCW being masked with others being unmasked were considered low-risk exposures and asked to self-monitor for symptoms.

2.2.2 Patient Exposures

Patient exposures vary slightly from the HCW exposure protocol. A patient whose symptomology resembles COVID-19 is considered a person under investigation (PUI) until their test results are finalized. Until then the PUI is put into respiratory droplet/contact precautions, per protocol, for the HCWs to utilize PPE measures for their safety. If the patient results were positive, they were transferred to either the designated Critical Care Medicine (CCM) COVID-19 unit or the Intensive Care Unit (ICU) depending on the severity of their symptoms. If the positive patient had a roommate, the roommate was notified about their exposure by IP and put into respiratory droplet/contact precautions, per exposure protocol, to be monitored over their fourteen-day quarantine period for any new-onset of COVID-19 symptoms.

2.2.3 Outbreak Identification

According to the Pennsylvania Health Alert Network (PA-HAN), a cluster of COVID-19 cases is defined as three positive healthcare workers and two positive patients within a seven-day timeframe that have an epidemiological link.[12] IP identified a pattern of four positive HCWs from December 15th through December 17th on Unit 1. On December 18th, two patients that had been receiving care on the unit tested positive. IP increased their presence on Unit 1 on December 18th to begin interventions that will be described in the next section of the methods. Unit 2 first met PA-HAN's case definition of a cluster on December 23rd, with the first cases of positive HCWs being reported on December 18th and patients on December 20th. IP also increased their presence on Unit 2 to employ the same interventions.

2.3 Interventions

2.3.1 HCW Education

IP deployed several methods to break the chain of transmission on the IPR units as ongoing case investigations and contact tracing occurred. IP began attending morning huddles on both Unit 1 and Unit 2 at the start of their respective clusters to provide re-education of transmission-based precautions to the nursing and clinical support staff, which included the donning/doffing order for droplet, contact, and airborne precautions, and the information on the different respirators. Protocols displaying these steps with corresponding imagery were hung on a positive patient's door as a visual cue to perform the donning and doffing in the correct order. All PPE was set up on a patient tray table outside of the patient's closed door for practical access to the sanitizer, gowns, gloves, goggles, and disinfecting wipes.

2.3.2 Universal Droplet and Contact Precautions

On December 23rd, universal droplet/contact precautions were implemented on Unit 1 by hospital leadership. These precautions are typically only required for a PUI who is displaying

COVID-19 symptoms. However, by that date everyone was considered an exposure due to the high number of positive HCWs who worked during their subclinical and communicable stage and other positive patients. This messaging had to be consistent for all HCWs on Unit 1 and Unit 2 who were entering patient rooms even if they were not a PUI as it contradicts the standard protocol.

2.3.3 Isolated Therapy Sessions

All PT, OT, and ST rehabilitation staff had to follow the universal respiratory droplet/contact precaution protocol which immediately moved all therapies into the patient rooms. Therapy staff had to perform the same donning and doffing techniques as nursing staff before entering the patient's room. Being restricted to the patient room limited some aspects of the rehabilitation due to not having access to all the therapy gym equipment. This decreased overall therapy time.

2.3.4 Isolated Lunches

HCWs were previously permitted to have socially distanced lunches in the unit conference room or kitchenette area that had specified occupancy count signage designated for each area. The spike in cases among HCWs demanded isolated lunchtime procedures to avoid being unmasked around a presymptomatic or asymptomatic coworker for greater than 15 minutes.

2.3.5 Lowering Symptom Threshold for Testing

Testing capacity was constrained during the holiday surge and the system protocol was to only test patients who were symptomatic for COVID-19. Patients that began with relatively mild symptoms, such as new documented complaints of congestion, sore throat, or brief spike in temperature, raised suspicion for a new infection. Testing was initiated for those patients due to the multiple positive HCWs on each unit.

2.3.6 Enhanced Unit Cleaning and Disinfecting

The Environmental Services (EVS) team was asked to perform enhanced cleaning on both Unit 1 and Unit 2 to eliminate a route of transmission. This intervention can disrupt the chain of transmission of certain infections by thoroughly disinfecting high-touch areas that could have unknowingly been fomites.

2.3.7 Closing the Units to New Admissions and Cohorting Positive Patients

Hospital leadership closed Unit 1 and Unit 2 to any new admissions beginning on December 23, 2020 to prevent any potential new exposures and new infections. As a result of the full capacity of the CCM COVID-19 unit and the ICU, all COVID-19 positive patients from Unit 2 were moved to Unit 1 to cohort all the COVID-19 positive rehabilitation patients.

2.4 Whole Genome Sequencing

IP requested that nasopharyngeal swab samples from HCW and patient cases on Unit 1 and Unit 2 be sent to the Microbial Genomic Epidemiology Laboratory (MiGEL) at the University of Pittsburgh's School of Medicine Infectious Disease Department. Total RNA was extracted and sequenced using a viral RNA targeted enrichment strategy. The reads were aligned to the Wuhan-1 reference genome and single nucleotide polymorphisms (SNPs) were identified. The National Center for Biotechnology Information's (NCBI) GenBank tool along with the Global Initiative on Sharing All Influenza Data (GISAID) have been valuable sources for uploading whole genome sequences of SARS-CoV-2 from clinical isolates that are available globally.[13,14] A pairwise comparison table of SNPs was compiled, and a phylogenetic tree was generated. Genetic lineage was determined using Phylogenetic Assignment of Named Global Outbreak Lineages (Pangolin) software found at https://github.com/cov-lineages/pangolin. SARS-CoV-2 has a mutation rate of about one SNP per week to two weeks.[15,16] This molecular clock can help identify common sources of exposure and speed of transmission based on the SNPs.

2.5 National Healthcare Safety Network

The CDC's Division of Healthcare Quality Promotion (DHQP) utilizes the National Healthcare Safety Network (NHSN) for passive surveillance of hospital-associated infections (HAI).[17] The only relevant NHSN HAI definition to call an inpatient who contracted COVID-19 that did not develop into pneumonia would be the upper respiratory tract infection, pharyngitis, laryngitis, epiglottis criteria. This criterion, taken directly from the definition, includes the following:

1. “Patient has at least two of the following signs or symptoms: fever (>38.0°C), erythema of pharynx*, sore throat*, cough*, hoarseness*, or purulent exudate in throat* And at least one of the following:

   a. organism(s) identified from upper respiratory site [specifically: larynx, pharynx, and epiglottis] by a culture or non-culture based microbiologic testing method which is performed for purposes of clinical diagnosis or treatment, for example, not Active Surveillance Culture/Testing (ASC/AST). Note: excludes sputum and tracheal aspirate because these are not upper respiratory specimens.

   b. diagnostic single antibody titer (IgM) or 4-fold increase in paired sera (IgG) for organism.

   c. physician diagnosis of an upper respiratory infection.

   *with no other recognized cause”[17]

The IPC department huddles to review these cases to determine if the patient met NHSN criteria for an upper respiratory tract infection and report it to the state’s Department of Health.

3.0 Results

3.1 Timeline of cases

3.1.1 Unit 1

The hypothesized index case on the first affected rehabilitation unit, named Unit 1, only worked two shifts during their subclinical communicable phase of disease. There were a total of eighteen positive healthcare workers comprised of RNs, PCTs, PTs, OTs, and a physician (**Table 1**). Seven total patients tested positive with three requiring admittance to the CCM COVID-19 unit. The rest of the patient cases remained on the rehabilitation unit due to the CCM COVID-19 units and ICUs being at capacity. **Figure 2** displays the epidemic curve on Unit 1. **Figure 3** displays the timeline of when the Unit 1 cases were considered contagious and the day that they tested positive. The cases on this unit spanned a three-and-a-half-week timeframe, with the last positive case confirmed on December 27th, 2020.

Throughout the HCW contact tracing interviews, it was learned that the patients that resulted positive were not always appropriately masking while receiving medical care in their rooms. Towards the midpoint of the outbreak on Unit 1, HCWs named the patients that they interacted with that were not masking during what we now know was the subclinical stage of their infection. This likely resulted in the HCW's positive result which is closely substantiated by the WGS genomic epidemiology.

The average age of the positive HCWs on Unit 1 was 33.8 years old with an age range of 21-62 years. The average age of the patients on Unit 1 was 77.1 years old with an age range of 58-93. 83% of the positive HCWs on Unit 1 were female and 71% of the positive patients on Unit 1 were female.

3.1.2 Unit 2

The hypothesized index case on the second affected rehabilitation unit, named Unit 2, was an inpatient on the unit during their presymptomatic stage of infection. There was a total of six positive healthcare workers comprised of RNs, PTs, and OTs (**Table 1**). Five total patients tested positive with one of those patients getting admitted to the CCM COVID-19 unit and later ceased to breathe. The other four positive patient cases on this unit were transferred to Unit 1 due to the two COVID-19 specific units and Intensive Care Unit (ICU) being at capacity. This kept the COVID-19 positive patients all cohorted onto one rehabilitation unit which eased the burden on HCWs on Unit 2.

Figure 4 displays the epidemic curve on Unit 2. **Figure 5** displays the timeline of when the cases on Unit 2 were considered contagious and the day that they tested positive. The cases on this unit spanned a two-and-a-half-week timeframe with the last positive case confirmed on December 25th, 2020.

The average age of the positive HCW on Unit 2 was 43.8 years old with an age range of 23-76 and the average age of the patients was 71.2 with an age range of 44-88. Of the positive HCWs on Unit 2, 83% were female and 80% of the positive patients on Unit 2 were female.

3.2 NHSN Criteria for Patient HAI

Of the twelve patients that tested positive between both rehabilitation units, only one patient met NHSN defined criteria for an upper respiratory tract infection due to their positive PCR result, new-onset cough, and fever within the infection window period. The rest of these patients did not meet NHSN defined criteria due to only having a positive PCR result and having a fever at some point without having a new-onset cough or sore-throat. Most of these patients experienced congestion or a sore throat, which alone, does not meet the NHSN criteria for HAI.

3.3 Whole Genome Sequencing

Of the 36 case nasopharyngeal swab samples between both rehabilitation units, 26 were sent to the MiGEL lab either directly after resulting positive or recovered from their brief time in storage. Three of the 26 samples failed WGS leaving 23 samples to be analyzed. A pairwise comparison was performed to observe the SNP differences between the isolates, displayed in **Table 2.** SARS-CoV-2 has a mutation rate of about one SNP per two weeks.[15,16] SNP differences of 0-4 indicate a cluster of rapid transmission occurred between those specific individuals, however, the WGS cannot give certainty of the exact order of who transmitted the virus to within those SNP clusters. SNP differences of 5+ indicate that transmission took place after a period and was not immediate.

MiGEL created a phylogenetic tree of the viral samples that were successfully sequenced from the Unit 1 and Unit 2 outbreaks with a corresponding heatmap displayed in **Figure 6**. The color-coded nodes define the genetic lineage that show the relationship between the viral samples. The heatmap corresponds to the SNP differences showing the relationship of transmission.

4.0 Discussion

The novel SARS-CoV-2 virus presented an unprecedented global challenge for healthcare professionals to adapt to everchanging environments as research evolved about the mechanisms of the COVID-19 disease and its transmission. SARS-CoV-2 poses a threat to vulnerable patients such as those with comorbidities, or like this study, require continuous assistance with relearning or adapting to new ADL capabilities. Another outbreak investigation on an inpatient rehabilitation unit had similar characteristics to this study due to the needs of this specialized population.[18] These studies with consistent results should bring attention to need for universal systems policies to be in place to protect IPR HCWs and patients during a pandemic, such as ones mentioned in the methods of this study.[19]

IPs rely on multidisciplinary collaborations hospital-wide to successfully implement infection prevention practices. These relationships have helped develop these pandemic-related policies in the case of this study. Daily meetings with hospital and system leadership began on December 23rd that included the Unit 1 and Unit 2 medical and unit directors, the rehabilitation directors, the hospital's director of quality and patient safety, executive directors and physicians, and the lead IP investigator for the units. After the IP described the developments in both investigations as they emerged, the team of stakeholders would discuss temporary changes to hospital practices and provide executive directives, such as closing the units with the outbreaks. The open line of communication between key personnel proved most helpful in executing orders to maximize the response.

These outbreak investigations highlight the importance of onsite IP support for clinical staff education and training. IPs are useful resources for the clinical staff, and help support the clinical staff for their targeted needs. The logistics, implementation, and timely intervention of IP practices all helped to decrease the cases on both units.

Strengths of this study include IP surveillance identifying the HCW positivity pattern on Unit 1 before a PA-HAN defined cluster was met. This provided a head start for IP to attend unit huddles for HCW questions, and to reiterate the importance of maintaining the universal masking protocol during the pandemic. Another strength of this study was the WGS performed on most of the samples. WGS was insightful in defining the intra-unit transmission that occurred verses the inter-unit transmission that was hypothesized to have occurred. This difference is helpful when distinguishing transmission routes with the traditional epidemiology information. Weaknesses of this study include the lag time between the HCW's positive result and the time it took that information to get reported to IP for case investigation initiation. On average, it would take one-to-three days for IP to receive notification of a positive HCW which puts the contact tracing one-to-three days behind. Another weakness was the missing genomic data from the beginning of the outbreak attributed to by the limited storage time for viral samples due to the increased testing during the holiday surge.

5.0 Conclusion

This pandemic has emphasized the necessity for hospitals to have strong public health foundations to respond to these crises quickly and effectively to prevent further morbidity and mortality. The knowledge of infection preventionists to deploy hospital policies and procedures on the afflicted units helped decrease further morbidity and mortality. This pandemic has been a call to the public health workforce to utilize their knowledge and apply it to a population-based problem.

This retrospective epidemiological analysis described two distinct outbreak investigations of the novel SARS-CoV-2 virus at a tertiary care facility on two separate rehabilitation units using traditional and genomic epidemiological techniques while describing infection prevention interventions to disrupt the chain of transmission. Each outbreak was subsequently halted once infection prevention and control measures were reinforced or added to disrupt the chain of transmission.

This study highlights the importance of maintaining public health and infection prevention practices in a hospital setting, and that the methods deployed in this study are effective once enforced. The traditional epidemiological transmission pathways were mainly supported by the WGS genomic epidemiology. This emphasizes the insightful role of WGS when performing outbreak investigations and determining routes of transmission during the COVID-19 pandemic.

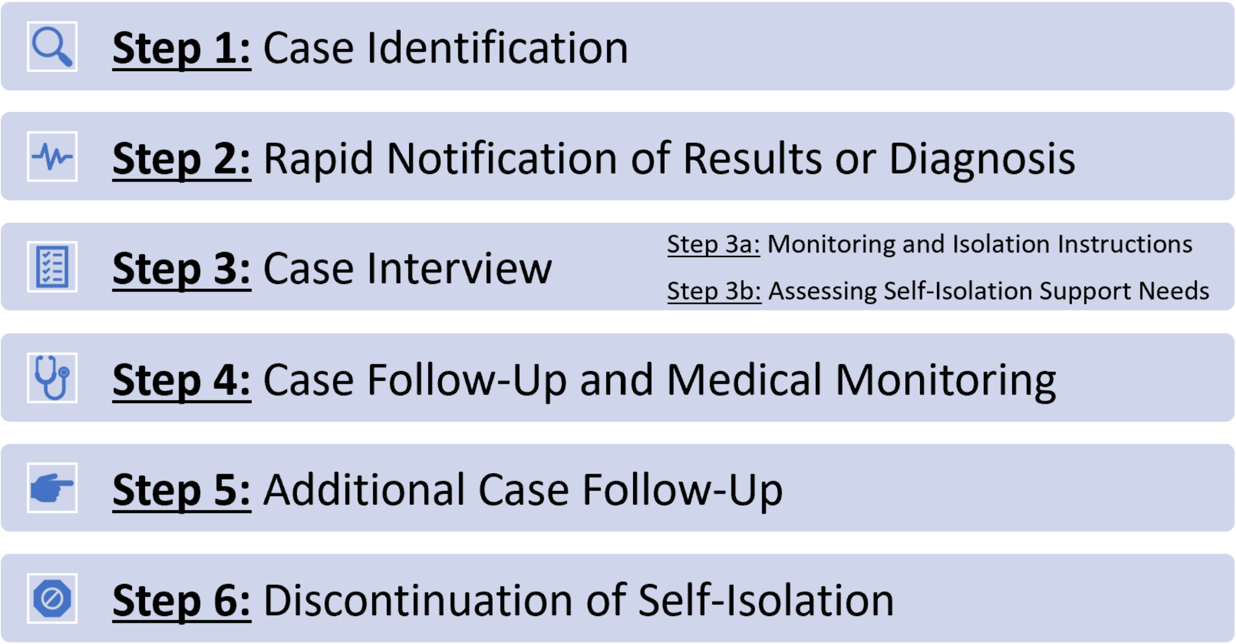


Figure 1. CDC Outbreak Investigation Methodologies

Table 1. Unit 1 and Unit 2 COVID-19 positive healthcare worker (HCW) cohort broken down by profession. Unit 1 had the majority of HCW test positive within the timeframe of the outbreaks

Healthcare Worker (HCW) by Profession	Unit 1: # HCW Testing Positive for COVID-19	Unit 2: # HCW Testing Positive for COVID-19	Total:
Medical Resident (MD)	1	---	1
Registered Nurse (RN)	8	3	11
Patient Care Technician (PCT)	3	---	3
Physical Therapist (PT)	4	2	6
Occupational Therapist (OT)	2	1	3
Total:	18	6	24

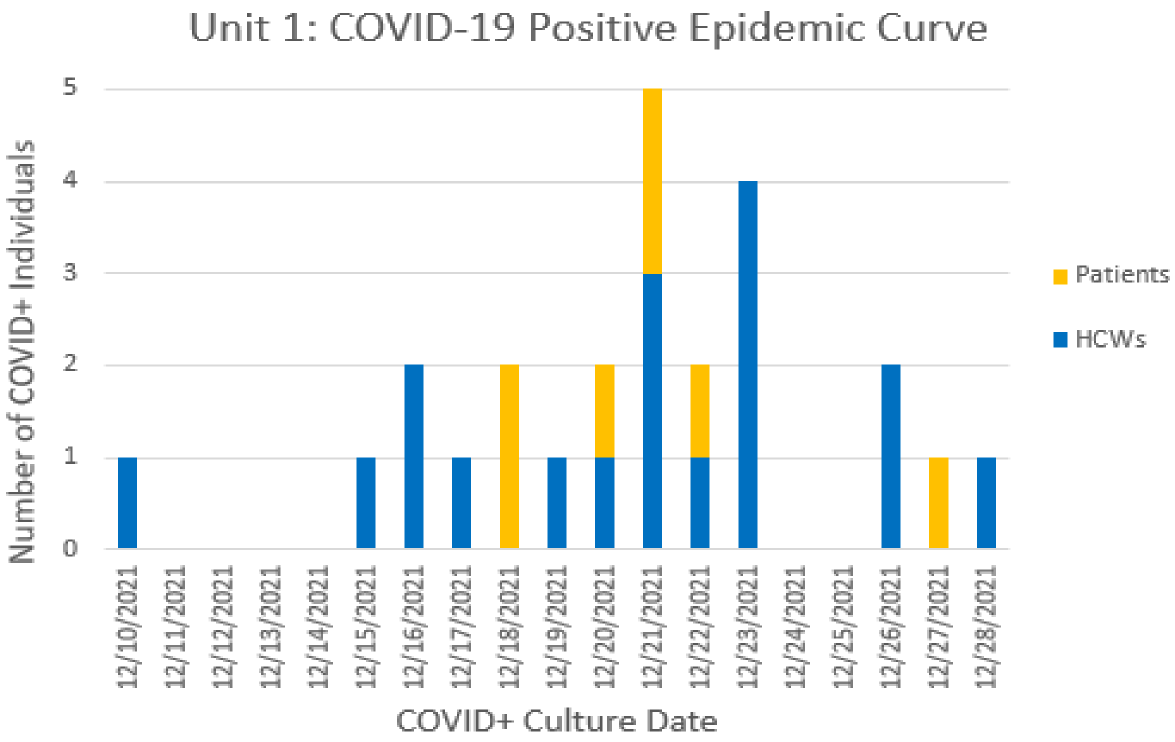


Figure 2 The epidemic curve of COVID-19 positive HCWs and patients on Unit 1.

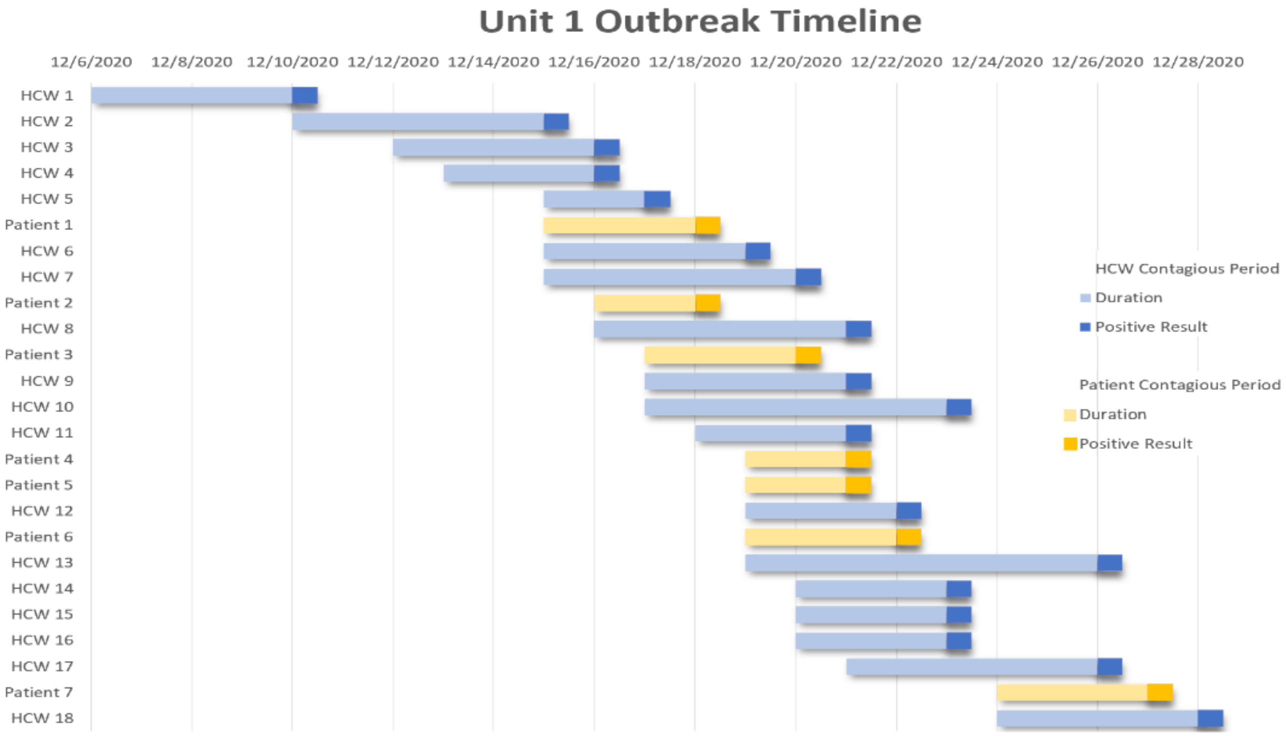


Figure 3. Timeline of the communicable periods of HCW and patients before they tested positive on Unit 1. After case investigations and contact tracing was performed, many healthcare workers reported working during the subclinical phase of their infection which

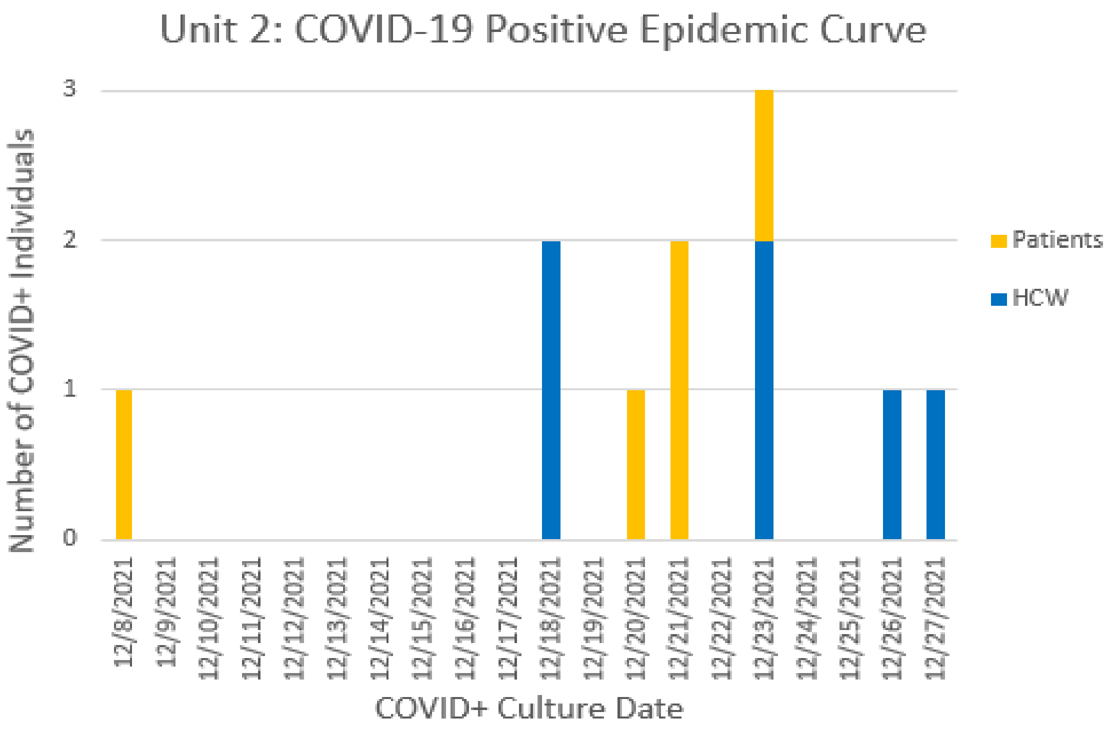


Figure 4. The epidemic curve of COVID-19 positive HCWs and patients on Unit 2.

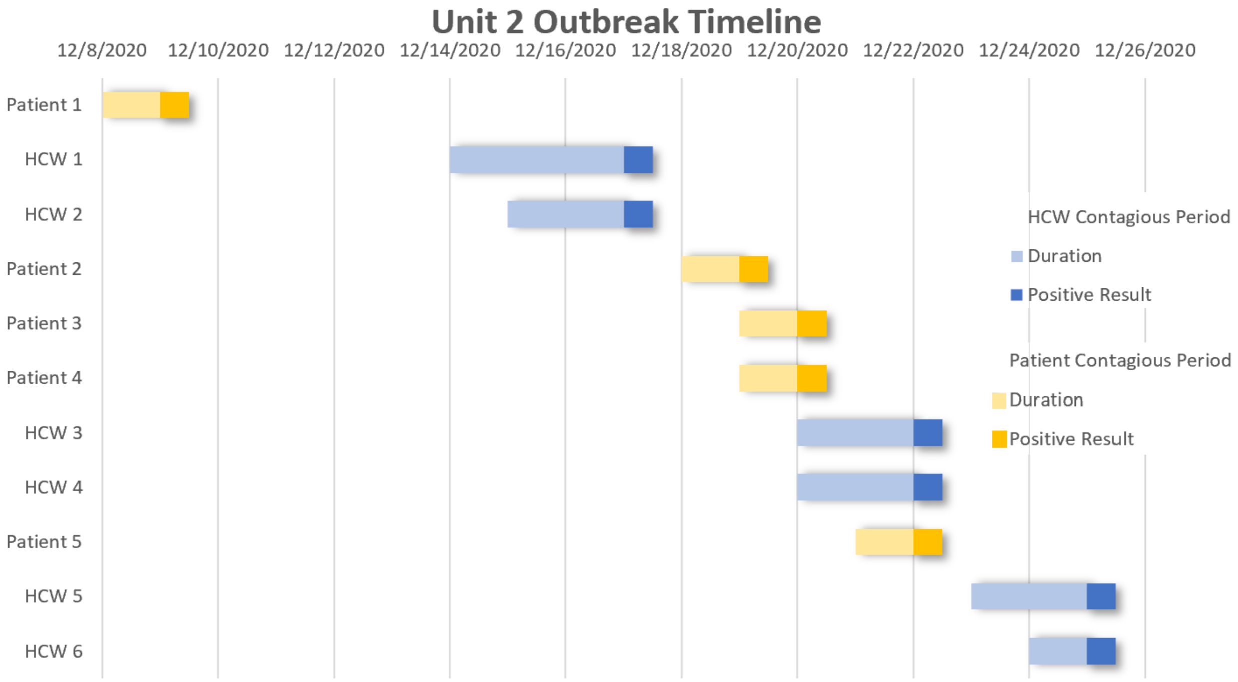
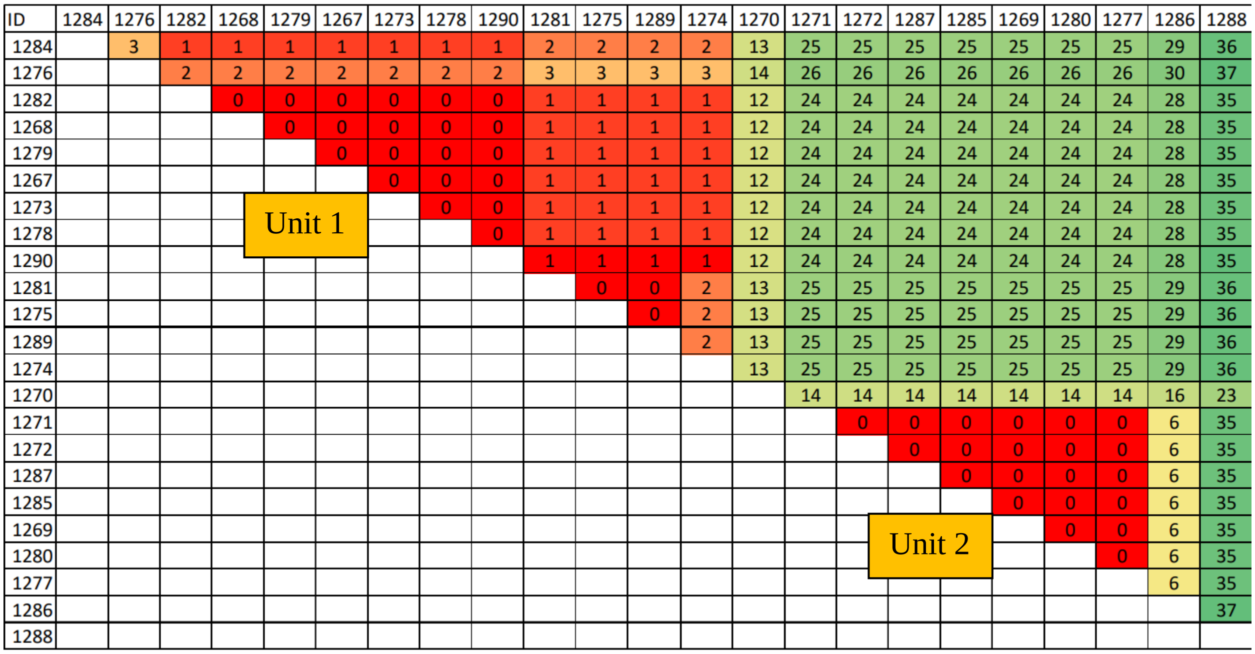


Figure 5. Timeline of the communicable periods of HCW and patients before they tested positive on Unit 2.

Table 2. Pairwise comparison of the single nucleotide polymorphisms (SNPs) of the Unit 1 and Unit 2 outbreak.



ID	1284	1276	1282	1268	1279	1267	1273	1278	1290	1281	1275	1289	1274	1270	1271	1272	1287	1285	1269	1280	1277	1286	1288
1284		3	1	1	1	1	1	1	1	2	2	2	2	13	25	25	25	25	25	25	25	29	36
1276			2	2	2	2	2	2	2	3	3	3	3	14	26	26	26	26	26	26	26	30	37
1282				0	0	0	0	0	0	1	1	1	1	12	24	24	24	24	24	24	24	28	35
1268					0	0	0	0	0	1	1	1	1	12	24	24	24	24	24	24	24	28	35
1279						0	0	0	0	1	1	1	1	12	24	24	24	24	24	24	24	28	35
1267							0	0	0	1	1	1	1	12	24	24	24	24	24	24	24	28	35
1273								0	0	1	1	1	1	12	24	24	24	24	24	24	24	28	35
1278									0	1	1	1	1	12	24	24	24	24	24	24	24	28	35
1290										1	1	1	1	12	24	24	24	24	24	24	24	28	35
1281											0	0	2	13	25	25	25	25	25	25	25	29	36
1275												0	2	13	25	25	25	25	25	25	25	29	36
1289													2	13	25	25	25	25	25	25	25	29	36
1274														13	25	25	25	25	25	25	25	29	36
1270															14	14	14	14	14	14	14	16	23
1271																0	0	0	0	0	0	6	35
1272																	0	0	0	0	0	6	35
1287																		0	0	0	0	6	35
1285																			0	0	0	6	35
1269																				0	0	6	35
1280																					0	6	35
1277																						6	35
1286																							37
1288																							

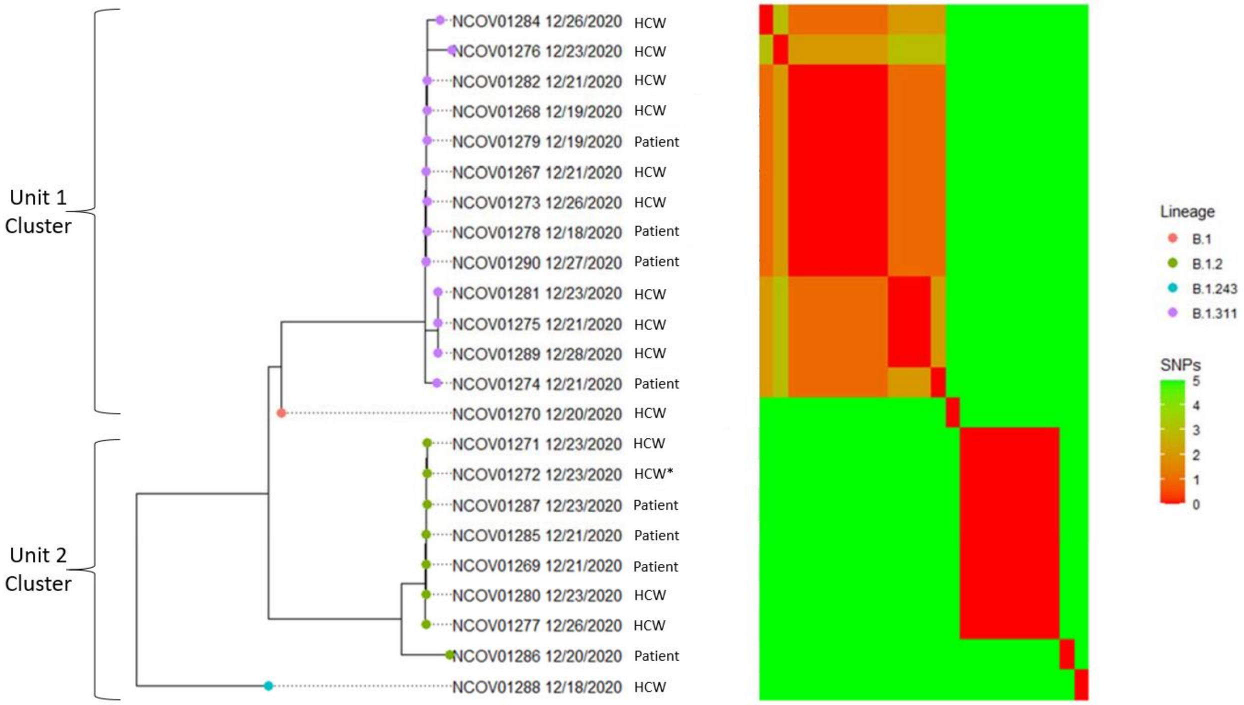


Figure 6. The phylogeny with the corresponding heatmap of SNP differences between the SARS-CoV-2 genomes. Unit 1 and Unit 2 are delineated. The nodes are color-coded by genetic lineage.

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