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Exposure Notification and Contact Tracing: How AI Helps Localities Reopen Safely and Researchers Find a Cure

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Thank you Chairman Foster, Ranking Member Loudermilk and distinguished members of the Task Force for the opportunity to testify before you today. I am extremely grateful for your interest and commitment towards helping support the novel Coronavirus Disease 2019 (COVID-19) efforts in the United Sates as we attempt to control this deadly pandemic. I am an Infectious Diseases physician by training and have extensive experience in global health and health security. I have considerable experience developing, operationalizing programs, and treating patients working on the frontlines of numbers infectious diseases outbreaks across the world. My clinical and research interests focuses on health systems strengthening in resource limited settings, outbreak preparedness and response, research and clinical care of emerging infections, and healthcare policy.

As the COVID-19 pandemic continues to spread across the United States, I hope to give you a greater understanding of the threat this and other emerging infections have to the global and economic security of the United States. I will discuss challenges facing public health experts and researchers leading COVID-19 efforts domestically. I will explain how we may better leverage available resources and tools to improve our response capacity, lessons we can learn from prior infectious diseases outbreaks, and examples of other countries who have successfully implemented policies and procedures to control COVID-19. During this unprecedented time, it is vital for the United States to collaborate with the global community so we can learn from each other and develop best practices to ensure that science informs policy.

Global Infectious Diseases Threats

Pandemics have repeatedly reshaped the course of civilizations resulting in significant human suffering and death along with substantial economic costs. The Black Death killed approximately 60% of the European population between 1347 and 1351.[1,2] European settlers introduced smallpox, measles, plague, typhus and syphilis that led to the death of up to 90% of the indigenous American population[2]. In the 1990s, a multi-

drug resistant tuberculosis outbreak in New York City cost over $1 billion, the bovine spongiform encephalitis ("mad cow") disease outbreak in the 1990s cost the United Kingdom $39 billion; and in 2003 SARS across Asia cost approximately $30 billion.[3,4] Most recently, the 2014-2016 West Africa Ebola outbreak led to over 28,000 cases, 11,000 fatalities and an estimated cost of $53.19 billion.[5] These statistics don't account for the intangible losses that occur during epidemics- families torn apart, children left as orphans, survivors treated as outcasts, hospitals unable to function, loss of critical healthcare workers, and so much more which all combine for a large unquantifiable human, economic, and social expense. According to the World Bank, the current COVID-19 pandemic is estimated to cause a contraction in the global GDP by 5.2% in 2020 leading to the deepest recession in decades.[6]

Severe Acute Respiratory Syndrome Coronavirus-2 (SARS CoV-2) the virus responsible for novel Coronavirus Disease-2019 (COVID-19) it the latest in a series of emerging and re-emerging infectious diseases with pandemic potential that have occurred with increasing frequency and severity. Over the past 40 years, there has been a four-fold increase in the number of emerging pathogens such as extensively drug resistant Tuberculosis (XDR TB), SARS, pandemic H1N1, MERS-CoV, Nipah, Zika, and Ebola.[7] Public health threats, and infectious diseases respect neither boundaries nor barriers and 70% of the world is underprepared to prevent, detect, and respond quickly and effectively. In short, we must do better. In this era of increasingly mobile and connected populations it is possible for an infection to spread around the world in 24-48 hours due to urbanization, human behaviors, and rapid transportation networks.

The world is constantly changing. We have altered how we live, the way we live and the planet on which we live, including the way we interface with nature and built environments and with animals, the way we travel, and our climate. This creates both the key ingredients for infectious diseases outbreaks and unprecedented opportunities to prevent and respond. Simultaneously, advances in biomedical and information technologies as well as analytic capacities have dramatically accelerated our ability to identify these emerging pathogens, sequence their genomes, develop diagnostic tests, drugs and vaccines, and share data across the globe. It is critical we work together as a global community so we can move forward with addressing COVID-19 and prepare for future emerging infectious diseases threats

The COVID-19 Pandemic

On December 31, 2019 cases of atypical pneumonia of unidentified etiology were reported in people in Wuhan, China.[8] By January 7, 2020 the pathogen was identified as SARS CoV-2 the virus responsible for COVID-19. Since then it has been declared a Public Health Emergency of International Concern (PHEIC) by the World Health Organization (WHO) and has infected more than 11 million individuals globally and caused over 500,000 fatalities.[9]

As the world watched COVID-19 sweep over Wuhan and spread through China, countries prepared for the inevitable. Many governments realized COVID-19 posed a

unprecedented risk to the physical and economic health of their countries and activated pandemic preparedness plans. Singapore and Taiwan with fresh memories of SARS (2003) and South Korea with MERS-CoV (2015), implemented preparedness plans and ramped up testing and contact tracing.[10,11] Alternatively countries such as New Zealand (who didn't ban travel from China until February 3, 2020- a day after the United States) took a hard stance and let science lead their response.[12] They instituted a mandatory quarantine for all visitors on March 15, 2020 when they only had 6 cases and 10 days later, instituted a countrywide lockdown including a moratorium on domestic travel.[12] These restrictions, despite being stringent were embraced because the message and plan to "eliminate COVID-19" were clearly communicated in daily briefings.

Countries who have managed to contain COVID-19 have a few things in common:

1. Science led the response plan
2. They developed a strong comprehensive national plan
3. Action was quick and coordinated
4. Communication about goals was clear
5. Community engagement was a priority
6. Case identification and testing scaled up quickly
7. Testing and care of sick patients was a priority
8. Contact tracing was prioritized and implemented
9. Lifting of public health measures has been step-wise and guarded
10. The public trusts their leaders

Challenges to COVID-19 in the United States

The first case of COVID-19 was detected in the United States on January 20, 2020 in a returning traveler from Wuhan, China.[13] In the 5 ½ months since this patient was detected, cases and fatalities in the United States have risen disproportionately compared to the rest of the world. As of July 7, 2020 the United States accounts for approximately 4% of the global population, but for 25% (2.9 million) of COVID-19 cases and 24.2% (130,000) of fatalities worldwide. More concerning is that as lockdowns have been lifted over the past month there have been a record increase in COVID-19 cases.[9,14] With over 45,000 cases/day since July 1st, there has been a halting and reversal of business openings across the country.[14]

The virus is expected to spread until a critical mass of the population, about 70%, develops immunity. As of May, an estimated 5-6% of people in the U.S. had been infected and it is still unclear how long immunity will last.[15] Thus, to control COVID-19, we must break the chain of human-to-human transmission. The fundamental principles of managing an infectious diseases outbreak are (1) Community Engagement (2) Case Identification (3) Testing and Care (4) Contact Tracing and (5) Isolation and Quarantine.

In addition to the significant health repercussions, the COVID-19 pandemic has had a large toll on the overall life of Americans. It has led to adverse physical and mental health outcomes, affected all aspects of daily life and society, resulted in emergency global lockdowns, and negatively impacted businesses and global trade. Over 40 million

people have filed unemployment claims, small businesses have closed their doors, and cities have implemented eviction moratoriums to protect renters which will have downstream repercussions for decades to come.[16] The adverse consequences are exacerbated by lifting public health measures only to halt and reverse re-openings which exacerbates the long-term economic repercussions of this pandemic.

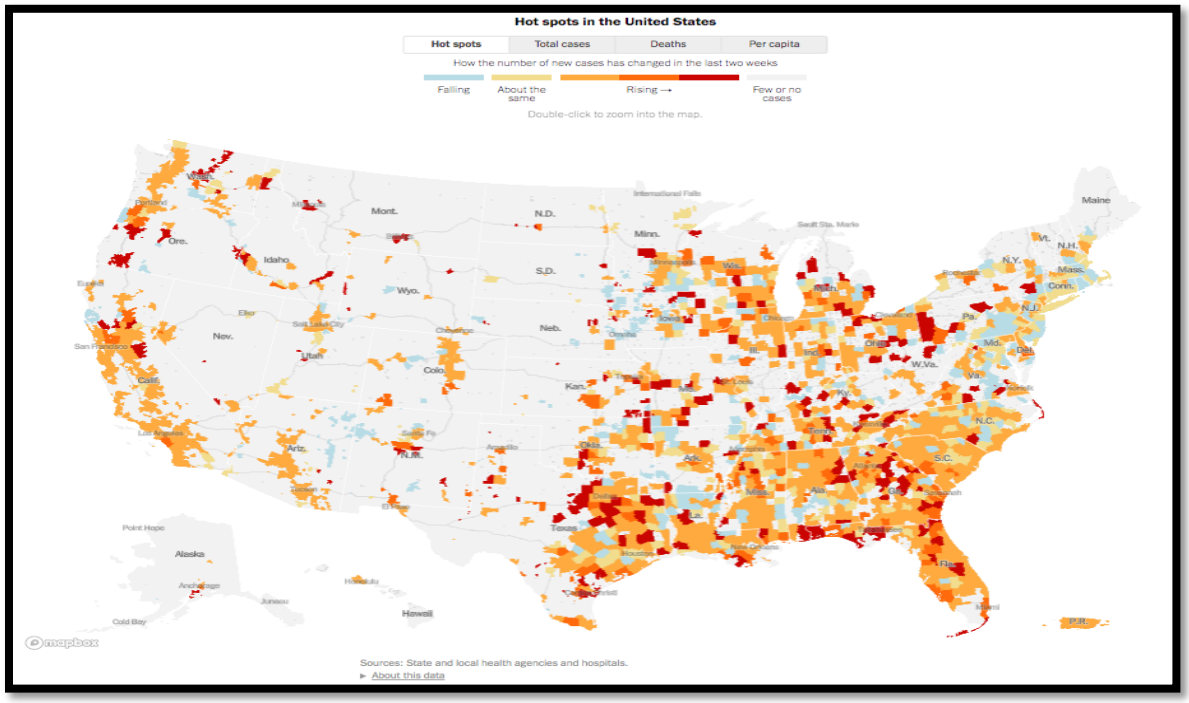

Figure 1: Map illustrating current COVID-19 hotspots throughout the United States

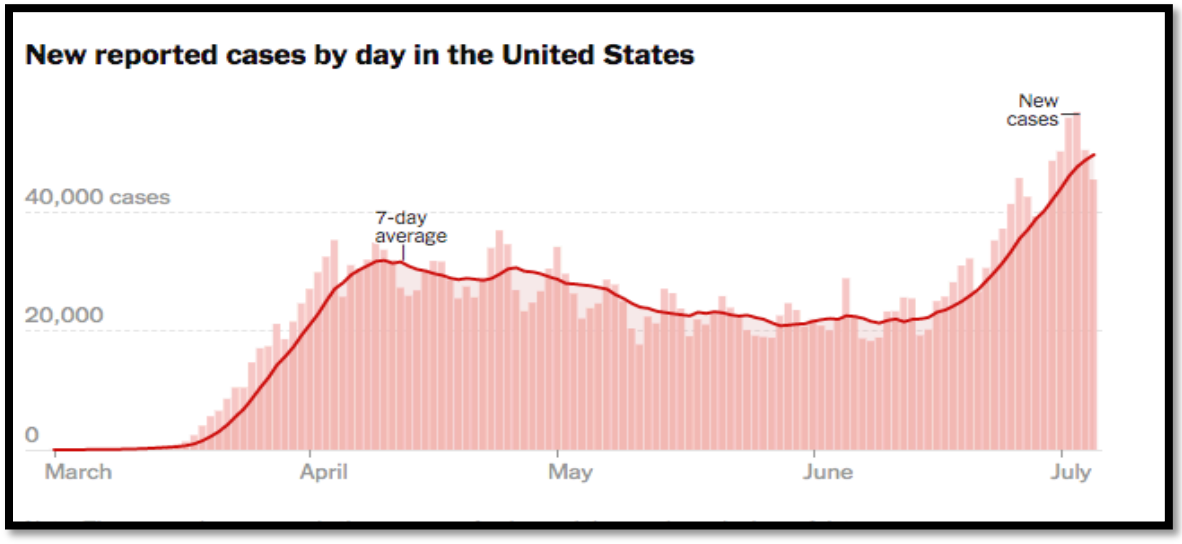

Figure 2: COVID-19 cases reported by day in the United States through July 6, 2020

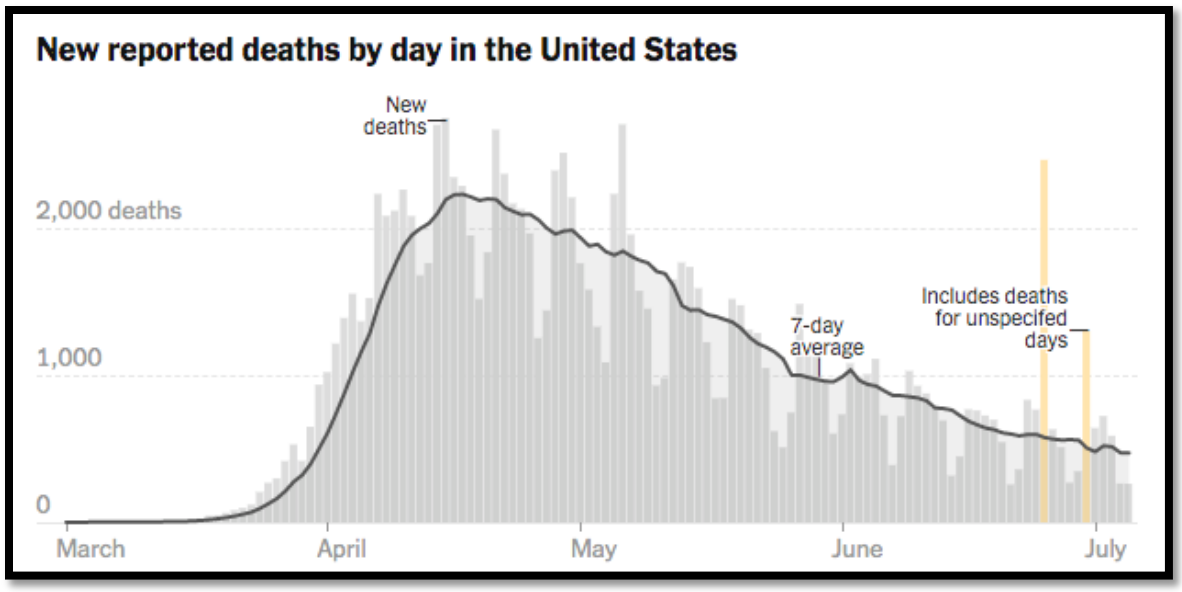

Figure 3: COVID-19 fatalities reported by day in the United States through July 6, 2020

What can the United States do?

With coronavirus cases surging across the United States, we must take bold steps to improve both the short-term and long-term health and economic recovery of our country. The longer this uncontrolled outbreak persists the greater the devastation and more significant the consequences. It is imperative to adopt the essential elements of outbreak response as follows:

(1) A National Plan

Many elements of a national plan are included in the Infectious Diseases Society of America COVID-19 Recommendations to Prepare for a Fall Surge that I had the privilege to advise on. Currently, the lack of a national plan limits understanding of the purpose of public health measures such as lockdowns which subsequently diminishes adherence. In addition, a regional, rather than a cohesive national approach, sends mixed messages to our citizens making it difficult for them to understand who to listen to and what guidance to follow, if any. Clear national goals are vital to success.

(2) Communication and Engagement

Along with communicating clear goals, it is important for our government and public health leaders to have clear and consistent messaging about evidence based recommendations to garner trust from the public. Trust, communication, and transparency are the keys to public endorsement or recommendations and guidance. Additionally, we must avoid the perception that the recommendations are inconsistently or unevenly applied in order to maintain strength and unity across the country.

(3) Personal Protective Equipment (PPE)

Despite ongoing efforts, an inadequate supply of PPE remain and increases the serious risk of infection primarily for healthcare professionals and secondarily for their colleagues, family members, and other patients.[17] The Centers for Disease Control and Prevention (CDC), reports that over 75,000 health care personnel have become infected with COVID-19, with over 400 deaths.[18] Frontline healthcare workers are forced to extend and reuse PPE, even in areas where cases are declining because we lack a long-term dependable supply of PPE. A strong supply of PPE is critical particularly now as healthcare facilities resume elective procedures and COVID-19 cases continue to surge. For example, at San Quentin prison in California is in the midst of a large COVID-19 outbreak among nearly 1,400 prisoners (1/3 of the prisoner population) and 165 employees, yet they lack adequate PPE and appropriate sanitation supplies.[19]

We need to develop and implement a long-term national strategy for PPE, including N95 respirators, powered air purifying respirators (PAPRs), Controlled Air-Purifying Respirators (CAPRs), masks, gloves, gowns, and face shields. Any strategy must emphasize the manufacture and distribution of PPE, including broader and continued utilization of the Defense Production Act. In addition clear communication between the federal, state and local government regarding the PPE supply and delivery chain is essential.[15]

(4) Testing

Five months after the first case of COVID-19 was detected in the U.S., testing continues to be one of the greatest challenges of this pandemic. The Kaiser Family Foundation compared models to calculate national-level testing capacity and determined a robust strategy would require about 1.25 million test/day or 8.75 million per/week, which is about 2.7% of the U.S. population tested weekly.[20] We continue to fall below these targets due to lack of swabs, reagents, and trained personnel. I have patients who are still unable to get tested for COVID-19. In some areas, patients wait 5-10 days for test results which diminishes the utility of testing from both a personal and public health perspective. During that 5-10 day wait time, the virus continues to spread and patients can decline clinically.

In addition to increased testing supply manufacturing and personnel training, the U.S. must have medium and long-term strategies that will allow us to adjust as needed. We need to consider developing a strategy that invests in developing adequate tests that are distributed equitably and expanding testing to locations that include all populations. We also need to streamline research for the development of tests that utilize alternate specimen sources (i.e. saliva), media (saline) and collection devices that will reduce PPE needs for testing. Finally we should focus on monitoring high-risk populations such as those living in congregate housing, incarcerated, homeless, and racial/ethnic minorities disproportionately affected by COVID-19.

(5) Facemasks

Until we have a vaccine or a preventative therapeutic, face coverings and physical distancing are the most effective public health measures we have to prevent COVID-19. A review of 172 observational studies across 16 countries and 6 continents found that transmission was lowered with distancing of at least one meter or more and that protection increased as you furthered your distance.[17]

Given the current widespread community transmission in the United States it is imperative that government and public health officials not only encourage but also personally demonstrate these measures to prevent onward transmission. Implementation of an evidence based public education campaign on the risk associated with different activities and how to reduce risk, and the importance of these tools to decrease the number of cases and facilitate the re-opening of society.

(6) Contact Tracing

Contact tracing often called the linchpin of an infectious diseases outbreak response, is critical to identifying those who have potentially been exposed and to halt onward transmission. Countries who have implemented robust testing and contact testing have been successful at containing COVID-19. While many states have hired contact tracers, additional federal resources, infrastructure, and training will be required to ensure we have a sufficient and well-coordinated work force to perform this vital task.[21] Based on the current population and data, experts estimate each case requires 10-25 contacts to be traced which requires at least 180,000-300,000 contact tracers.[15,22] Recognizing the importance of contact tracing, Johns Hopkins University has developed a free online course dedicated to training people in the principles of contact tracing https://coronavirus.jhu.edu/contact-tracing.

Given the growth of culturally diverse populations in the United States such as racial and ethnic minorities, members of tribal nations, immigrants, and refugees it is important that contact tracers mirror the U.S. populations and that case investigations are conducted in a culturally appropriate manner.[23] We are already witnessing what history has demonstrated; severe illness and death rates tend to be higher for racial and ethnic minority groups during public health emergencies. For this reason, it is important to engage representatives from affected communities and take into account the social and economic contexts in which these communities live and work (i.e. agricultural workers). In order to build trust, the CDC recommends that jurisdictions employ public health staff of the same racial and ethnic background as the affected community with fluency in their preferred language. Finally since minority populations are at increased risk for discrimination and stigma it is important to maintain privacy and confidentiality.[15,23]

One of the key components of a successful contact-tracing program is community participation and engagement. During the 2014 West Africa and 2018 North Kivu/Ituri DRC Ebola outbreaks community trust and engagement were barriers that had to be

overcome in order to effectively engage the community. The public thought Ebola was a myth, were wary of Ebola Treatment Units, and did not want to engage in safe burial practices because they conflicted with cultural norms. Through hard work of contact tracers who worked with community leaders and stakeholders a communication strategy was developed and focused on educating and engaging the community.[24] This took a lot of time and required tailored culturally sensitive messages to reach targeted populations however eventually they were able to dispel myths, gain community engagement, and drive the Ebola cases to zero allowing for the end to these epidemic.

Another vital component to successful contact tracing is leveraging new and innovative technologies to promote efficient and broad implementation strategies. The CDC and WHO provide guidance on the use of electronic tools and information technology for contact tracing and the WHO has developed their own software application called Go.Data.[25,26,27] Although different technologies are increasingly used, it is important to remember the ethics of public health information, data protection, and data privacy when using any of these technologies.

As such, the WHO has provided some items for consideration[25]

1. Safeguards must be in place to guarantee privacy and data protection in accordance with the legal frameworks of the countries where systems are implemented.
2. Everyone involved in contact tracing must adhere to the ethical principles of handling personal information, to ensure responsible data management and respect for privacy throughout the process.
3. How data will be handled, stored, and used needs to be communicated to those concerned in a clear and transparent manner. This is important for buy-in and engagement as well as to avoid misperceptions that could jeopardize the effectiveness of a contact-tracing program.
4. Digital tools used for contact tracing should be assessed before use to ensure safeguarding data protection according to national regulations.

Likewise, the CDC has identified some potential advantages, disadvantages, and implementation challenges with integrating technology use into contact tracing[27]

Advantages

1. Potentially higher likelihood of buy-in from patients and users by prioritizing individual trust.
2. Augments capacity of case investigator and contact tracer workforce (e.g., may decrease burden of manual contact elicitation, help to identify contacts in a timelier manner, facilitate communication with contacts, and help ensure rapid isolation of contacts to interrupt the chain of transmission).
3. Augments contact identification by identifying potentially unknown contacts.

4. Provides more comprehensive mobility history, which allows the contact to better detail their movements and provides public health authorities with more accurate information in the aggregate.
5. Provides granularity of proximity and associated temporal data that may be useful in stratifying contacts into different exposure risk categories that public health agencies can match with differing levels of tracing, notification and monitoring.

Disadvantages

1. Has inherent socioeconomic and technology literacy biases – requires that client and contacts have access to a smartphone, knowledge of how to install apps, and literacy to navigate app menus.
2. May not be effective until a "critical mass" of users in a community are using the apps.
3. Requires individuals to keep their smartphones on them at all times with the appropriate functions enabled and depends on users to elect to share their information with public health agency.
4. Disparate data formats from multiple apps may not be interoperable and could add burden on public health agency for integrating data seamlessly into their case management and contact tracing systems and workflows.
5. Expansion of tool capabilities will require more consultation on the **ethical** and **legal** issues related to electronic tracking.
6. Hacking and other unauthorized access or use of data may compromise data security and confidentiality.

Implementation Challenges

1. Social mobilization and mass marketing media campaigns are required to gain a critical mass behind one or more application for broad public usage.
2. Building and sustaining public trust in public health agency's ability and intention to preserve the privacy of individuals is crucial to widespread adoption of new technologies.
3. Systems are needed to integrate disparate data streams into public health agency information systems without compromising the integrity of existing workflows and to safeguard against false-positive alerts.

As we continue to develop our contact-tracing workforce in the United States it is important to explore the pros, cons, and potential barriers toward using technology. It is understandable the public may be hesitant to share information which is why it is important to learn from countries such as Canada, the United Kingdom, and South Korea that have successfully implemented and used technologies such as medical records, GPS, financial services to understand how they have been implemented without compromising individual privacy concerns.[28,29]

(7) Vulnerable Populations

Infectious Diseases tend to disproportionately affect vulnerable and disenfranchised patient populations and the COVID-19 pandemic has amplified that. According to the CDC's COVIDview, Non-Hispanic Black and Non-Hispanic American Indian/Alaska Native populations have a hospitalization rate 4.5 times that of non-Hispanic Whites, and Hispanic/Latinos have rate 3.5 that of non-Hispanic Whites. When looking at data from 40 states, the mortality rate for COVID-19 in African American's is 2.4 times higher than for Whites and 2.2 times as high as the rate for Asians and Latinos.[15] Given these disparities, resources to address the disproportionate impact of COVID-19 on African Americans, LatinX and Native American communities should be considered along with strengthening the response to other vulnerable populations.

Another unintended consequences of the COVID-19 physical distancing restrictions has been the drop in early childhood immunization rates. During the week of April 5, 2020 the administration of MMR vaccine dropped 50%, diphtheria and pertussis vaccines dropped 42%, and HPV dropped 73%.[15] The steep decline in vaccination rates may lead to outbreaks of vaccine preventable diseases, such as measles and whooping cough. Additionally with concerns for a fall/winter COVID-19 surge high rates of influenza vaccination and pneumococcal vaccination (in those whom indicated) will be critical to prevent high levels of hospitalizations from these diseases from overwhelming our healthcare system.

It will be important to consider novel approaches to safely administer routine vaccines during the COVID-19 pandemic so we can reach underserved populations and individuals living in congregate settings. These may be things such as drive through clinics or mobile units and increased funding to support outreach to patients and families who are due or overdue for vaccines.

(8) Support

Living through the current COVID-19 pandemic is unlike any other time during modern history. This has caused a great amount of physical, emotional, and economic stress on individuals that continues to take a toll over time. It is important that we acknowledge these stresses and provide support for all individuals in our society to weather this crisis.

In particular if we want to break chains of transmission, we need to recognize and support the needs of people in isolation and quarantine. This may include a safe location to stay during this time (particularly for individuals who are homeless or living in settings where physical distancing is not possible). It could also mean emotional support as well as paid sick leave, food, and access to medical care. Recognizing that individuals have numerous needs during this challenging time is vital and it is incumbent on all of us as a society to come together and provide assistance.

Countries Who Have Successfully Controlled COVID-19

Since the start of the COVID-19 pandemic many countries have developed strategic plans, mobilized resources, invested in testing and contact tracing, and followed guidance of public health experts in the management of this health emergency. There are examples of countries from around the world that have successfully approached COVID-19 head on, containing viral transmission and minimizing the overall impact of the pandemic to the health and economy of their country.

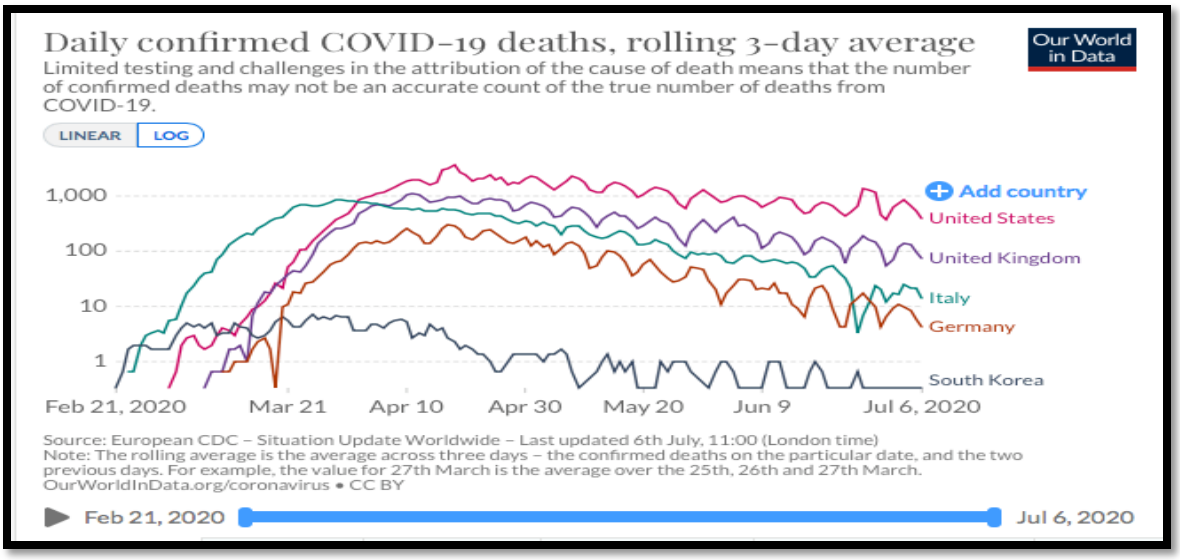

Figure 4: Daily confirmed cases from COVID-19 comparing the United States, EU, Germany, South Korea, and New Zealand through July 6, 2020

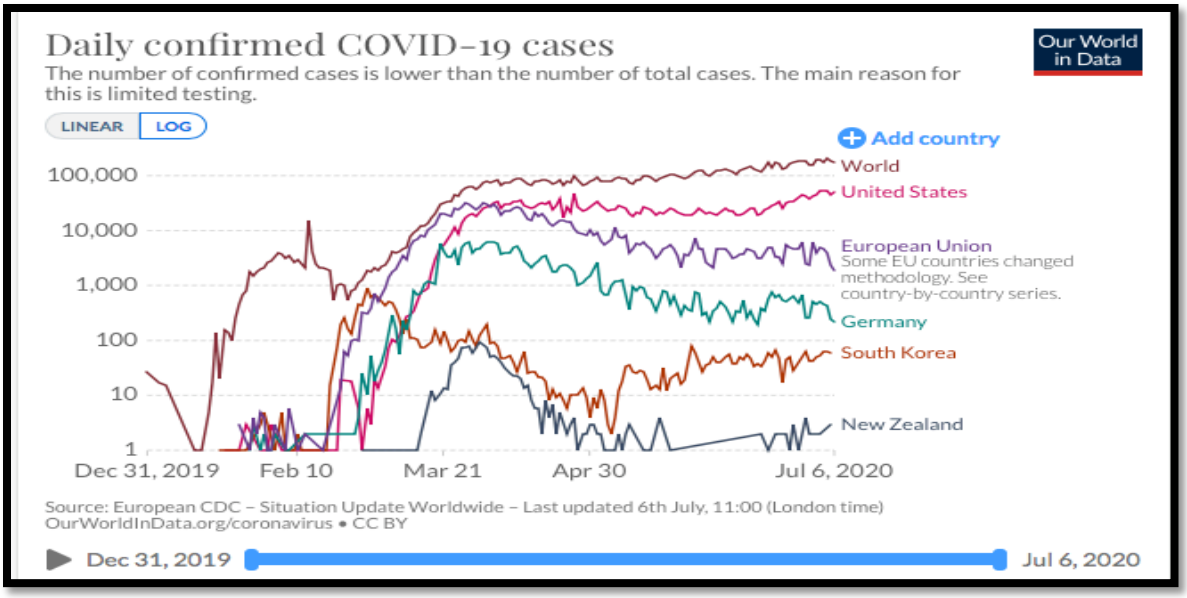

Figure 5: Daily confirmed fatalities from COVID-19 comparing the United States, UK, Italy, Germany and South Korea through July 6, 2020

1. South Korea

The United States and South Korea identified their first imported cases of COVID-19 on the same day, January 20, 2020. South Korea, with a population of 51.26 million people, has had 13,137 cases and 284 fatalities from COVID-19. In comparison the United States with 331 million people, has reported 2.9 million cases and over 130,000 fatalities.[9]

In 2015 South Korea was affected by the Middle East Respiratory Syndrome Coronavirus (MERS-CoV) outbreak. In the aftermath of that outbreak S. Korea invested resources in training healthcare personnel, and developing response systems, infrastructure, and laboratory capacity for future infectious diseases outbreak. As a result, South Korea has been largely successful in containing this outbreak and is a country to look to for guidance as we continue to adjust our response. Their first case was identified during quarantine screening at the airport when a woman was identified with a fever. She was immediately tested and diagnosed with COVID-19.[30] Subsequently, cases imported from China and those linked to imported cases were traced by contact investigation until patient 29 was identified. Patient 29 was the first case that raised the possibility of community transmission. The outbreak took off in South Korea after a superspreading event linked to a religious group in Daegu that accounted for a majority of the positive cases. Despite this event the country was able to prevent further escalation in cases because the South Korean government along with the Korean Centers for Disease Control and Prevention (KCDC) quickly and efficiently implemented contact tracing, testing, quarantine and isolation, physical distancing, and school closures. The public health officials and government understood that the mortality from COVID-19 was higher than influenza, that symptoms could be mild even though transmissibility is high, and that a lack of effective therapeutic or vaccine created significant management challenges, so they reacted accordingly.[30]

Previous investment in outbreak response and preparedness allowed South Korea to quickly ramp up diagnostic testing for the entire country, perform mass screenings of patients, develop innovative methods to ensure people were tested, and developed policies to protect those at highest risk for infection (elderly, vulnerable populations, and healthcare workers).

In South Korea, in addition to quickly scaling up conventional methods of contact tracing, other methods were used to verify patient claims. Given the experience with the MERS-CoV in 2015 laws were revised to supplement areas that needed strengthening, which included contact tracing. In conjunction with routine contact tracing methods, medical records, global positioning system, credit card transactions, and closed circuit transactions were used when contact tracing was being performed.[28,29]

These methods were used because they provided more accurate information on a persons location, duration of exposure, and other details which may be relevant to the exposure that a patient may not be able to recall or confirm. Considerations for privacy were taken into account and protocols to protect privacy and ensure that patient

information unrelated to the communication regarding risk of infectious diseases must be protected by defining what information is important for public information up front.

Overall, lessons learned from the 2015 MERS-CoV outbreak made South Korea well prepared for the SARS-CoV-2 outbreak and able to be proactive in the face of a new infectious diseases threat. The public health and government officials responded early and quickly after the outbreak was detected in Wuhan by scaling up an organized plan that included testing, contact tracing, self isolation, physical distancing, and clear effective communication.

2. Scotland

Early on in the pandemic the Scottish government recognized the importance of working towards ending community transmission and moving towards a goal of elimination and led the push to "Zero COVID". This strategy has been largely successful and the last two weeks of June there was a decreasing number of cases, hospitalizations, and fatalities and the positivity rate has fallen to less than 0.5% on most days.[31]

Scotland entered lockdown on March 23, 2020 and the government released the Coronavirus (COVID-19): Framework for Decision Making a national plan made widely available to all citizens of the country which outlined and set forth steps required for a managed transition out of lockdown. It focused on the following principles.[32]

1. **Suppress** the virus through compliance with physical distancing and hygiene measures, ensuring that the reproduction number remains below 1 and that the National Health System remains within capacity.
2. **Care** for those who need it, whether infected by the virus or not.
3. **Support** people, business and organizations affected by the crisis.
4. **Recover** to a new normal, carefully easing restrictions when safe to do so while maintaining necessary measures and ensuring that transmission remains controlled, supported by developments in medicine and technology.
5. **Protect** against this and future pandemics, including through effective testing, contact tracing and isolation.
6. **Renew** our country, building a fairer and more sustainable economy and society.

In order to achieve the goals that had been developed, the Scottish government developed a system called "Test and Protect" focused on the principles of "test, trace, isolate, support" which has been effective at interrupting chains of transmission and containing SARS-CoV-2.[33] The "Test and Protect" system is illustrated below:

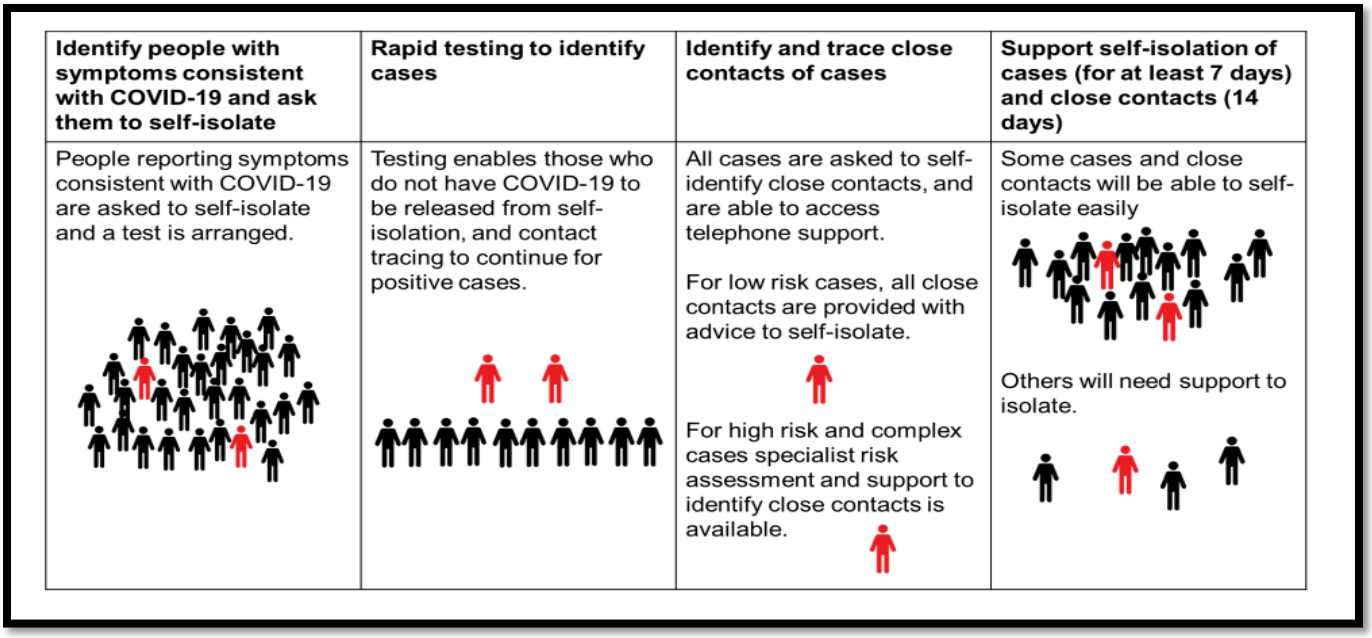

Figure 6: Schematic describing "Test and Protect"

"Test and Protect" was successful because it was combined with public health interventions that have been shown to be important to curbing transmission. These interventions included clear messaging to the public, physical distancing, the use of face coverings, and appropriate respiratory and hand hygiene.[33]

"Test and Protect" was initiated among priority groups and broadened to the general community. In order for the program work, disease prevalence needs to be low so management is possible. The five pillars of "Test and Protect: are

1. **Effective disease surveillance:** Recognizing it was essential to identify patterns of disease activity and local outbreaks.
2. **Early identification and isolation of possible cases:** Ensuring that everyone needs to be aware of COVID-19 symptoms and understand what they need to do to support the "Test and Protect" approach.
3. **Early and rapid testing of possible cases:** Working towards making sure that everyone who needs a test can get one. This included developing the ability to scale up testing as needed and which included working to expand testing for those living in remote areas.
4. **Early and effective tracing of close contacts of a confirmed case:** Involves people providing information about who they have been in close contact with, and supported by staff as required and technology while appropriate. It is understood that contact tracers are essential to the work force as they have in depth discussions with cases and contact while providing an in depth risk assessment.
   It was also recognized that enhancing existing digital infrastructure already used for tracing other infections could augment the work being done by contact tracers. The Digital Health and Care Institute is developing a secure web-based

tool for NHS Scotland that will be accessible on mobile devices and will allow individuals to input details of people they have been in contact with and send that information directly and securely to contact tracing teams. A UK government led project being developed by will support contact tracing through proximity tracking. This will use blue tooth technology to identify close contacts among other app users and will be useful for identifying people who are in close physical proximity but are unknown (i.e stranger on public transportation).

5. **Early, effective and supported isolation of close contacts:** Chains of transmission can only be broken if those who can transmit the disease to others are isolated and have support they need to maintain that isolation.

Another component to Scotland's success has been the slow, methodical and step-wise lifting of public health measures as the country has exited lockdown. This strategy has been a few weeks behind the rest of the UK but constant communication and messaging with citizens has been clear which has led to overall compliance with the paln.[31]

Finally, and likely the most component to Scotland's success in containing COVID-19 is the high confidence and trust the public has in the government. From the beginning, the government established an advisory group with complete transparency in the membership, meeting minutes which are published online, and daily briefings by First Minister Nicola Sturgeon to discuss the pandemic and answer questions from the media.

Overall the Scottish governments development of a methodical national plan with deliberate metrics that has been clearly communicated to the public while simultaneously building capacity for testing, tracing, and isolation has been paramount to their success in containing COVID-19.

Lessons from the 2014-2016 West Africa Ebola Outbreak

Public health experts have experience in managing outbreaks of not just highly communicable diseases, but doing so in challenging environments, with various patient populations, and at times dire situations. We should draw on their knowledge, background, and recommendations as policies and procedures are developed on how to best address the COVID-19 pandemic.

As an infectious diseases physician who worked on the frontlines of the 2014 Ebola epidemic in Sierra Leone at the director of an Ebola Treatment Unit, I witnessed first hand many challenges that arise during an outbreak. While not readily apparent, lessons from managing an outbreak in Africa can be applied to the current pandemic.

During the West Africa Ebola outbreak, there were over 28,000 cases and 11,000 fatalities in the three most heavily affected countries of Guinea, Liberia, and Sierra Leone. Given how Ebola spreads, the cornerstone of control is effective contact tracing to identify and monitor all individuals exposed to a confirmed case. Due to a lack of trained staff, stigma associated with having Ebola, community mistrust of contact

tracers, limited phone and internet, and difficulty traveling around due to the terrain in the context of having a high number of individuals to screen, innovative methods for contact tracing were developed.

In Sierra Leone a mobile health application was also developed to support public health officials and improve contact tracing. This proof of concept study demonstrated that an electronic system was more accurate, timely, complete, higher quality, and improved security. Additionally the use of the app allowed for real-time transfer of information to prevent communication delays and decreased data entry work. Most importantly, contact tracers preferred the use of the app over a paper based system despite limitations such as network and technical challenges, and short battery life of the phones.[34]

Overall lessons from initiating mobile technologies for contact tracing during the West Africa Ebola epidemic show promising results that could be applied in the context of the COVID-19 pandemic. Thus mobile apps can be leveraged by contact tracers to enhance efficiency and accuracy particularly when managing large numbers of contacts as in the COVID-19 pandemic.

Recommended Actions and Opportunities

The current pandemic is an unprecedented event of our lifetime and urgently requires a comprehensive national plan for the management of COVID-19. The United States is at a critical juncture in its struggle to manage the COVID-19 pandemic. It is clear that the current approach of local and state governments making decisions regarding implementing and lifting public health measures is not working. Until we have a vaccine, control of the outbreak will must rely on:

1. Identifying new cases by surveillance, testing, and isolation to prevent transmission
2. Tracking all contacts of cases and quarantine
3. Physical distancing ranging from 1-2 m, banning of mass gatherings, to imposing lockdowns
4. Travel restrictions to stop importation of infections
5. The use of face masks or cloth face coverings

A study by Kucharski and colleagues demonstrated the first three strategies are not competing but rather need to be combined to bring the epidemic under control. The lowest effective reproduction number was achieved with isolation, contact tracing, quarantine, and physical distancing.[22] While these measures are inconvenient we must adopt them particularly if we hope to re-open businesses in our country, have children return to school and adults return to work, and resume social activities. Without these measures, cases will continue to mount and eventually overwhelm hospitals, providers, and the healthcare system as was seen in Italy, Spain, and New York City. I fear what will happen in the United States if this happens again so many months of lockdown and subsequent economic hardship. This would only prolong and compound the devastating effect COVID-19 has had on the health of our economy and amplify hardships for all

Americans. In short, the sooner we unify to decreased COVID-19 cases, the sooner we will emerge from this, and can focus on building a stronger and more robust America. For that the happen, everyone has a part to play and must realize we are all in this together for the greater good of our society and country.

Looking Forward

COVID-19 is the greatest social, health, and economic threat of our generation and how we choose to manage it will be our legacy. One thing we know for certain is like SARS-CoV-2, there will continue to be infectious diseases threats to humans. Given our increasingly mobile and global populations it is impossible to prevent spread across national borders. The best we can do is invest in programs that aim to enhance surveillance systems and strengthen workforce, laboratory capacities, and healthcare systems, domestically and internationally at greatest risk for emergence of diseases with pandemic potential so we can respond to future outbreaks before they become national or global emergencies.

Thank you again for the opportunity to testify before you, and I look forward to answering your questions.

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