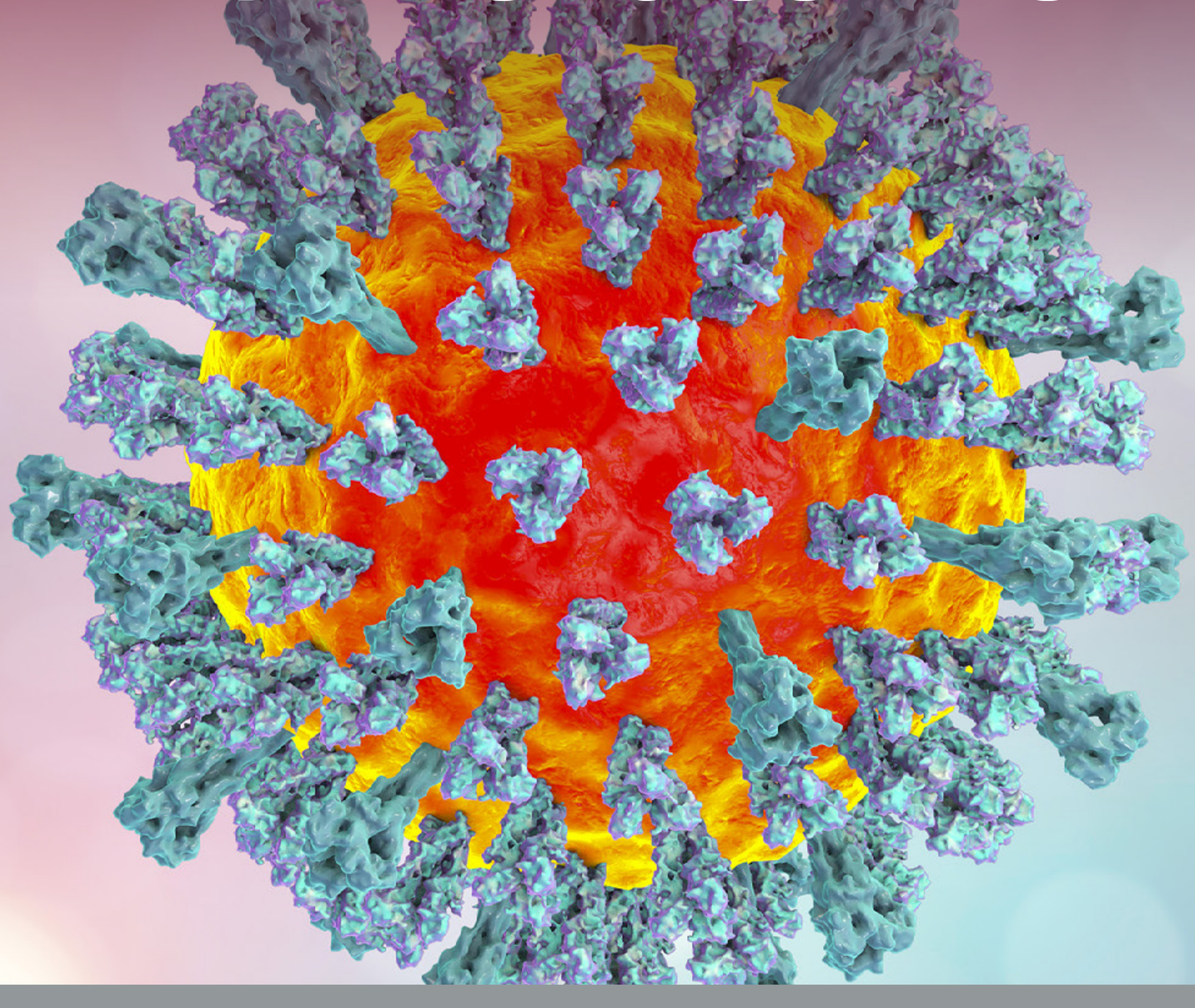
PANDEMIC PREPAREDNESS: AN INTERDISCIPLINARY APPROACH TO DISEASE PREVENTION & CONTROL



LESSONS FROM THE 2018 SCOWCROFT INSTITUTE PANDEMIC SIMULATION • MAY 2019

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INTRODUCTION

On October 14, 2018, the Scowcroft Institute of International Affairs conducted a pandemic simulation designed to give students from across Texas A&M University a high-impact, interdisciplinary learning experience. All of the authors of this paper are student participants of the simulation exercise in which we responded to a simulated H7N9 outbreak that began in a Chinese province and quickly spread to a number of countries throughout the world. To respond to this simulated outbreak, we worked together in interdisciplinary teams. Each team was guided by a mentor with extensive international disease outbreak preparedness and response experience. Over the course of four hours, the teams tackled problems as they arose and worked to contain the pandemic.

There were many important lessons learned throughout the simulation, but one of the most important was the indispensability of an interdisciplinary approach to pandemic preparedness and response. The greatest global health challenges cannot be solved without innovative, cross-cultural, and cross-disciplinary thinking. Expertise from biological sciences, social sciences, and more, allow for the complete and nuanced approach necessary for disease containment. This is a lesson that we hope to reiterate throughout the paper.

The pandemic simulation exposed all of us to some of the greatest challenges in pandemic response. The following paper is an examination of the some of the “takeaways” from the simulation. In this paper we discuss the importance of surveillance, detection, and diagnostics, as well as the gaps in our current systems. We examine failures in public education and outreach in order to provide recommendations for increasing trust and effective communication. Lastly, we examine the legal challenges of response elements and the economic impacts of pandemics. Within each topic area we provide recommendations to fill the gaps and increase pandemic preparedness and response.

TOPIC AREA 1: **SURVEILLANCE**

Rapid detection is a critical step in containing an infectious disease outbreak at the source; before it becomes a pandemic. But this ability to rapidly detect diseases relies on a number of factors, most importantly, rapid field diagnostics and large-scale, accurate disease surveillance. In this section, we address three broad areas of surveillance—physical, agriculture-based, and Internet-based—and discuss the importance of developing accurate, rapid field diagnostics in resource-constrained environments.

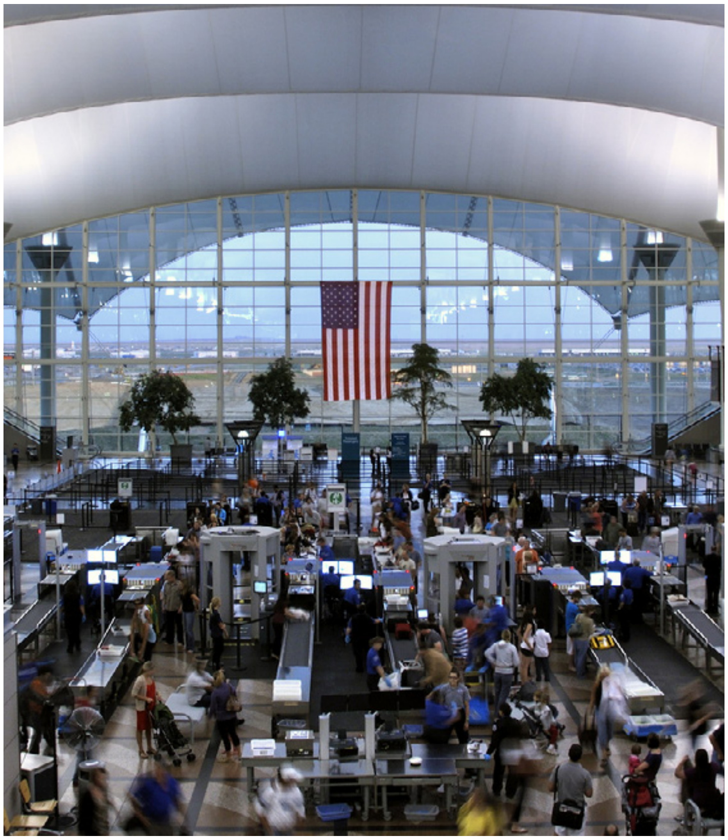
Physical Surveillance

Physical surveillance, as used for the purposes of this paper, refers to surveillance conducted by healthcare personnel in care settings or by government officials at ports of entry. Physical surveillance is an important part of the broader surveillance system, but there are gaps and challenges that have yet to be addressed and many of these gaps leave society vulnerable to a deadly pandemic.

The Centers for Disease Control and Prevention (CDC) conducted the Real-Time Outbreak and Disease Surveillance project in 1999 to test whether or not reports gathered from hospital emergency rooms could provide accurate disease detection and surveillance (Wagner et al., 2004, p.28). The Real-Time Outbreak and Disease Surveillance project relied on the analysis of electronic information that was collected at the time a patient was admitted to the hospital. Statistical analysis was then used to facilitate early detection of infectious disease (Wagner et al., 2004, p.28). The scope and abilities of the Real-Time Outbreak and Disease Surveillance project are limited. It is only able to examine a limited number of conditions and, even five years after implementation, significant improvement was needed in for the system to function effectively. (Wagner et al., 2004, p.29).

The Real-Time Outbreak and Disease Surveillance project is not the only care setting focused surveillance system in use, however. Several retrospective studies have looked at the accuracy of using symptoms descriptions, electronic medical records, or a combination of the two, in predicting infection. These studies determined that electronic medical records can be effective in accurately predicting diseases outbreaks because they can identify the factors most commonly present in infected individuals (DeLisle et al., 2010, p.1). Symptom descriptions, however, are not as useful. They have been shown to be inaccurate in predicting influenza infections (May et al., 2010). All of these studies should that some options for physical surveillance are more effective than others and that conducting retrospective studies that can help identify accurate predictors of disease.

While these studies are useful, physical surveillance extends beyond medical and symptoms records. Another important aspect of surveillance, especially during a pandemic, is surveillance and detection at ports of entry. In the United States, the Department of Homeland Security (DHS) is tasked with protecting America's borders through their smaller agencies, such as Customs and Border Protection (CBP), the U.S. Coast Guard (USCG), and the Transportation Security Administration (TSA). Within DHS, there are three main offices that aim to coordinate outbreak response. The Office of Health Affairs is the principal medical authority that coordinates all medical and surveillance efforts and provides health and medical guidance to the department's operational components. Additionally, the Directorate of Management provides guidance to DHS personnel on how to protect themselves from infection (e.g. personal protection equipment (PPE) guidance). Lastly, the Science and Technology Directorate develops surveillance, prevention, and operational capabilities for DHS to detect, rapidly diagnose, and counter biological threats (DHS, 2016). The purpose of these three offices is to guide DHS pandemic preparedness and response with the goal of containing an outbreak before it can impact the American population.



Despite these existing mechanisms for pandemic surveillance and detection, DHS still has inconsistencies that could inhibit effective preparedness and response. A recent Office of Inspector General Audit of DHS found the following:

> The Federal Emergency Management Agency and [U.S. Citizenship and Immigration Services] (USCIS) determined they would not maintain PPE for pandemic purposes and, if needed, will order them using a just-in-time method, as recommended by the ILSP [Integrated Logistics Support Plan]. While the Transportation Security Administration (TSA) planned to maintain a 2-day supply, U.S. Customs and Border Protection (CBP) and the National Protection and Programs Directorate (NPPD) identified a pandemic PPE supply that significantly exceeded the maximum lead time of 14 days. Specifically, CBP maintained a 60-day stockpile, and NPPD had a 90-day stockpile requirement. Without clear guidance and proper oversight, the Department cannot ensure components have the necessary amounts of PPE to protect their personnel during the initial stages of a pandemic response. (Roth, 2016)

Put simply, the lack of standardization of preparedness protocols means that some areas of DHS do not have the adequate supplies needed to safely respond to an outbreak. This inconsistency leads to a potentially devastating loss in capabilities for DHS. If the agencies designed to protect our borders are unable to protect their own employees, then they will be unable to accomplish their mission and infectious disease is likely to come into the United States through ports of entry.

Agriculture-Based Surveillance

The importance of ongoing surveillance extends beyond physical surveillance in healthcare settings and at ports of entry. Surveillance of agricultural systems, particularly food animal production, is necessary to reduce the threat of pandemics. Oftentimes, reporting infectious diseases within a herd or flock results in the mandatory culling of the affected population, which can result in large economic losses for the producer. This discourages disease reporting and even encourages slaughter of the animal before the infection is discovered. Hiding infection within a flock or herd exacerbates the spread of disease because it provides an opportunity for continued infection among the herd or flock and external transmission during transportation to market (FAO, 2017).

Our pandemic simulation began with infected poultry in a wet market, or a market selling fresh meat--often live animals--and produce, which expanded into a pandemic due to a lack of disease reporting and proper surveillance. By investing in the synchronization of surveillance systems, exploring new opportunities, and providing proper incentives for producers to report disease, local level disease reporting can be improved.

Understanding the One Health approach—an approach acknowledging the interdependence of human, animal, and environmental health—to disease surveillance, detection, and response can also improve containment efficiency in agricultural-based outbreaks. Partnering with veterinarians to monitor disease trends in animals helps detect potentially deadly zoonoses before they infect humans. Several such pilot programs have been put in place but are often unsuccessful due to loss of interest from participants (Vourc'h et al., 2006). Vourc'h et al. (2006) found that declining adherence to these programs by veterinarians occurs as the novelty of the program wears off. While attrition may be a issue to overcome, utilizing the One Health approach provides better surveillance among animal populations and can

help stop potentially deadly outbreaks before they make the jump to humans.

Internet-Based Surveillance

In detecting outbreaks of infectious disease, rapid detection of pathogens and personnel exposure is vital (Wagner et al., 2004, p.28). Physical and agricultural surveillance can greatly increase the ability to detect outbreaks, but to strengthen the system it is important to use technological advances to our advantage. Technological developments have allowed governments to aggregate data on a scale never before possible and, while there are drawbacks to this, it does provide an opportunity for more extensive global surveillance. If properly utilized, this data can be harnessed to aid in the rapid detection of infectious disease outbreaks and a better use of resources.

While underutilized, Internet-based surveillance does exist. Examples of such systems, which use big data to conduct global surveillance, are: Flu Near You, Harvard University's HealthMap, Canada's Global Public Health Intelligence Network (GPHIN), Medscape's EpiSPIDER, and the Centers for Disease Control and Prevention's

(CDC) National Syndromic Surveillance Program (NSSP) Biosense. Flu Near You is a crowdsourced system, or an Internet-based system using information from a large number of people, designed for the early detection of influenza. Flu Near You allows individuals to voluntarily offer information about how they are feeling, which can help determine the location of flu hotspots. HealthMap is utilized by many federal and international agencies to observe the location and type of pathogen causing disease throughout the world by using freely available information from PubMed, global health agencies, and other disease surveillance platforms.

Aside from crowdsourcing systems, there are several data aggregation platforms that rely on expert analysis. These include GPHIN, EpiSPIDER, and Biosense. GPHIN scans newly published reports and articles regarding infectious disease cases and distributes relevant articles to government and health experts. EpiSPIDER looks at reports published by Medscape and allows for a visual representation of the data. Finally, Biosense uses cloud computing to allow surveillance data to be shared and analyzed by public health professionals.

These surveillance systems often complement one another (Keller et al., 2009; Hay et al., 2013) and, together, provide a deeper look at the movement and spread of a disease. However, maps and other special surveillance mechanisms need to be dynamic platforms adapting to incoming data in order to display the most accurate and up-to-date information. Additionally, as in the case with GPHIN, there should be a level of human oversight to ensure accuracy and relevancy. Common problems regarding all these forms of disease surveillance include privacy, search relevancy, and lack of Internet access (Chan et al., 2011, Simonsen et al., 2016).

The problem of search relevancy can be particularly difficult to counter because search history can be misleading. For example, a person may be searching for a book (Simonsen et al., 2016) or doing research on an infectious disease topic (Chan et al., 2011), in which they would search for similar topics to an individual attempting to gain information about their disease symptoms. This conflation can create an illusion that a disease is more prevalent than it is. Additionally, Internet-based technologies tend to provide the most benefit in countries with extensive electronic records and a stable Internet connection (Eisenstein, 2018). There are programs being developed to address these issues, but the problem has not been solved (Eisenstein, 2018).

In parallel with developing new technologies, it is important to strengthen traditional surveillance systems. Automated digital surveillance approaches have proven their value by detecting outbreaks of Dengue (de Almeida Marques-Toledo, 2017) and Zika (Eisenstein, 2018) and fine-tuning Internet-based surveillance for infectious disease detection will be an asset for identifying infectious disease outbreaks in the future.

RECOMMENDATIONS

1) Synchronize surveillance systems

Efforts should be made to synchronize a multitude of surveillance systems. This synchronization would allow for a dynamic evaluation of disease movement and provide a single, uniform source for this information.

2) Limit internet-based surveillance to endemic diseases

Internet-based surveillance should be limited to endemic diseases, as Chan et al. (2011) notes, due to higher accuracy and a lesser risk of panic-based web searching.

3) Incentivize disease reporting in animal production settings

A system that creates incentives for livestock producers to report disease and removes or reduces the fear of economic loss and hardship must be developed. Such a system will increase reporting of zoonoses.

4) Teach disease reporting in low-resource environments

Education of basic disease reporting mechanisms and networks in areas in which Internet connection is unreliable can improve disease surveillance. This should be combined with efforts to improve modes of communication involving disease reporting. Improving even basic systems in low-resource settings will advance surveillance efforts until more advanced techniques are available.

5) Invest in the development of modern surveillance and detection approaches

Digital surveillance technology should be developed by using retrospective analysis of well-documented outbreaks to design algorithms that can analyze the wealth of information available. The development of such algorithms will provide early detection of biological outbreaks and allow time for crucial mitigation efforts.

TOPIC AREA 2: DEVELOPMENT OF DIAGNOSTICS

Rapid Detection Approaches

Early detection is a key component in the prevention and mitigation of disease outbreaks, but for any type of early or rapid detection system to be effective it must be able to be deployed to the field (Walper et al., 2018). Field detection devices are especially important in providing early identification in areas with limited access to care. Biosensors are one technology which has been used successfully to detect disease spread. Biosensors are devices that utilize a reaction between the pathogen of interest and a detection system to determine whether the pathogen is present (Walper et al., 2018). An example of this is the malaria Rapid Diagnostic Test, which detects the parasite using a blood sample on a small, self-contained device (WHO, 2015).

There are three major classes of rapid detection approaches. The first is identifying a unique interaction between the pathogen of interest and some other molecule, which can be contained in the detection device (Walper et al., 2018). The second is observing a unique element of a pathogen in response to exposure to a particular wavelength of light, also known as fluorescence spectroscopy (Walper et al., 2018). The third is identifying a unique element of mass or mobility in a particular phase (ex. Mass spectrometry) (Walper et al., 2018).

Fluorescence spectroscopy is one of the most promising modern approaches due to its accuracy, but it still has large obstacles preventing field deployment. One currently developed device utilizing fluorescence spectroscopy is small and portable and has an accuracy of over 97% (Gerbert et al., 2018). Unfortunately, it requires growing a sample for at least 2 hours prior to analysis, making it impractical for field use (Gerbert et al., 2018). Additionally, this method has also only been tested on three bacterial species and no viral threats (Gerbert et al., 2018). Despite the time required for growing the sample, Walper et al. (2018) finds that growing the suspected pathogen for subsequent analysis is the gold standard approach for accurate identification.

Protein binding assays that directly detect pathogens can be very useful in cases where it is not possible to grow a sample and real-time analysis is necessary (Walper et al., 2018). This detection method makes it possible for an air sample to be passed into a fluid phase and analyzed using a microfluidics device. Although the microfluidics chip would need to either be replaced or regenerated after a positive confirmation, this approach seems to pose the greatest opportunity for portable, multi-pathogen, real-time detection. However, due to the low level of pathogen extracted from air or water, a high sensitivity of detection will be necessary and the ability to discriminate between background noise and a pathogen is a difficult challenge to overcome.

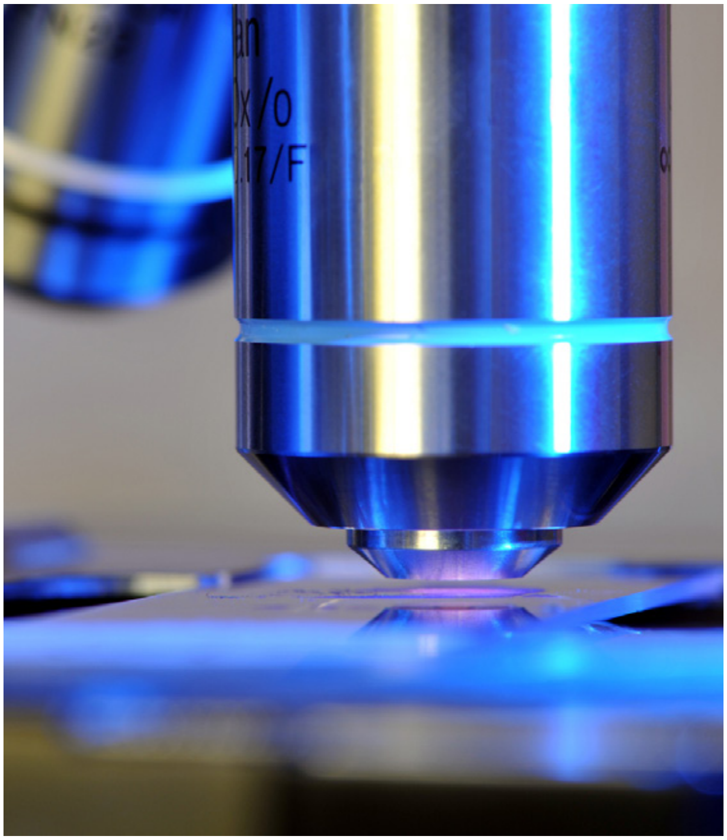
Field methods are most effective when a specific outbreak is already identified but unfortunately, they are not very successful in the early detection of environmental pathogens prior to an identified outbreak. Further, they have not proven especially useful in the screening of asymptomatic patients. The goal of early detection is to intercept pathogens and potential outbreaks prior to the appearance of ill patients and many field methods are unable to do this.

Redesign of existing detection systems to allow simplified analysis of air samples would significantly enhance the capability of these techniques. This is a major hurdle though, because environmental samples often have extremely low concentrations of pathogen and significant levels of organic and inorganic molecules, or "background noise" (Walper et al., 2018, p.1901). Developing simple, easy to use detection technology to a point where a significantly large number of detection stations can be deployed to locations throughout the US is paramount.

Optical-based systems, another option for detection methods, have experienced significant improvements in recent years (Walper et al., 2018, p.1920). Although they can be useful in the clinical setting, they cannot feasibly be used in low-resource settings, such as developing countries, (Walper et al., 2018, p.1920) and, at this time, do not seem well-suited for field deployment.

Another possible option for rapid detection is a laser-based detection system, which analyze contaminated air samples. A plethora of laser-based detection systems have been tested by the North Atlantic Treaty Organization (NATO), but they have to be calibrated for each unique environment in which they will be used (RTG-55, 2010), making them somewhat impractical for field deployment. They are also extremely bulky and best utilized in a vehicle-mounted system (RTG-55, 2010, p.35). Lastly, significant improvement of the analysis software is necessary to minimize false positives before this type of system could effectively be implemented (RTG-55, 2010, p.36).

Mass spectrometry, specifically electrospray ionization (ESI-MS), overcomes most of these hurdles (Walper et al., 2018, p.1918). The equipment is expensive and sophisticated, but the feasibility of detecting pathogens relies only on the ability of the scientific community to establish appropriate protocols for collection and identification of pathogen-specific molecules. This type of system requires a modest power supply and can be confined to the size of 1-2 large suitcases, making it ideal for field deployment.



The greatest challenge posed by these field-based systems is an inherent risk in relying on any diagnostic system in which a false-positive or false-negative occurs and leads to improper treatment (Walper et al., 2018) or mobilization of a large-scale response when no threat exists. As long as the limits of the field-based devices are recognized and complemented with follow-up confirmation in a laboratory setting, field-based systems can be useful tools of detection.

The Unique Challenge of Influenza

The ability to rapidly and accurately detect the presence of the influenza virus in humans before it is able to spread is a significant challenge in pandemic preparedness and response. The complexity lies in the nature of the influenza virus itself, as well as, the nature of diagnostic tests. The influenza virus is able to create a hybrid version of itself when a host is infected with two different strains, one which the host may have little to no immunity to, a mechanism known as "antigenic shift". These viruses are constantly changing, therefore we continuously need to develop both new diagnostic tests and vaccines.

Various laboratory methods for influenza testing exist, including viral culture isolation, rapid influenza antigen detection (RIDTs), and nucleic acid amplification tests (NAATs). RIDTs work by detecting antigens and NAATs work by identifying genetic material from the pathogen. Determining which test is appropriate is dependent on a number of factors, such as expertise available, budget, and patient population. While RIDTs are particularly useful because they provide a confirmation within 30 minutes and do not require specialized tools or technical expertise, they are the least likely to be able to confirm the presence of the virus (Balish et al., 2013). NAATs are able to provide a confirmation of the disease within 3-5 hours and are able to do so accurately, but they are also costly and require specialized expertise (Landry, 2011).

Viral isolation can accurately confirm the presence of the virus, but it takes between 3-10 days to confirm the result from the time of sample collection (Landry, 2011). Viral isolation of the Influenza virus, similarly to other infectious disease tests, is dependent on the circumstances under which the sample was collected, transported and stored. Ideally, a sample is collected within 48 hours of symptom onset, so that the appropriate antiviral therapy can be started. However, a sample collected 72 hours after symptom onset can decrease the likelihood of false negatives. A sample should be refrigerated when transported and stored. Delays in transport to testing laboratories and poor electricity at storage sites can negatively affect specimen quality, leading to inaccurate results. This is an especially difficult problem to overcome in rural areas and low-resource countries.

RECOMMENDATIONS

1) Research and development funding for physical detection equipment

Physical detection equipment needs Research and Development (R&D) funding to advance to a point where a large number of independent, automated, and culture-free stations can be deployed. Optical-based air sampling systems will likely provide the greatest capability in the future.

2) To promote the timely development of diagnostic tests by creating more efficient ways to share samples.

This is in alignment with 2018 National Biodefense Strategy (NBS) goal 2.2, because this is facilitated by reducing barriers involved with information sharing. This is also included in goal 3.3 of the NBS.

3) Stockpiles of Personal Protective Equipment (PPE), vaccines, and other components essential to pandemic response need to be closely monitored and updated.

Personal Protection Equipment (PPE) provides a physical barrier in order to reduce the transmission of communicable diseases. The storage of large quantities of PPE can be costly, but an appropriate stock is required in order to be able to safely respond to large-scale outbreaks in a timely fashion.

TOPIC AREA 3: PUBLIC OUTREACH & TRUST-BUILDING

The 2014 Ebola outbreak demonstrated the importance of communication, education, and outreach at the community level. Effective disease response and containment is not possible without the establishment of a collaborative relationship between responders and the affected community. In this section we outline some of the current challenges in public outreach and education, including timely information dissemination, establishing humane medical care, increasing the involvement of non-governmental organizations (NGOs), and creating effective public messaging.

Communication Transparency to Build Trust

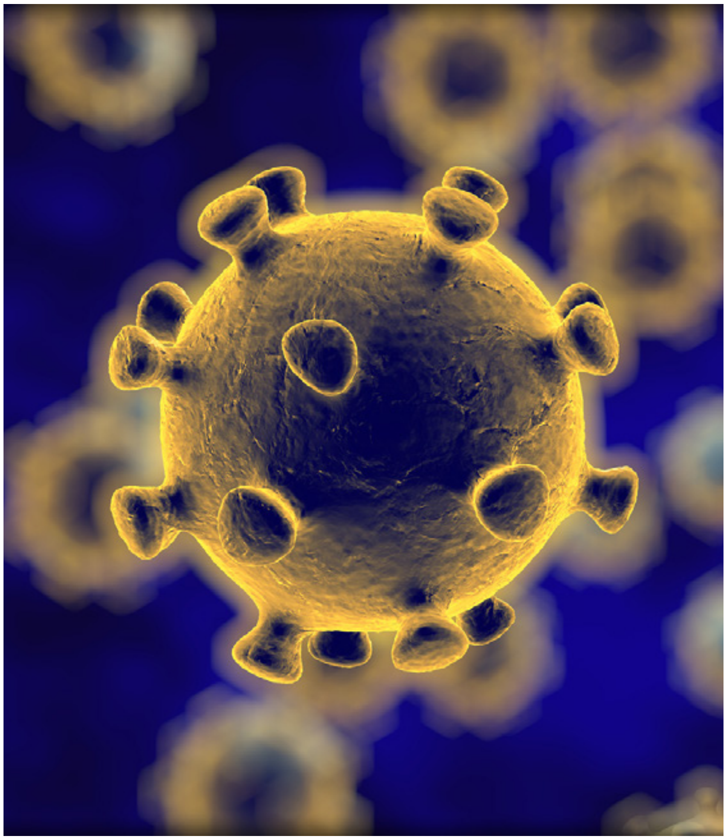
An often overlooked aspect of pandemic control is the importance of timely dissemination of information and consistent, accurate communication with the public. Communication strategy during an outbreak is frequently an afterthought and responders are forced to create ad hoc solutions to problems that should have been addressed during the preparedness stage. There are two main gaps in education, outreach, and communication during pandemic response. First, information dissemination from government entities is not sufficiently considered in most outbreak situations. We see this as an oversight in pandemic preparedness since the public should be engaged in protecting themselves from infection. Second, most recommendations for public outreach and communication are focused on educating the affected population about disease prevention and mitigation behaviors, such as avoiding crowded places and hand washing, with the assumption that the public will follow the guidelines. This is rarely the case, however. In many countries, including the United States, there is strong distrust and/or disregard for government guidance among the population. Incorrect or ineffective education and outreach during a disease outbreak can serve to only exacerbate the problem.

The primary focus of any public outreach plan should always be building trust between citizens and government, corporations, or non-profit entities, as well as increasing awareness of the problem or issue. With regards to pandemic preparedness and response, both of these functions of public education and outreach remain extremely important. One of the most frequently cited examples of poor disease communication and outreach by a governing body is the case of the 2003 Severe Acute Respiratory Syndrome (SARS) outbreak in China. During the 2003 SARS outbreak, there was a three month delay from the time the first case was identified to the time the public was informed of the outbreak (Qui et al., 2016). Even after the Chinese government acknowledged the outbreak, they continued to mislead the public about the number of ill and dead in an attempt to downplay the severity of the outbreak (Huang, 2004). Indeed, throughout most of the SARS outbreak, limited or purposefully inaccurate information was shared with the public, resulting in confusion about what SARS was, how it spread, and how severe the outbreak was (Huang, 2004).

China's secrecy in this outbreak can be explained by many reasons, including a focus by party elites on the upcoming National People's Congress (NPC) in March 2003 (Huang, 2004). The NPC would mark the beginning of a new government and public acknowledgement of the SARS outbreak may have caused economic instability, as well as tainted the party's image. Furthermore, the government's ability to develop a disease management plan was impeded by low-level government officials intercepting and distorting information as it moved up the hierarchy (Huang, 2004). These officials feared that any mishandling of the outbreak in their jurisdiction might be used as an excuse to pass them over for a promotion (Huang, 2004).

China's government-controlled media was also prohibited from reporting on or warning about the disease in order to protect the Chinese economy. During the 2003 SARS outbreak, there was a 39-day delay in informing the public. Additionally, newspapers and television news outlets were silenced by the government. In the recurrent H7N9 outbreaks, news broadcasts have been allowed to update citizens about the outbreak, how to stop spread of the disease, and what areas of the country are most affected (Qui et al., 2016). This shift in transparency was exhibited through a change in the freedom of the press in the nearly ten years between the two experiences. An interview with one TV reporter stated, "The Propaganda Department controlled and did not allow us to have an interview. We had no way to find any information about the disease outbreak except hearsay [in SARS]" (Qui et al., 2016).China learned from these mistakes, however, and has been an example of effective public outreach and communication during the annual H7N9 outbreaks in China this decade.

Additional examples of poor communication transparency and its negative impact on outbreak control can be found in the current Ebola outbreak in the Democratic Republic of Congo (DRC) and the 2014 Ebola outbreak in West Africa. The current outbreak in DRC began in August 2018 and has been exacerbated by conflict and public mistrust of government and outbreak responders (Maxmen, 2019). Public mistrust of the government, among other reasons, stems from the political instability and corruption the DRC has experienced since gaining independence from Belgium in 1960. The existing toxic political climate helps to



explain why distrust of government boiled over after the government prohibited people in Ebola-affected areas from voting in the presidential election in December 2018 (Maxmen, 2019).

Throughout the outbreak, the government in the DRC has displayed a lack of transparency in explaining why voting was not allowed in Ebola-affected areas. This lack of transparency has only served to increase fears among a public with already high levels of distrust, turning an outbreak control measure into, what appears to those in the affected community, to be voter suppression. Since then violence has increased, including organized attacks on Ebola Treatment Centers (ETC) and assaults on healthcare workers (Cousins, 2018; Gulland, 2018; Maxmen, 2019).

In order to strengthen pandemic preparedness and response it is essential that timely and transparent communication and outreach is used to build and uphold trust among all members of the public. Trust can never be established between two parties if one party feels their voice is suffocated or that those in authority are lying to them. Trust among members of a society is pivotal to the public's response to a pandemic and encouraging a conversation between all parties in a society will lead to trust. With the establishment of trust, public compliance will follow suit.

Engaging Minority Communities & Crafting Public Messages

Establishing a trusting relationship between the public and outbreak response organizations should include engagement with minority and marginalized communities. Minority groups are typically socially disadvantaged and thus, can be especially vulnerable during outbreaks. For example, indigenous populations were one of the hardest hit during the 2009 H1N1 pandemic (CDC, 2010). In the United States, minority groups, have higher rates of serious disease and are hospitalized at rates more than double those of non-minority groups (Debruin, Liaschenko, & Marshall, 2012). This pattern repeats itself globally: in Australia, New Zealand, and Canada, hospitalizations and deaths were 3 to 8 times higher in indigenous people than in general populations. (Debruin et al., 2012). To mitigate the impact of an outbreak on vulnerable demographics, organizations must specifically target minority communities. Effective outreach to disadvantaged and minority communities requires trust-building best achieved by empowering members of minority communities and tailoring outreach to the unique needs of those communities.

Representatives from underserved populations should be invited to participate in public outreach and outbreak communication response and policy making. Additionally, trusted individuals within a minority group, including epidemic survivors, religious leaders, traditional healers and healthcare providers (shamans, midwives, etc.), tribal leaders, and prominent business owners, should serve as an intermediate between government officials and the community. These representatives can help educate policy makers on socio-cultural aspects that determine communication efficacy with specific demographics such as preferred language(s), routes of communication, and message tone. Lastly, amplifying the voices of respected community members lends validity to public outreach messages and creates a sense of shared public experience.

An example of effectively using respected community members for public education and outreach can be seen in the 2014 Ebola outbreak in Guinea. In this case, survivors of Ebola who were treated at Ebola Treatment Centers (ETC) were utilized as spokespeople to promote the idea that ETCs were safe (Martín et al., 2016). Survivors dispelled rumors surrounding ETCs by discussing how they were treated with dignity while in ETCs. These survivors' stories improved community compliance with reporting to ETCs, helping decrease the spread of Ebola in that community, and showed the positive impact of using respected community members for education and outreach in communities with low levels of trust.

Another trust-building strategy is to tailor public outreach messages to specific communities. It is common for one uniform message to be broadcast at the early stages of an outbreak, which covers basic risk and prevention recommendations. However, the efficacy of these original messages needs to be evaluated as the outbreak progresses. In the 2009 H1N1 pandemic in Europe, a "one size fits all" advertising campaign was used, and messages were never tailored to individual communities (young, old, poor, etc.) (Crosier et al., 2014). Many factors contributed to this lack of nuanced communication including, lack of planning, resource deficits, lack of quality audience research, and the assumption that widespread coverage on mainstream news outlets was getting to all audiences. By ignoring these communication gaps, policymakers risk ignoring vulnerable subpopulations, which can perpetuate and intensify an epidemic and further alienate minority demographic groups.

Humane Medical Care

Another measure that can be taken to ensure sustained trust between all groups of a society is to provide humane care of infected patients. This includes recognizing the psychological needs of patients. In the case of China's SARS epidemic, citizens would not go to the doctor for fear of forced hospitalization. When people were hospitalized for a disease, they were cut off from all family and visitors. Hospitalization was more like a prison sentence than a place of healing and recovery.

One doctor said it best:

> Human care was very bad during SARS. The family was not allowed to visit a SARS patient in hospital. Pagers and mobile phones were collected on one side and the patients were not allowed to use them as they had been infected. [...] Some patients could not see anyone before they died in hospital. (Qui et al., 2016)

The SARS outbreak is not the only instance where subpar medical care has served as an obstacle to disease containment. A well-known example of how well-intentioned outbreak control measures can become detrimental to effective control is in the 2014 Ebola outbreak in Sierra Leone. In this situation, the government enforced quarantines, but these "cordons sanitaires" usually didn't provide adequate food or water and the local police enforcing the quarantines were not trusted (Kennedy & Nisbett, 2015). The combination of these logistical and socio-cultural factors, along with the already fraught atmosphere of an outbreak, discouraged public compliance with quarantine.

Proving that care can be provided in a compassionate way, such as by speaking the local language, treating patients with dignity, and allowing contact with relatives, can increase trust in institutions and help the public believe that hospitals and care workers really are providing the best quality care possible (Martín et al., 2016).

Involvement of Non-Governmental Groups

In addition to the importance of trust-building and accurate communication from government entities, the role of non-governmental groups and the private sector is important to effective public education and outreach. A study by Schwartz and Yen (2017) assessed the role of a "whole-of-society" approach to epidemic response which calls for enhanced cooperation, trust building, resource sharing and consensus-oriented decision making among multiple levels of government, business, non-profits, and the public in general. The authors conclude by recommending governments "seriously consider" adopting this approach (Schwartz & Yen, 2017).

Outbreak preparedness and response also needs to include cultural anthropologists and sociologists to maximize effectiveness. To understand why this is important, it is necessary to examine another lesson from the 2014 Ebola outbreak in West Africa. Traditional funeral practices of washing and preparing bodies were a significant cause of new exposures and infections. However, attempts to ban and prevent these practices proved ineffective and the sudden intrusion of government restrictions sowed distrust and decreased public compliance with outbreak control efforts (Blair, Morse, & Tsai, 2017). Banning fundamental cultural rituals following an outbreak shows a lack of understanding of the public's emotional and mental needs and leads to evasion of protocols.

Employment of sociologists in making and communicating outbreak preparedness and response guidelines could have predicted this response. Sociological surveys after the outbreak revealed that funerals in Sierra Leone serve two key purposes. They are meant to honor the dead and prepare their spirit for the afterlife and also serve as the occasion for dividing up the property of the deceased and determine the fate of their widows (Richards et al., 2015). This explains why the public was so hostile to outbreak responders, "outsiders", taking over funeral rites and why compliance with funeral bans was low. These intricate social details vary widely from country to country and from region to region. Cultural anthropologists and sociologists are best equipped to understand how and why traditional practices factor into outbreak policies and can help develop more robust, effective, and respectful guidelines and how to convey them.

A more holistic approach to pandemic response policy should be developed to facilitate more effective disease containment. Pandemic control and response is not just the responsibility of government officials but the responsibility of every member of a society. The implementation of the following recommendations will bolster the United States Government's disease response to domestic and international disease outbreaks and allow for efficient and timely control of pathogen transmission. Policy makers must learn from the mistakes of the past.

RECOMMENDATIONS

1) Build trust with the public through transparent communication, humane medical care, and outreach to minority communities.

In order to strengthen pandemic preparedness and response it is essential that timely and transparent communication and outreach is used to build and uphold trust among all members of the public. Communication strategies must address existing public mistrust and should focus on preventing creation of rumors where information gaps exist. Thus, we recommend that communications to the public need to include rapid notification of an outbreak occurring, timely and up-to-date information on the outbreak that is readily accessible by the public (e.g. via local news stations, newspapers, social media, etc.), relevant information on preventive measures including what the public can and cannot do, and must express the purpose behind any outbreak control measures perceived to be controversial to assuage current public fears. Once trust is established, public compliance will follow suit.

Another measure that can be taken to ensure sustained trust between all groups of a society is to provide humane, dignified care of infected patients. In many epidemic treatment centers, basic human emotional and mental needs are disregarded for the sake of disease control. This can sow public suspicion and distrust in treatment centers and reinforce rumors that these centers do not have patients' best interests in mind. Therefore, patients in treatment centers should be communicated to in their local language, allowed to communicate with their loved ones, given up-to-date information, prompt treatment, forms of entertainment, and guaranteed access to food and water.

To engage with the public, and especially minority communities, trusted individuals should be incorporated into outbreak response organizations. Trusted community members, such as religious leaders, should be included in outbreak preparedness meetings, outbreak response and communication teams, and should be consulted by government officials and NGOs when conducting disease surveillance. Empowering influential individuals from minority communities can lead to increased trust in government and healthcare institutions by association.

2) Increase private sector involvement in outbreak response efforts.

Along with minority communities, we urge increased cooperation between private companies, government bodies, and citizens. We also believe more of these companies and foundations should become involved in pandemic response and spreading information to the public as well as funding relief efforts. Grocery stores such as Wal-Mart, department stores, shopping malls, and public transportation could all be used as avenues to disseminate information and dispel rumors and hearsay. Foundations and organizations, such as the Bill and Melinda Gates foundation, and the Chevron Health Initiative to fight malaria, tuberculosis, and HIV, have already contributed millions and proven the effectiveness of private companies, foundations, and corporations involvement in pandemic response. A whole community approach is needed to control a pandemic situation most effectively and can result in strengthened and holistic epidemic preparedness and response infrastructure.

3) Form interdisciplinary response teams

Cultural anthropologists and sociologists should be included as mandatory members of all outbreak response teams. As members of outbreak response teams, these professionals need to be consulted especially when limitations or restrictions (e.g. quarantines or prohibition of local traditions) will be imposed on local populations, and when significant public pushback is expected. Additionally, they should be consulted when crafting outbreak communication messages and when working directly with local populations. Cultural experts can help bridge the gap between the goals of outbreak control and the needs of local populations. By bridging this gap, outbreak control measures can be improved by assuring public compliance before implementation of control measures instead of afterwards.

TOPIC AREA 4: LEGAL CHALLENGES IN PUBLIC HEALTH

In the case of disease outbreaks with a highly contagious or unknown pathogen, quarantine is an effective and necessary tool for disease containment. For the purposes of this paper, quarantine will refer to the separation of exposed persons who are not yet ill from the unexposed population, and isolation will refer to the separation of ill persons from the rest of the population. In the following section we will discuss quarantine law in the United States, quarantine regulations and challenges in an international context, and obstacles in vaccine compliance.

Quarantine in the United States

The Commerce Clause of the US Constitution and Section 361 of the Public Health Service Act gives the federal government the authority to detain individuals in regards to public health. This power is restricted to specific diseases, a list of which are authorized via several Executive Orders, and applies only to the transmission of disease and ill persons between states and from foreign countries (Yu et al., 2014). However, within state boundaries, the power of quarantine and isolation remains with the state. The implementation of quarantine and isolation varies drastically between states, both with regards to protocol and the punishment for refusing to abide. Furthermore, the quarantine and isolation authority of both the state and federal government may overlap in scenarios, necessitating a clear plan for coordination and chain of command. An example of such a scenario was presented by the Congressional Research Service in their 2014 document on Federal and State Quarantine and Isolation Authority involving the arrival of an aircraft into a large city with infected persons from a foreign country.

The federal courts in the United States have consistently upheld the power of quarantine and isolation through Commerce Clause and Due Process challenges, as long as the government was deemed to be acting in the best interest of the individual or the public, and is not "unreasonable, unjust or oppressive" or discriminatory (Jew Ho v. Williamson, 1900). The ruling of primary importance to these issues was Jacobson v. Massachusetts (1905) in which the Supreme Court ruled that public health considerations take priority over individual liberties. In his opinion Justice Harlan wrote that "in every well ordered society charged with the duty of conserving the safety of its members the rights of the individual in respect of his liberty may at times, under the pressure of great dangers, be subjected to such restraint, to be enforced by reasonable regulations, as the safety of the general public may demand" (Jacobson v. Massachusetts, 1905).

In the case of a pandemic, the biggest legal consideration for the United States is Eminent Domain. This is relevant in the event that care facilities can no longer accommodate quarantined or isolated personnel, and the lack of clarity as to whether the federal government has the authority to impose home quarantines. The issue of Eminent Domain came to light in Mayhew v. Hickox (2014) where a nurse returning from West Africa refused to comply with voluntary home quarantine in the State of Maine, and she said that the state did not prove the quarantine was scientifically necessary, which is a requirement for the use of quarantine by the states. The court agreed with her.

Quarantine in the International Context

The protocol for quarantine and isolation varies between countries and geographical regions. The World Health Organization (WHO) has outlined its policies regarding quarantine and isolation for member nations in the International Health Regulations (IHR) (WHO, 2005). Most of these regulations address the rights of the member State to deny an individual entry to a country if illness is suspected, and the rights of the quarantined or isolated person to be treated with dignity and respect. It also places responsibility on the Member States to have the capability to appropriately contain and respond to a Public Health Emergency of International Concern (PHEIC). While the WHO provides its expectations of the Member States, these requirements are not necessarily met. Previous outbreaks that have triggered PHEICs include Influenza A H1N1 "Swine flu" in 2009, and Ebola in 2014. The IHR also allows for countries to demand that travellers provide proof of vaccination in areas where the disease is endemic (WHO, 2005).

Some countries that have experienced outbreaks, such as China with the 2003 SARS outbreak, have more specifically codified policies regarding quarantine and isolation. Unlike the United States, which considers quarantine adherence the responsibility of the quarantined individuals, the Chinese government holds local health and government officials responsible for failure to follow containment protocol (Article 66, Law of the People's Republic of China on Prevention and Treatment of Infectious Diseases). China, and other countries such as the Republic of Korea, have codified their outbreak response plans. In particular, following the MERS outbreak in Korea in 2015, a law was developed as a "Special Act to lay foundations for epidemiological investigation, quarantine, isolation, laboratory diagnosis, vaccination and treatment" (Park, 2017, p.6). This is unique in the fact that it addresses all aspects of containment, above and beyond just having policies regarding quarantine and isolation.

Lastly, quarantine and isolation procedure in West Africa during the 2014 Ebola outbreak forced some countries to revisit their laws regarding personal freedoms during outbreaks. In particular, Guinea's constitution protected freedom of assembly during a public health emergency. Liberia and Sierra Leona banned mass gatherings, and were also declared "Ebola free" before Guinea (Emrick, Gentry, and Morowit, 2016). Some countries outside of Africa, such as Canada and Australia focused on banning entry from countries where the outbreak was active. This is a permissible method of quarantine under the IHR.

Vaccine Compliance

In addition to Global Influenza Pandemic, the World Health Organization named "Vaccine Hesitancy" as one of the Top 10 Threats to Global Health in 2019 (WHO, 2019). The United States is already experiencing the re-emergence of diseases previously declared eliminated in the country due to low vaccination rates. The dip in vaccination is attributed to "personal and philosophical objection" waivers, used by parents who send their children to public schools or daycares (Romo & Neighmond, 2019). Outbreaks have been found to increase in schools where the exemption rate is as low as 2% (Ventola, 2016).

This issue has come to the forefront in the Pacific Northwest region of the United States, where a measles outbreak is ongoing as of this publication. There are 268 confirmed cases of measles in 2019, as of March 14, according to the CDC, with the majority of cases in unvaccinated persons (CDC, 2019). The outbreak was traced to Clark County, Washington, where the current Measles, Mumps and Rubella (MMR) vaccination rates are below both national and state rates from previous years. As of December 31, 2018 the Clark County Department of Public Health reported that only 78% of 6-18 year olds had received 2 doses of the MMR vaccine and 81% of 1-5 year olds had received their age appropriate 1 dose of the MMR vaccine (Clark County Public Health, 2019), compared to a national MMR vaccination rate of 91.5% and a state rate of 88.5% (Hill, 2018). Hall and Jolley (2011) found that for every 1% increase in measles vaccination, there was a 2% decrease in incidence of the disease. The state of Washington fell 2% below the national vaccination rate, making it 4% more susceptible to the incidence of measles cases in their population. This risk was not representative of the county where the outbreak began, however, where the vaccination rate was at least 10% lower than that of the state, incidence susceptibility increased by more than 20%. The 2019 measles outbreak and the increasing power of the anti-vaccine movement has propelled discussion about whether or not states can forcibly administer vaccinations. While Jacobson v. Massachusetts (1905) does provide this power to state public health departments, none have moved toward compulsory vaccinations at this time.

The risks associated with low vaccination rates stretches beyond "childhood vaccinations" like the MMR vaccine, to include the seasonal influenza vaccination. Between the years of 2006-2017 less than 50% of the U.S. population under 65 received their influenza vaccination (CDC, 2017). In the case of a pandemic like the 1918 influenza outbreak, which disproportionately affected a population of the young and healthy, the consequences of low vaccination rates could be catastrophic (Taubenberger & Morens, 2006). For the 2017-2018 flu season, the vaccine effectiveness was estimated at 40%. The influenza severity for that year was classified by the CDC as "high" across all age groups,with the Influenza A H3N2 subtype predominating. The 1918 influenza was also caused by an Influenza A strain, with subtype H1N1, similar to the "Swine flu" of 2009. The CDC estimates influenza vaccination rates for the 2017-2018 flu season for adults at 37.1%, 6.2% lower than the previous year (CDC, 2018). In children, the vaccination rate was 57.9%, down 1.1% from the previous year. Vaccination dropped across all age groups in a year that the flu was more severe than previous years. Pediatric influenza deaths are reported to the CDC, and there were 185 during the 2017-2018 flu season, while the estimated flu mortality for all Americans was 80,000. Of the pediatric deaths mentioned, 80% were of unvaccinated children (CDC, 2018).

RECOMMENDATIONS

1) Codify and standardize quarantine measures

The United States CDC currently uses the National Incident Management System (NIMS) framework for response to outbreaks and coordinate between agencies from federal, state, and local governments. Implementation of the system could be improved with

standardization for outbreak response among the different levels of government. Instead of personalizing outbreak plans for each state and locality, one plan would work across the different government levels for faster response and enhanced coordination. This would also reduce the number of potential legal challenges.

2) Develop a specific plan encompassing all aspects of outbreak response

While we have the CDC as the primary agency dealing with infectious disease, and they operate under internal policies, it would be beneficial to condense all policies into a special act. This would reduce the number of Executive Orders necessary to act in response to infectious diseases. It would also make the protocol less ambiguous from state-to-state and in local areas.

We need consistency amongst the agencies on how they will react to an outbreak (e.g. PPE, surveillance). It is also necessary to develop relationships with the private sector for outbreak response for full efficacy of response. An unambiguous chain of command needs to be established for instances where authorities and jurisdictions overlap. Agencies need to develop explicit guidelines and memorandums of understanding for how they will work together in the event of an outbreak response.

3) Encourage vaccine compliance

Vaccines are proven to reduce disease. Declining vaccination rates put us at risk for future outbreaks, with the re-emergence of previously eradicated diseases in under-vaccinated populations. Developing a culture of vaccine use and acceptance is paramount for the control of future outbreaks. Technology may be able to rapidly develop a vaccine, which unfortunately has no effect without use. Combating vaccine hesitancy requires a coordinated approach through continued safe design of vaccinations, community education, and vigilant refutation of pseudoscience and misinformation.

TOPIC AREA 5: ECONOMIC IMPACTS OF PANDEMICS

A modern-day influenza pandemic of similar magnitude to the in 1918 influenza pandemic would illicit global economic losses on a massive scale. Just a century ago, the 1918 pandemic took the lives of over 50 million individuals (CDC, 2018). This large-scale loss of life is not the only outcome to be concerned about in modern times, however. Calculations published by the World Bank estimate the economic costs of an outbreak of similar scale today could cause a 0.7-4.8% loss of global gross domestic product (GDP), depending on its virulence (Jonas, 2013). Beyond GDP, global economic damages would encompass higher business and commerce costs, labor shortages, investment hesitancy, trade and supply chain disruptions, and resource hoarding. Low-income countries would likely suffer amplified losses due to a lack of preventive and resilience capabilities as well as scarce public services.

In this section we will discuss the potential economic impacts of a pandemic on the United States and global economy. We focus specifically on the agricultural, trade, and tourism sectors of the United States and global economies to demonstrate the potential catastrophic scale of a pandemic.

The Agricultural Sector

The US food production portfolio is diverse, ranging from food animals like poultry, swine, and cattle to crops like grains, fruits and vegetables. Not only do these animals and crops provide nutritious food for those residing within US borders, but also many others around the world. Failures in US food production due to a pandemic would diminish the supply of food domestically and worldwide, instigating mass food shortages, economic insecurity, and significant losses to US GDP.

To put potential US food production losses into perspective, in 2014-15, a highly pathogenic avian influenza (HPAI) outbreak caused the worst US poultry health disaster to date. HPAI caused the deaths, via disease or culling, of over 50 million chickens and turkeys in the US (Ramos, MacLachlan, & Melton, 2017). These losses equated to 12% of the US egg-laying chicken population along with 8% of the turkey population for meat production (Ramos, MacLachlan, & Melton, 2017). In economic terms, the total loss from the 2015 H5N1 outbreak in poultry was over $3.3 billion (Greene, 2015). This type of outbreak not only lowers production levels, but can be grounds for import restrictions from foreign consumers.

In 2003, the United States experienced one case of bovine spongiform encephalopathy (BSE), commonly known as "mad cow disease." The market impact to the US beef sector from this single case of BSE was estimated at $200 million (Coffey et al., 2005). Not only did the beef sector experience loss at the time of the case, but long-term economic consequences persisted. Fifty-three countries, including many major markets, banned the import of US cattle, resulting in an 82% decline in beef exports in the year following the BSE case (Coffey et al., 2005). The domestic market was also impacted by this single case, with US cattle prices declining 16% and domestic demand for beef declining almost 15% (Coffey et al., 2005). This single case of disease in the United States agricultural market demonstrates the potential for economic devastation within the agricultural sector for incidences of zoonotic disease.

As the H5N1 and BSE examples demonstrate, the economic impacts of disease within the US agricultural sector can mean price shocks or the inability for producers to sell their products as demand falters from consumer distrust or fear. In the case of a price surge, consumers suffer from a more severe budget constraint as normally inexpensive protein meats suddenly become expensive, likely due to the higher cost of importing products. Conversely, producers may suffer profit losses from consumer hesitancy for domestic products or from reduced exports as trading partners enact food safety restrictions on foreign products.

On a global scale, pork and poultry are the primary sources of animal protein in the world, accounting for approximately 36% and 35% of meat consumption respectively (FAO, 2019). The top pork producers are the US, China, the European Union (EU), Brazil, Russia, Vietnam, Canada, Philippines, Mexico, and Japan (Szucs & Vida, 2017; Mottet & Tempio, 2017). The top poultry producers are the US, China, Brazil, and the EU (Szucs & Vida, 2017; Mottet & Tempio, 2017). Unsurprisingly, the top pork producers are also among the top pork consumers (kg/capita/year) (Szucs & Vida, 2017). As key protein staples in everyday diets across numerous cultures, pork and poultry are difficult to substitute. The issue of acceptability of a protein alternative is compounded by the hardship of finding a protein source that is also affordable and provides similar nutritional value. Another complication is that increases in wealth generally spur increases in the consumer demand for animal proteins. A meta-analysis of food demand literature in Sub-Saharan Africa by Melo et al. (2015) found evidence to support the notion that as a population becomes wealthier, they demand more nutrient-dense foods.

The importance of pork and poultry to the global diet means that a disease impacting these food animal sectors would have both a significant economic impact and a significant food security impact. The Food and Agriculture Organization of the United Nations

estimated in 2005 that the impact of a single outbreak of H5N1 in poultry could cost a 1.5% drop in GDP across all Southeast Asian economies (McLeod et al., 2005). Additionally, the 2004 H5N1 outbreak in Southeast Asia led to a 20% increase in poultry prices due to shortages and an 8% decline in the global poultry trade (McLeod et al., 2005). If a similar outbreak of H5N1 were to hit the poultry markets of Brazil and the United States, the global market could see a 70% reduction in the poultry trade (McLeod et al, 2005), the implications of which are into the tens of billions of dollars and a reduced supply of an important global source of protein.

International Travel

International travel is negatively impacted by a disease outbreak, but can also complicate infectious disease containment and generate long-term economic costs. Fomites, such as clothing or furniture, are inanimate objects and materials capable of carrying pathogenic microorganisms for two to three days, becoming clandestine vehicles for disease transmission. This is to say that individuals traveling between countries can unknowingly move disease from one country to another.

For example, Oxford et al, (2014) found that the influenza virus can survive for between 8 and 48 hours depending on the surface it resides on, meaning that an individual exposed to a pathogen may inadvertently transport it via their luggage into another nation or region.

The role of international travel in disease spread means that an outbreak can lead to travel advisories, which can have a severe economic impact on tourism-based economies. For example, the 2003 SARS outbreak in Toronto, Canada cost the city an estimated $1 billion in lost revenue, largely the result of decreased tourism after the WHO added the city to its SARS outbreak list (Canada CBC, 2003). A reduction in business and tourist travel to West Africa also had an economic impact for Ebola affected countries. A 2018 report by The World Travel and Tourism Council estimates that West Africa (excluding Nigeria) suffered a 7.7% loss in arrivals in 2014 as a direct result of the Ebola outbreak. Regardless of the ease of transmission of a pathogen, the fear of infection may be sufficient to keep potential travelers at home. This fear can translate into profit losses for individual businesses, regions, and countries heavily reliant tourism.

RECOMMENDATIONS

1) Economic safety net for producers

Diseases outbreaks within a herd or flock can cost producers through lost birds, lost market share, and losses in long-term demand. Because of the potentially catastrophic economic losses from reporting incidences of diseases, some producers may choose not to report or to get the animal to market before the disease causes a loss of the animal. In both cases, the risk of disease spreading outside the ill herd or flock is heightened. While many countries have culling compensation schemes, they are typically insufficient to cover all economic losses and many developing countries do not have any form of compensation for production losses due to disease outbreaks. To help mitigate the threat of disease spread from and within the agricultural sector, culling compensation schemes must be strengthened. For countries without such policies, these must be developed and enforced.

2) Improving communications around travel bans and travel advisories

During an outbreak, service-based economies are particularly vulnerable to decreases in business travel and tourism because a larger segment of overall GDP is dependent on this income. The issuance of travel bans and advisories by countries and the WHO must be done with care to avoid compounding the economic losses a country faces during a disease outbreak. Premature or improper issuance of travel bans and advisories can do more economic harm without added value to the disease containment efforts.

3) Creating an economic prioritization matrix

Due to limited resources, we need to prioritize what agencies, departments, and programs will receive funds and resources first. This will prevent critical infrastructure from collapsing at all levels of government. An economic prioritization matrix needs to be created at the federal, state, county, and city levels so that everything is streamlined and predetermined in the event of an outbreak.

4) Proper training and medical screenings for at-risk occupations

Occupations that require personnel to come into direct contact or near animals need to receive proper training on hygiene, personal protective equipment, required vaccinations, and how to recognize abnormalities in the species they are working with (Gray, Trampel, & Roth, 2007). This will prevent the rapid spread of an outbreak via the workers or animals at different farms and processing plants. Additionally, these workers should get regular medical screenings because there are many pathogens that do not affect animals, but will make a person sick (Gray, Trampel, and Roth, 2007). Regular screenings will help contain an outbreak during the early stages, by giving employes time to self-isolate or first responders time to quarantine individuals.

5) Diversify the species of food animals raised

Relying on a single species of food animal can lead to devastating economic consequences if an outbreak were to occur. It is best to diversify the types of animals raised for economic gain so when an outbreak occurs, the economic consequences will not be as severe.

CONCLUSION & INTERDISCIPLINARY LESSONS LEARNED

Interdisciplinary collaboration is crucial to preparing for, mitigating, and responding to an infectious disease outbreak. For these reasons, the student simulation that was the catalyst for the paper brought together students from the disciplines of veterinary medicine, human health sciences, agriculture, economics, biochemistry, political geography, and more. One of the key lessons learned in this interdisciplinary simulation was the importance of posing questions to practitioners and researchers in fields outside one's own. When complications or intersections of disciplines are realized, the opportunity for fruitful collaboration arises. All fields bear unique knowledge and training which can be indispensable components of the preparation and response to disease outbreaks. It was through this interdisciplinary interaction in the pandemic simulation that we were able to fully identify the gaps and challenges addressed in this paper and to develop actionable recommendations for future pandemic preparedness and response.

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AUTHORS*

Rachel Paige Casey

Rachel Paige Casey is a beginning PhD student in Agricultural Economics at Texas A&M. She earned her BSE in Kinesiology and MS in Agricultural Economics from the University of Arkansas. She recently completed a Master of International Affairs in International Development and Economic Policy from The Bush School of Government & Public Service at Texas A&M University.

Since 2016, Rachel Paige has been the editorial assistant for the *Journal of Drug Education: Substance Abuse Research and Prevention.* Additionally, she has been involved in various research activities regarding the economic, public health, and socio-political impacts of infectious diseases as well as the relationship between infectious diseases and conflict.

Andres Castro

Andres Castro grew up in Irving, Texas, and is a first-generation college student. He attended Texas A&M University and received his Bachelor of Science degree in Biomedical Science. He is currently a second-year veterinary student at the Texas A&M University College of Veterinary Medicine & Biomedical Sciences (CVM).

He wants to pursue a career in public health or practice mixed-animal medicine somewhere in the Dallas-Fort Worth metroplex. After graduation, he wants to pursue a Master's in Public Health so he can apply for the Epidemic Intelligence Service through the Centers for Disease Control and Prevention (CDC). His hobbies include playing soccer, volleyball, hiking, and watching movies.

Spencer DeBrock

Spencer DeBrock is a PhD student at the CVM working in Dr. Sarah Hamer's vector biology lab. He received his Bachelor of Science in Zoology from the University of Maine in 2018, where he completed an undergraduate thesis project in the Honors College. His thesis was entitled *The Effects of the Hemlock Woolly Adelgid on Abundance and Nymphal Infection Prevalence of Black-legged Ticks in Maine* and involved a mixture of field work and lab work. Currently, he is starting his dissertation, where he is interested in the role that migratory passerine birds play in the dispersal of pathogens and neotropical ticks in the United States. To investigate this, Spencer is collaborating to trap, band, and sample wild birds as they make landfall on the Gulf Coast of Texas during Spring migration, and then analyzing parasite samples in the lab to learn about their origin and impact on avian health. Lab work will involve PCR and deep sequencing. Spencer jumped at the opportunity to be a part of the Scowcroft Institute's Pandemic Simulation to expose himself to this sector of epidemiology and emphasize the importance of considering wild animal reservoirs when predicting human disease emergence.

Spencer also enjoys teaching. He spent approximately five semesters in undergraduate as a teaching assistant in multiple classes. He took a pedagogical course on teaching theory and effectiveness in undergraduate and has continued his interest in teaching in his graduate studies by not only becoming a member of the Academy for Future Faculty at Texas A&M but also taking a 'for-credit' course in Teaching STEM courses in a college setting. Such courses and extracurriculars have been great for not only his professional development, but his teaching ability and course development as well. He hopes to graduate from Texas A&M in 2022, and looks forward to a career as a college professor or a research scientist.

Tesserae Komarek

Second Lt. Tesserae (Tess) Komarek is a medical student at the F. Edward Hébert School of Medicine, Uniformed Services University of the Health Sciences. Prior to attending medical school, she served in the United States Peace Corps in Senegal, West Africa, where she worked on maternal and child nutrition, malaria surveillance, clean water access, and health improvement in rural Senegal.

She attended Emory University and received a Bachelor of Science in Anthropology and Human Biology, and a minor in Global Health, Culture, and Society. Her interests include global health policy, infectious disease, and quality improvement.

Sherdina Romney

Sherdina Romney received her Master of Science degree in Marine Biology from Texas A&M University, following the completion of her Bachelor of Science degree in Developmental Biology from Wageningen University, The Netherlands. She is currently a laboratory instructor, teaching anatomy and physiology for the Biology department at Texas A&M, and is an international visiting research scholar in the laboratory of Dr. Annie Newell-Fugate in the Department of Veterinary Physiology & Pharmacology at th CVM.

Her research projects examine the effects of hyperandrogenemia (abundance of androgens) on ovarian function and the sexually dimorphic effect of the local androgen/estrogen environment on adipose tissue and lipid metabolism. She aspires to become a physician researcher to address human health issues that arise from the human interaction with the environment.

Thomas Snavely**

Thomas Snavely is a graduate student at Texas A&M University pursuing a PhD in Biochemistry with a focus on novel treatments for human infectious diseases. As a part of large international collaborations, his work involves studying the *in vivo* safety and efficacy of therapeutic approaches to help advance these treatments into human clinical trials. Thomas is also studying homeland security with an emphasis in emergency management at The Bush School of Government & Public Service.

Before coming to Texas A&M, Thomas was a nuclear reactor operator in the U.S. Navy. He has a bachelor degrees in Nuclear Engineering Technology and Biochemistry. Thomas is an avid technical SCUBA diver and likes to spend his free time volunteering as a technician with a local K-9 search and rescue team, where he is training as a K-9 handler.

Ethan A. Taylor

Ethan A. Taylor is a PhD Candidate at the CVM. An infectious disease epidemiologist with a passion for biosecurity, he has had involvement in five different outbreak responses, including foodborne illnesses, vector-borne diseases, and hemorrhagic fevers. His role in these situations have included public health, laboratory, and analytical capacities. These outbreaks have involved animal and human components, often times interlinking the two. In addition to those responses, Ethan has been involved in other disaster responses, including Hurricane Harvey, and has advocated for biosecurity and public health preparedness with State Representatives and Congressional staffers.

His current research involves the epidemiology and molecular mechanisms of cephamycinase and extended-spectrum beta-lactamase antimicrobial resistance profiles among enteric bacterial populations in dairy cattle. The genes responsible for these profiles code for resistance to antimicrobials considered critically important and of highest priority for human medicine by the World Health Organization (WHO). Ethan will defend his dissertation entitled *Effects of Two-Dose Ceftiofur Therapy for Metritis on Antimicrobial Resistance among Fecal* Escherichia coli *and Salmonella in Dairy Cows at Slaughter-Eligibility* in June 2019. Prior to attending Texas A&M, Ethan completed his Master of Public Health degree with a critical analysis focused on preventing an endemic presence of dengue in the Hawaiian Islands, inspired by the 2015–16 outbreak.

Sarah Walsh

Sarah Walsh is a second year MD/PhD student at the Uniformed Services University. She is currently completing her dissertation with the Regenerative Medicine Team in the Department of Surgery, working with a simulated blast injury model to investigate early biomarkers for traumatic injury complications seen in service men and women. Sarah plans to commission into the U.S. Army in 2020, and continue to pursue a career as an officer in the medical corps.

She serves as the president of the Global Health Interest Group at the Uniformed Services University, working to provide opportunities for other students to explore public and global health challenges. Sarah graduated from Michigan State University in 2017, with degrees in Biochemistry, Molecular Biology, and Public Policy. As an undergraduate, she worked with international researchers at the German Diabetes Center in Düsseldorf, Germany, and continues to enjoy engaging with scientists from around the world.

Serene Yu

Serene Yu is a second-year veterinary student at the CVM. Her career interests include Global One Health, emerging zoonotic diseases, and public health. Serene's interest in infectious diseases began in the sophomore year of her undergraduate studies, when she took a class on field techniques in vector-borne disease research. From there, she went on to complete her senior undergraduate thesis studying the vertical transmission of avian bornavirus.

Serene's current research is focused on the prevalence of zoonotic tick-borne pathogens circulating in wildlife from south Texas. After graduation in 2021, she intends on serving her community as a general practitioner before going back to school to attain a Masters of Public Health. Her ultimate goal is to bridge the gap between human and animal diseases.

**All authors contributed equally to the writing of this white paper.*
***The manuscript was edited by Thomas Snavely.*

STUDENT PROJECT MENTOR

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Dr. Blackburn is an Assistant Research Scientist with the Scowcroft Institute for International Affairs in The Bush School of Government & Public Service and an adjunct faculty member in the Department of Health Promotion and Community Health Sciences in the School for Public Health at Texas A&M University. In these roles she conducts research on issues related to pandemics, zoonotic diseases, and the health of vulnerable populations. Dr. Blackburn teaches courses on infectious disease in the developing world, refugee health, the social and political impacts of pandemics, and bioterrorism.

Prior to her position at the Scowcroft Institute, she worked as a postdoctoral researcher in the Field Disease Investigation Unit in the College of Veterinary Medicine at Washington State University. Dr. Blackburn received her PhD in 2015, from Washington State University as part of the Individual Interdisciplinary Doctoral Program, a degree program that requires three major fields of study. Dr. Blackburn's doctoral fields were Political Science, Communication, and Veterinary Clinical Sciences.

Scowcroft Institute 2018 Pandemic Simulation poster

President George H.W. Bush & Lt. Gen. Brent Scowcroft

“We live in an era of tremendous global change. Policy makers will confront unfamiliar challenges, new opportunities, and difficult choices in the years ahead. I look forward to the Scowcroft Institute supporting policy-relevant research that will contribute to our understanding of these changes, illuminating their implications for our national interest, and fostering lively exchanges about how the United States can help shape a world that best serves our interests and reflects our values.”

— Lt. Gen. Brent Scowcroft, USAF (Ret.)

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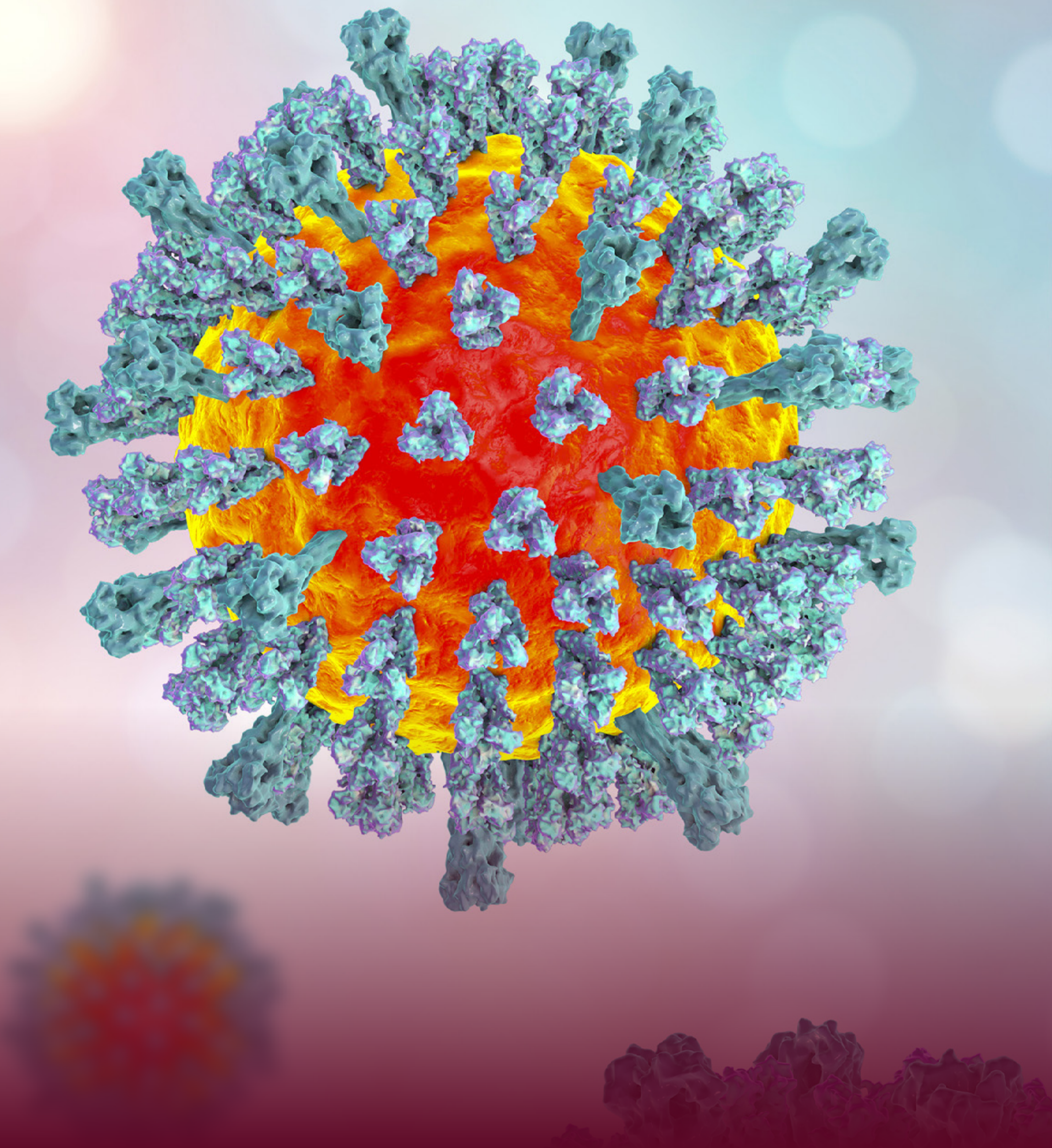
Texas A&M University | College Station, Texas, USA | *cvmcommunications@cvm.tamu.edu* | *vetmed.tamu.edu/communications*



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