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REVIEW ARTICLE

PANDEMIC READINESS: LESSONS LEARNED FROM THE PAST

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Abstract

A pandemic occurs due to complex interactions between total number of population on earth, food supplies, environmental condition, human activities and behaviour, human susceptibility, science and technology and health care system. The past pandemics have shown us that the spread of the disease has been facilitated by the movement of people, whether by land, sea or air, by trade or war. When the cause of the disease is not known, the pandemic results in high mortality and economic depression. During the ancient pandemics, such as Justinian plaque and Byzantine plaque (Black Death) where no prior knowledge or experience in dealing with the calamity was known, the reaction of the people was through avoidance, isolation, quarantine and destroying the source (infected person). Over time, the development of science and technological invention, socioeconomic progress, and the health care system development has increased our capacity to recognise the agents of the pandemics, developing the medicine to treat the disease and vaccine to prevent further spread of the infections. During several pandemics of influenza in the last century, the public health intervention at the earliest stage of the epidemic such as social and physical distancing, wearing mask, frequent hand washing, and movement control of the people has helped in slowing down the spread. Medical treatments and immunizations help prevent severe complications and death. The pandemic ended when herd immunity was established in the population because of natural infection or vaccination. However, rapid population growth and human activities have led to environmental intrusion into wildlife habitat, leading to the zoonotic transfer of new infections to the people. Preparedness for any pandemic threat should focus on reducing poverty and poor living conditions, changing risk behaviours that trigger infection, and strengthening public health infrastructure. The monitoring system should be able to detect a life-threatening infection and provide early warning to other areas for rapid response. Risk communication with vulnerable groups, source containment strategies and multinational collaboration are required to prevent the spread. Public health measures should be implemented promptly until specific treatments and vaccines are available for the pandemic. Effective planning to balance health priorities with economic and fiscal policies is critical to the country's survival. This requires strong leadership and political stability at the local and global levels.
Keywords: pandemic, lesson learned, readiness, preparedness.

Introduction

The pandemic is the occurrence of epidemic or outbreak of diseases, especially infectious diseases in a very wide area, crossing international boundaries and usually affecting many people (1). The incidence of pandemic becoming more often lately due to increasing people mobility, transportation efficiency and environmental changes. It causes social, economic, and political disruptions locally and internationally (2). Most of the countries normally have a substantial monetary and human resource allocation and preparation to overcome the epidemic of diseases within the country and prevent the entry of diseases from the other countries. However, due to economic differences between countries, the poorer countries will have to face bigger burden to fight against the spread of diseases within the country and stop the disease from entering the country (3). The pandemic will only stop after all countries are able to prevent the spread despite their economic differences. These require international efforts and multilateral cooperation in providing expertise, skilled manpower, monetary funding, drugs, vaccine, and equipment to the country in need.

Although many pandemics have occurred in the past, the extent of its spread and the severity of the disease are different. Many of the organism responsible for the pandemic is almost similar including the mechanism of spread and its host. Most of this organism originated from animals and close encounters with these host factor probably the reason for the transmission in human. They are now becoming much more common. Since 2003, we have experienced severe acute respiratory syndrome (SARS), an influenza pandemic (H1N1 in 2009), a Zika pandemic (2015), and Ebola epidemic that involved many people (4)

The risk factor for a pandemic is divided into Spark Risk Factors and Spread Risk Factors (1). The introduction of pathogens from domestic animals or wildlife into humans via zoonotic routes will trigger an infection. It usually occurs in regions with intensive and extensive agriculture and dense animal production systems, including China, India, Japan, the United States and Western Europe. Zoonosis between animals and humans can trigger an infection in parts of China, India, West and Central Africa and the Amazon Basin. Encroachment of wildlife habitat for logging and road construction will facilitate zoonotic disease transfer. Consumption of wild animal meat and the use of traditional animal-based medicines may create risks (5). The risk of a pathogen spreading through a population is influenced by genetic adaptation and the mode of transmission of pathogens. They are linked to environmental conditions such as climate, degree of pollution, population density, population mobility, population susceptibility and the effectiveness of control measures (6). Since human does not have immunity against this pathogen, human will develop a disease. The organism will continue to reproduce in human and spread to others through common route such as faecal-oral, respiratory and through skin. So far influenza virus has been the most likely organism that cause severe pandemic (7). These viruses transmit efficiently between humans, have a long incubation period, and asymptomatic infections and ability to mutate rapidly. A second group of pathogens that may cause a moderate global threat, namely Nipah virus, H5N1 and H7N9 influenzas. These organisms have not shown to be sustained in human-to-human transmission. A third group of pathogens such as Ebola, Marburg, Lassa has the potential to cause regional epidemic because of a slow transmission between human to human so that there is a high probability of detection and containment of the pathogens.

Past pandemics

History has shown that humanity has long been at constant risk of disease epidemics and pandemics. Some of the important and significant pandemics that changed human development and progress are mentioned here.

1. ANTONINE PLAGUE

The Antonine plague was possibly an early appearance of smallpox. It started in Asia and spread to Europe due to commerce and war in 165-180AD. The infection spread to the entire Roman Empire and killed five to ten million people. No known treatment was available then. The pandemic ended by isolating patients and burning cadavers (8).

2. JUSTINIAN PLAGUE

It began in Egypt, then spread across Palestine and the Byzantine Roman Empire in 541 A.D. and killed about 30-50 million people (about 30 percent of the world's population). It is thought that this is the first appearance of bubonic plague and it is carried by rats and spread by fleas. No known treatment was available at this point. No known reason on how it stopped, but some evidence showed it was through the implementation of quarantine and isolation. Infected individuals will be left on their own and uninfected individuals will usually stay in their homes or move to less densely populated areas (9).

3. BUBONIC PLAGUE (BLACK DEATH)

It began in Asia, brought by the Mongols as they invaded the Middle East and Europe. The maritime trade is responsible for its spread throughout the continent. Nearly one third of the population in the affected regions has been decimated by the plague. It led to the introduction of quarantine, the publication of leaflets and posters to guide personal and public actions, and self-isolation (10)

4. SPANISH FLU

Influenza disease originated in Europe in 1918 and spread to Americas and the world during the First World War. It has infected an estimated 500 million people and caused 50 million deaths around the world. Back then, there were no effective drugs or vaccines to treat this influenza disease (11). Most countries have instructed their citizens to wear masks, and schools, theatres and businesses have been shut down. The threat of influenza disappeared in the summer of 1919, when most infected persons had developed immunity or died. It was discovered later in 2008 that the H1N1 virus that causes the pandemic has the capacity to weaken the victim's bronchi and lungs. They brought on bacterial pneumonia and killed the patient. The influenza outbreak re-emerged in 2009 from China, killing over 300,000 people worldwide.

5. ASIAN FLU

The flu started in Hong Kong in 1957 and spread across China, then into the US and the rest of the world. Total mortality is estimated at about 1.1 million around the world. A vaccine was developed (less than 5 months) and effectively contained the pandemic (12).

6. SARS

It started in China and extended to other parts of the world by air transportation. Although it does not cause many deaths, addressing the SARS pandemic is a wake-up call for many countries to strengthen their public health response and their overall health system. The simplest and oldest public health tools, such as contact tracing, quarantine, and isolation, helped to overcome the pandemic. The SARS pandemic in 2003 was able to stop because of the rigorous efforts of the affected countries (13). They identify and isolate the cases in the hospital early, tracing the sources of infection and their contacts, managing the hospital infection, bed availability, crowd control, and travel restriction locally and internationally. Risk communication to the public has been enhanced through all media including daily briefings on the pandemic situation. The political commitment to provide adequate funding and resources up front and to enforce the Infectious Diseases Act, among others, has been a success factor. It was shown that massive resources use to control the outbreaks almost as soon as they appeared was more cost-effective than having to apply resources continuously over time to control the disease.

7. EBOLA

The 2014–2016 outbreak in West Africa was the largest and most complex Ebola outbreak since the virus was first discovered in 1976. The first Ebola Virus Disease (EVD) outbreaks occurred in remote villages in Central Africa then spread between countries, starting in Guinea then moving across land borders to Sierra Leone and Liberia. Weak surveillance systems, poor public health infrastructure and poor community engagement contributed to the difficulty in the containment of this outbreak (14). During the pandemic, more deaths occurred due to reduced access to treatment for malaria, HIV/AIDS and tuberculosis than the EVD.

Lessons learned from past pandemic and preparation for the future

Pandemics are caused by specific organisms. These organisms have been around for millennia without causing harm. Once there is a close encounter between man and animals in villages and cities, it provides the opportunity for these organisms to switch their hosts from animal to humans and cause human smallpox, measles, and other diseases. Sparking factors include clearing forests, hunting wild animals, and eating exotic or wild animals, while spreading factors include the infectibility of organisms, the efficiency of the vehicle to spread and the vulnerability of populations. These factors are known to affect the seriousness of the pandemic. By looking at the scenarios of pandemic in the past, we will be able to anticipate the emergence of new infection and take an action to stop the spread as soon the infection starts (table 1). By understanding the nature of the pathogens, the population behaviour, the susceptibility of the population, the development in science and technology, the robustness of the health care system and multisectoral cooperation, the impact of future pandemic can be minimised. Let us examine some the lessons learned from the past pandemics and human development since then and use those experiences to prepare our future response to any pandemic threats.

1. Development in Science and Technology

Before the 18th century, science and technology were not well developed, and pandemic control was largely based on trial and error. The people do not know about germ, its mode of spread and treatment, etc. The way the people react to the pandemic was by avoidance (not entering the epidemic areas), isolation (stay at home when sick) and burn the dead. During the Black Death, the quarantine was introduced, the sick and contacts will be kept in the house for 40 days and if the death took place, the house will be burned. The pandemic ceased because those affected died and only those immunized were alive. Between 30 and 50% of the population in the affected areas died at that time. The population has resumed growth, and advances in science and technology have been observed to better adapt to nature. Since the Industrial Revolution, many inventions and discoveries have led to the identification of the organism responsible for the infection, its mode of spread and its prevention. This includes invention of a microscope, treatment with drugs and nutrition, vaccination, etc. (15) However, with the increase in the number of population, international trade by land and sea and conflict between countries, the spread of infection became faster such as during cholera pandemic and the Spanish flu. It accelerated after the introduction of commercial airliners (2). Rapid development of science and technology in industrial revolution 2 (IR2) , IR3 and IR4 has helped to better detect the epidemic, monitor disease progression, identify the organism, and development of vaccines. Yet the pandemic on a much broader scale continues to haunt us from time to time. Behavioural factors and population growth need to be further explored to address some of the uncertainties.

2. Population expansion and behaviour

The global population in 2020 stands at 7.8 billion people. It is expected to increase to 9.9 billion by 2050. With the exponential increase of world population in last 200 years, the need for food, shelters and security is becoming challenging to all countries (Malthusian theory). Deforestation, intensification of agriculture, urbanisation and ecosystem disturbance are inevitable consequences (16). This allows individuals to encounter wildlife and its potential zoonotic pathogens. These activities have resulted in emerging diseases such as haemorrhagic fevers, Nipah infection and hanta virus infections. Since 1999, markets for live animals in China have resulted in three major pandemics: H5N1 and H7N9 avian flu, SARS and now SARS-CoV-2 (COVID-19). We have no control on the world's population growth since every country has its own population planning and policy, including growth, support system, employment, and health care. Since the previous outbreak, we have noted the emergence of a deadly pandemic due to the behaviour of people who eat exotic animals (5). The control of this market and of this behaviour will probably avoid a risk of spark in the future. However, the most lethal behaviour that must be anticipated is a terrorist attack using a mortal organism (bioterrorism) (17).

3. Socio-behavioural development

The movement of people is an important factor in the spread of the pandemic. The enabler includes transportation and travel (18). When people travel, germs travel as well. In the 'black death' pandemic, the germ followed the silk trade routes of Mongolia and China to Europe. Cholera spread along travel routes between India and Europe. Influenza pandemics also follow the human population movement. In the last 100 years, the infection spread through rail, ship, and air routes. It is important that the mobility of people between countries should be monitored using the current technology to allow only those who are healthy can travel. Use of green card or immunization certificate for international travel can be helpful.

The Aedes aegypti-borne diseases (yellow fever, dengue, Chikungunya, and Zika) are all associated with human overcrowding, imperfect sanitation, water storage and exportation of vector mosquitoes.

4. Health system development

Robust and resilient health systems are necessary to combat any outbreak (19). In the past, healthcare systems were designed to treat the disease when it occurred. In the normal situation, the system can cope with the disease occurrence, but during the epidemic or pandemic when there is a rapid increase in the number of cases in a short period of time, the system may fail to function normally. Even in the best-equipped and best-prepared countries, it is difficult to contain the outbreak, as in the COVID-19 pandemic. Additional health-related measures are required to support the health response, such as the application of lockdown, movement restriction orders, or emergency policies (20). In the event of an epidemic, health care system should execute current infection prevention and control (IPC) practices such as the use of personal protective equipment (PPE), working protocols for health care providers and social support when needed. Patients should be treated following the strict guidelines and evidence-based protocols. These will prevent the transmission of diseases within the health care setting. Data on patient care, such as death, complicated cases that require special assistance need to be shared between hospitals, treatment facilities and health authorities. Communication with the public should be opened to reduce panic and irresponsible responses.

5. Pandemic responses

Responding to an outbreak varies across countries and regions. It depends very much on the ability of the affected country to finance the outbreak control and prevention, including skilled human resource, diagnostic and tracing facilities, treatment facilities, drugs, personal protective devices, etc. It is in the countries' own interest to spend more and better on pandemic preparedness

compare to other country. This will depend to a great extent on the political commitment, economic and political stability (leadership) of the country (21). However, worldwide cooperation is required to limit the spread of the disease in low and middle-income countries (22). In this aspect, WHO should lead and coordinate the pandemic responses globally (23). In addition to providing more funding and technology to support prevention efforts, creating, and disseminating knowledge to overcome the outbreak and promote best practices in the response. It is also important to reduce inequality in health services and avoiding the disruption in other critical healthcare provision such as maternal and child health, other communicable and non-communicable diseases.

What can we learn from the current COVID-19 pandemic?

Coronavirus disease (COVID-19) is an infectious disease resulting from a novel coronavirus, SARS-COV-2. It is spread primarily through droplets generated when an infected person coughs, sneezes, or exhales. Other people will get infected by breathing in the virus from the infected person (symptomatic or asymptomatic) in proximity, or by touching a contaminated surface and then touch your eyes, nose, or mouth. Now, more than 120 million people have been infected and more than 2.7 million deaths around the world (24). The most advanced nation and considered as the most prepared nation in combating epidemics in the world, the United States of America (25) unfortunately has the greatest number of infection and death till date..

Key lessons that we can learn from the current pandemic so far include the need for early warning system to other areas when the new incidence of bizarre presentation of disease detected in the community. Transparency of data is required to stop the spread at the source. Stringent measures should be implemented early in the pandemic to control the spread by conducting widespread testing and contact-tracing, and legally enforced physical distancing. Strong leadership at the highest level, locally and internationally is required to provide financial and legal support to contain the pandemic. All countries should work together to tackle the pandemic under the direction of the WHO including strengthening the public health infrastructure, stocking of personal protective equipment (PPE) and life support equipment. Sharing information and data is vital to building public trust and inclusive decision-making. The use of new technology in detecting and eliminating the virus, monitoring a public compliance with SOP, contact tracing and vaccine development may enhance our capabilities to fight against any infectious disease threat in the future.

Pandemic response and preparedness

The most cost-effective strategies for pandemic preparedness are investing in public health initiatives (26). This includes providing clean water and sanitary hygiene for the people, vector control and safe animal husbandry. Risk communication to a public on the potential pandemic should be enhanced. Disease surveillance must be strengthened, and quick action should be taken on the potential source that could lead to epidemic and pandemics (1). One initiative by the WHO is setting up a Global Influenza Surveillance and Response System (GISRS) in 1952 to monitor influenza epidemiology around the world, and advice the affected countries to take action to contain the epidemic (27). Since many influenza diseases occur due to a rapid and seasonal viral mutation, the identification of influenza caused by new viruses that lead to a lethal outcome is essential to prevent its spread. Seasonal influenza with lower transmissibility and less fatality can be controlled through public health measures and herd immunity.

At the beginning of the pandemic, the risk communication to public should be enhanced through coordinated efforts by government, NGOs and community. For an example of COVID19 pandemic, the public should be

informed immediately about the severity of the event, the pathogens, and the population at risk. The delivery of health interventions must be scaled up proportionately to reduce the transmission and protect the public. In the early phase of pandemic, not much information was available about the virus and its potential effect on humans, the specific health intervention and treatment, which is still not available. This may lead to fast spread of the disease causing many deaths.

To manage the pandemic, immediate political involvement and leadership at the highest level is essential. Decisions on movement orders, adequacy of PPE and diagnostic testing, quarantine and treatment beds, and vaccine availability must be timely and effective. The public must be informed as soon as possible using the available mode of communication to reduce dangerous rumours and unscientific evidence of the information. Authorities must build trust and confidence in the public to accept standard operating procedures to prevent the spread of the disease. Double standard or ambiguous SOPs need to be avoided. When credibility is compromised, trust takes time to return.

The current science and technology advances are beginning to provide hope that the emergence of an epidemic can be predicted and hopefully begin to lower the risk of spread and its consequences. Monitoring past origins of the pandemic allows us to identify spark risk factors and prevent emergence. Ongoing monitoring of wildlife species carrying high-risk viruses that prevent close contact with these animals may reduce zoonotic transfer. The bio-medical development of vaccines has reduced the incidence of certain diseases such as smallpox, measles, polio, etc. The most significant first step in pandemic control is prevention and education. Some medications and vaccines are seldom available early in the outbreak and may not be available for years. Public health efforts, including those organized by local and state health departments, and those provided by government, industry, and nongovernmental organizations (NGOs) are by far the most critical components of early pandemic responses. In case of influenza diseases, physical distancing, masking, frequent hand washing, restricted movements, preventing mass gatherings, travel restrictions, etc., appear to be effective when adopted early and rigorously. Aggressive early public health interventions, such as mass testing, contact screening and isolation, may contain the virus from later spread.

We could expect to face pandemic challenges repeatedly, and it is now very clear that global pandemic threats cannot be managed only through domestic responses. Pandemics are probably a warning sign for humans to manage the world efficiently. With 8 billion people on earth today, survival will depend on our existence in harmony with nature.

Conclusion

History has taught us how to fight effectively against the epidemic or pandemic. Due to complex interactions between number of populations on earth, food supplies, environmental condition, human activities, people's mobility, science and technology development and health care system, the epidemic and pandemic of diseases will continue to emerge from time to time. To prevent from the spark of the infection, its spread and the serious complication of the disease, the socioeconomic status of the world population must be improved including those displaced by war or conflict. All countries should always be prepared in response to any epidemic or pandemic, such as stocking of personal protective equipment (PPE) and life support equipment, strengthening public health surveillance and data sharing mechanism. If the pandemic does occur, the essential health services must be maintained to reduce additional death from other diseases. The public-health measures instituted such as limited movement order, wearing mask, physical distancing during pandemic must get a public trust through an effective risk communication. At the same time, effort to develop a vaccine is crucial to stop the pandemic.

Table 1. Lessons learned from the pandemic.

	Pandemic Event	Public health intervention	Care and Treatment	Lesson learned
1	Bubonic plague (Black Death)	The establishment of quarantine, publication of flyers and posters to guide personal and public actions, and self-isolation. Stopped probably due to herd immunity.	none	Isolation of cases and risk communication
2	Cholera	PH efforts – hand washing, toilet sanitation and clean water for drinking.	Limited use of vaccine (discovered in 1885)	Personal hygiene, clean water and proper toilet are still an important measure. Risk communication and Vaccine may help.
3	Spanish flu influenza	All citizen to wear masks, and schools, theatres and businesses were closed. Stopped probably due to herd immunity.	none	Flu infection with unknown pathogen and no available treatment, wear mask, physical distancing and limited mobility.
4	Asian flu influenza	PH efforts -mask, social distancing, quarantine, hand washing, MCO. Stopped after mass vaccination (A vaccine was developed less than 5 months and effectively containing the pandemic.	Antibiotic for secondary infection and vaccine	Use of antibiotic to treat secondary infection and vaccine to develop immunity in the population.
5	Hong Kong flu influenza	PH efforts -mask, social distancing, quarantine, hand washing, MCO. Bird flu was once eradicated by the culling of all poultry in Hong Kong.	Antibiotic for secondary infection and vaccine	Use of antibiotic to treat secondary infection and vaccine to develop immunity in the population.
6	SARS	Early case detection through the "people's surveillance" and large-scale quarantine, isolation, and infection control at designated SARS hospitals.	Antiviral medications and steroids	Strong PH response at the beginning of the outbreak.
7	Swine flu influenza	PH measures- mask, social distancing, quarantine, hand washing, travel restriction.	Antiviral drugs	Disease has become endemic. Surveillance system to detect the epidemic.
8	MERSCOV	PH measures- hand washing, sneeze etiquette, avoid personal contact with patients and suspected animals.	No specific treatment	Strong PH response and risk communication. It has continued to cause sporadic, localized outbreaks.
9	Ebola	PH measures - Avoid infected people, their body fluids, and the bodies of anyone who has died from the disease. Avoid contact with wild animals, like bats and monkeys, and their meat.	No specific treatment. Monoclonal antibodies have been used. Vaccine will help	Engaging with people to build community trust. Decentralising care for suspect Ebola patients to improve access to care for other health problems and avoid violence to force people's adherence to public health measures.
10	Zika	PH measures - preventing mosquito bites indoors and outdoors, avoid pregnancy if suspected infection or exposure.	No specific treatment	Risk communication- pregnant women and international travellers.

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