An overview of global epidemics and the challenges faced

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Key points

- Global epidemic events, that is, plague, influenza, coronaviruses have been evolving from deadly human pathogens.
- Most of the emerging pathogens are of "zoonotic" or animal origin.
- Practicing nonpharmacological interventions is an effective weapon in fighting against an epidemic.
- The 2019 Global Health Security Index indicated the weakness of global preparedness.
- The next global pandemic is not so far away.
- A number of preparative measures should be undertaken for tackling future epidemics.

1.1 Introduction to global epidemics

The disease of a living system is a mechanism of dysfunction that includes specific symptoms and signs that hinder the body's normal homeostatic processes (Wikipedia, 2020b). Many external and internal factors may be responsible for a disease. Usually, there are four main types of diseases: infectious diseases, deficiency diseases, hereditary diseases, and physiological diseases. In terms of the transmission chance of any disease, it can either be communicable or noncommunicable. Communicable diseases are mostly infectious diseases, which introduced the epidemic phenomenon into the world a long time ago. A very rare disease that does not occur randomly in a population is usually categorized as an epidemic. The term epidemic originates from the two Greek words "epi," meaning "upon," and "demos," meaning "population". According to WHO, a regional outbreak of an illness that spreads unexpectedly is known as an epidemic (Jha, 2020). The broad definition of epidemic disease delivered by the Centers for Disease Control and Prevention (CDC) is "the occurrence of

large number cases of disease, injury, or other health condition than expected in a given community or region or among a specific group of persons during a particular period."

There are three major components of an epidemiologic triad: external agent, susceptible host, and environment. The agent means an infectious pathogen such as a virus, bacterium, parasite, or other microbes that can attack the host in a favorable and balanced environment. All these three components work together to cause disease and other health events. The assessment of the interactions among these three components is required for developing effective interventions to control an epidemic (CDC, 2006).

There are four phases of an epidemic: the emergence of a disease in a community, outbreak of the disease with localized transmission, sustained outbreak of the disease in the community, and reduced transmission by controlling the disease or acquiring immunity. The epidemic concept is different from the other related infectious disease terms like "endemic", "outbreak," and "pandemic" in terms of the spreading of the disease. Knowing the difference among these terms is important for understanding the baseline rate of incidence and public health updates and thus implementing appropriate health responses (CDC, 2006). An endemic disease belongs to a particular geographic area. For example, malaria was an endemic disease in parts of Africa. An outbreak deals with an increase in the number of endemic cases and becomes an epidemic if not controlled quickly. The terms "epidemic" and "outbreak" are sometimes used interchangeably. While a disease-causing agent is different from current strains and much more infectious, the epidemic disease spreads over multiple countries by affecting a substantial number of people, and thus a situation, named a pandemic, arises (CDC, 2006). In general, pandemics affect far more people than an epidemic in wider geographical areas in the entire world and cause impaired health and many more deaths than epidemics, which often creates enormous social disruption, economic loss, and hardship (CDC, 2006).

1.2 List of epidemics

Until the 21st century the world has faced several global pandemic and epidemic diseases including COVID-19, (Fig. 1−1 and Table 1−1) ranging from asymptomatic to lethal and caused by different viruses and bacteria (Wikipedia, 2020c). All these pandemics posed a major challenge across the world and ultimately led to the death of thousands of people and the destruction of civilization as well as the economy.

1.3 Origin of epidemics hitting the globe

Usually, most of the epidemics may have a common origin (CDC, 2006). Despite the fact that the etiology of the multitude of shimmered pandemics is at first dark, the origin of the continuously evolving epidemics hitting the globe seems to be natural and comprises a diverse species of bacteria, viruses, fungi, and parasites.
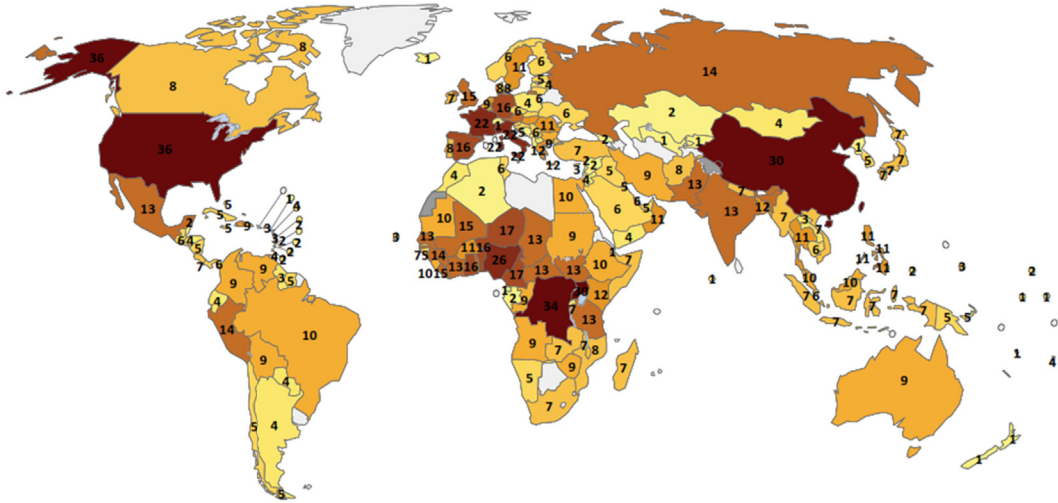
FIGURE 1–1 Burden of epidemics: illustrations: epidemic events* globally, 2011−17**: a total of 1307 epidemic events in 172 countries. *Courtesy: Managing epidemics, Key facts about major deadly diseases, Version 1, World Health Organization, 2018.*

Table 1–1   List of epidemics that occurred worldwide until the 21st century.

Name of epidemic	Period	Type of disease	Place	Number of deaths	Reference
Athens Plague	429−26 BCE	typhus, typhoid fever, or viral hemorrhagic fever	Greece, Libya, Egypt, Ethiopia	75,000−100,000	(Papagrigorakis et al.)
Justinian Plague (1st plague)	541−42	Bubonic plague	Europe and West Asia	30−50 million	(Burki, 2007)
Black Death (2nd plague)	1346−53	Bubonic plague	Europe, Asia, and North Africa	75−200 million	(Robinson, 2004)
1510 influenza	1510	Asia, North Africa, Europe	Influenza	Around 1% of those infected	(Morens et al., 2010)
Naples Plague	1656	Bubonic plague	Italy	240,000−1,250,000	(Scasciamacchia et al.)
1st cholera	1817−24	Cholera	Asia and Europe	100,000 +	(Hays, 2005)
2nd cholera	1826−37	Cholera	Asia, Europe, and North America	100,000 +	(Hays, 2005)
3rd cholera	1846−60	Cholera	Russia	1 million +	(Hays, 2005)
3rd plague	1855−1960	Bubonic plague	Worldwide	12 million +	(Hays, 2005)
4th cholera	1863−75	Cholera	Middle East	600,000	(Hays, 2005)

(Continued)

Table 1−1   (Continued)

Name of epidemic	Period	Type of disease	Place	Number of deaths	Reference
5th cholera	1881−96	Cholera	Asia, Africa, Europe, and South America	298,600	(Hays, 2005)
1889−90 flu	1889−90	Influenza or HCoV-OC43	Worldwide	1 million	(Hays, 2005)
6th cholera	1899−1923	Cholera	Europe, Asia, and Africa	800,000 +	(Hays, 2005)
Spanish flu	1918−20	Influenza A virus subtype H1N1	Worldwide	50 million +	(Patterson Kd Fau et al., 1991)
Asian flu	1957−58	Influenza A virus subtype H2N2	Worldwide	1−4 million	(Paul, 2012)
Hong Kong flu	1968−70	Influenza A virus subtype H3N2	Worldwide (mainly in Hong Kong)	1−4 million	(Paul, 2012)
HIV/AIDS	1981−present (data as of 2018)	Human immunodeficiency virus	Worldwide	32 million +	(UNAIDS, 2010)
Bangladesh cholera epidemic	1991	Cholera	Bangladesh	8410−9432	(Ali et al., 2012)
SARS	2002−04	Severe acute respiratory syndrome (SARS)	Worldwide	774	(WHO, 2015b)
Swine flu	2009−10	Influenza A virus subtype H1N1	Worldwide	Estimated death toll: 284,000	(Gordon et al., 2012)
MERS	2012−present	Middle East respiratory syndrome/MERS-CoV	Worldwide	935 (as of 4 July 2020)	(Desk, 2020)
West African Ebola	2013−16	Ebola virus virion	Worldwide, primarily concentrated in Guinea, Liberia, and Sierra Leone	11,323 +	(WHO, 2016b)
Avian influenza	2013−19	Influenza A virus subtype H7N9	China	616	(FAO, 2019)
Zika virus	2015−16	Zika virus	Worldwide	53	(Wikipedia, 2020a)
Dengue fever	2019−present	Dengue fever	Asia-Pacific and Latin America	3930	(WHO, 2020)
COVID-19	2019−present	SARS-CoV-2 virus	Worldwide	1.3 million + (as of December 2020)	(Acter et al., 2020)

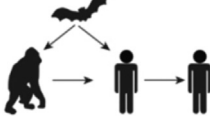Since the ancient age of human ecology, any novel microbe or pathogen, either newly emerging or reemerging, has been considered an independent variable to which the immunologically susceptible population lacks significant degrees of procured invulnerability to

avert the disease (Morse, 2009). Until the 21st century, 70% of more than 1500 emerging human pathogens have been proven to be "zoonotic" or of animal origin, which indicates that the next pandemic would be a zoonosis. The major sources of zoonotic transmission are farmed animals (such as poultry), livestock production systems, wildlife reservoirs, unsafe storage of farmed animals in commercial places, consumption of wild species, and contact with wildlife such as wild animal trade (Morse et al., 2012). Besides, certain animal disease vectors are responsible for animal-to-human transmission. Other nonanimal disease vectors contributing to the diffusion of epidemics in a region are contaminated drinking water, food, air, and surfaces, and human touch (WHO, 2018).

Pandemic risk mainly depends on the survival and adaptation behavior of zoonotic pathogens. The adaptation behavior of pathogens can be spanned into five stages (Table 1−2), ranging from animal reservoir transmission (stage 1) to human-to-human trans-mission (stage 5). In the case of stages 2−3, the geographical spread of pathogens is restricted by the territorial scope of an animal reservoir, and thus pathogens cannot adapt well to humans, causing only localized outbreaks. These stages subsequently increase the adaptability of pathogens within a human population. Over stage 3, the pathogens adapt well to humans, increasing the risk of pandemic (Madhav et al., 2017).

For example, the origin of human plague may be the wild rodent fleas found in rural areas such as Southwestern United States (Gage et al., 1995); infected animals such as guinea pigs in Peru and Ecuador (Gabastou et al., 2000); infected camels in Central Asia and the Middle East

Table 1–2 Pathogen adaptation and pandemic risk.

Stages	Transmission to humans	Type of pathogen	Route of transmission
(1) Transmission to animal reservoir only	None	H3N8 influenza virus	
(2) Primary infection	Only from animals	Anthrax	
(3) Limited outbreaks	Limited human-to-human transmission chains	Marburg virus	
(4) Sustained outbreaks	Many human-to-human transmission chains	H1N1influenza virus	
(5) Predominant human transmission	Human-to-human	Smallpox virus	

Source: Adopted from Jamison DT, Gelband H, Horton S, et al., Disease Control Priorities: Improving Health and Reducing Poverty. 3rd edition. Washington (DC): The International Bank for Reconstruction and Development/The World Bank; 2017 Nov 27 under the Creative Commons Attribution 3.0 IGO license (CC BY 3.0 IGO).
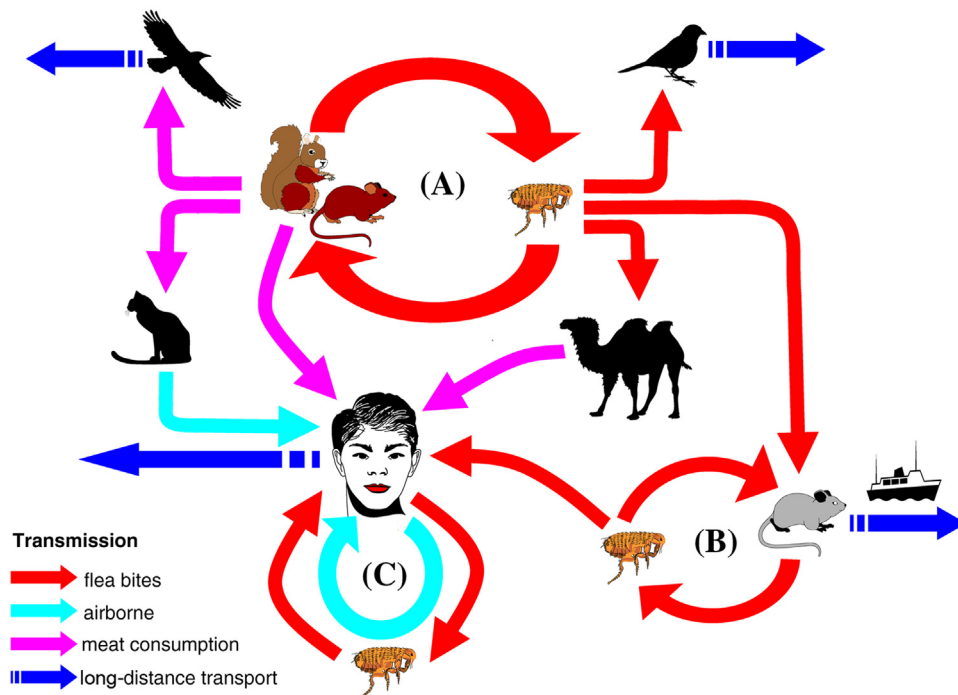
FIGURE 1–2 Possible transmission pathways for the plague agent *Yersinia pestis. Reproduced with permission from Figure 2, Stenseth, N. C. et al, Plague: Past, Present, and Future, 2008, PLoS Med 5(1), under the Creative Commons Attribution 4.0 license.*

(Fedorov, 1960); or the handling of infected cats and the consumption of plague-infected rodents in Africa (Isaäcson et al., 1973) or the United States (Gage et al., 2000).

Fig. 1−2 represents the possible transmission pathways for the plague foci through rodent hosts and their associated fleas. When a commensal rodent consumes an infected flea, the cycle continues (Fig. 1−2B) until the commensal rodents die, and then their fleas move to alternative hosts, for example, humans. Finally, human-to-human transmission may occur depending on the favorable conditions if humans are infected by pneumonic plague through the transmission of respiratory droplets as well as the handling of infected animals such as rodents, cats, camels, mammal predators, and birds (Fig. 1−2C). The most likely sources of the Ebola virus are bats transmitting the virus to other animals, that is monkeys, apes, duikers, and humans (WHO, 2016a). A major reservoir host of the MERS-CoV infection is dromedary camels transmitted by bats. Since 1986, acquired immunodeficiency syndrome (AIDS) has emerged from different primate species and generated new pathogens through cross-species infections with lentiviruses named simian immunodeficiency viruses (SIVs). The species of human immunodeficiency virus type 1 (HIV-1), human immunodeficiency virus type 2 (HIV-2), and SIVs may have originated from the zoonotic transfers of viruses, (Fig. 1−3) which infected mostly different primates such as African green monkeys, sooty mangabeys, mandrills, and chimpanzees found in sub-Saharan Africa (Sharp and Hahn, 2011).
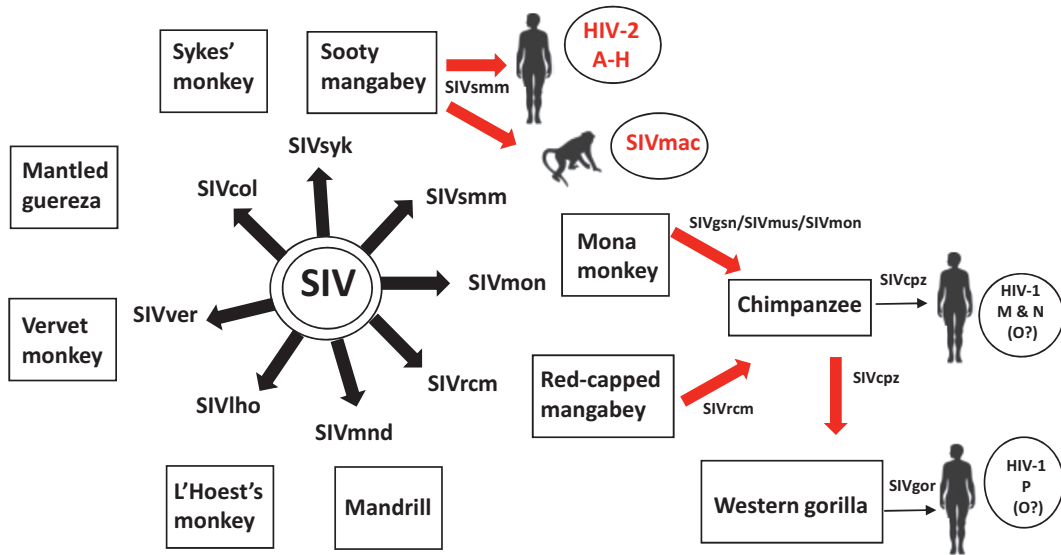
FIGURE 1–3 Origins of human AIDS viruses. *Modified from Figure 1, Sharp, P. M. and Hahn, B. H., Origins of HIV and the AIDS Pandemic, Cold Spring Harb Perspect Med. 2011 Sep; 1(1): a006841.*

The main causes behind triggering an epidemic are the recent introduction of a new strain of an infectious agent to a host population that is unknown to the hosts' immune systems, sudden reduction of the host immunity to the agent below the endemic equilibrium, and the increment of virulence of the agent due to its exceeding threshold that leads to an enhanced mode of transmission. A number of strains of multidrug-resistant microorganisms can evolve due to the inappropriate use of antibiotics for treating viral infections. There are also some seasonal epidemics such as whooping cough, influenza, and measles (Marcovitch, 2005).

The number of cases and usual frequency of disease during an epidemic can vary according to the time and place of occurrence and the size and type of population exposed to the disease in an area (Cliff et al., 1998). The possible diverse epidemic drivers speeding up the pathogenic proliferation on a global scale are trade-induced pathogenic diffusion such as increased speed of trade and migration, advances in transportation technologies, qualitative changes in globalization processes, knowledge and fear diffusion via telecommunications media, burgeoning human population, increased speed of travel, and accelerated genetic mixing (Morse, 2009).

1.4 Comparison of the magnitude of all epidemics

1.4.1 The plague epidemic

One of the most ancient scourges in human history is the plague, which is an acute infectious disease caused by the bacillus *Yersinia pestis* (Stenseth et al., 2008, Gage and Kosoy, 2005). Different *Y. pestis* strains that have different phenotypic properties are of four types of biovars or

geographic origins, namely Antiqua, Mediaevalis, Orientalis, and Microtus (Zhou et al., 2004). Different biovars of *Y. pestis* caused three major world pandemics having different paths of spread, which resulted in devastating mortality among people. The first pandemic, occurring in the 6th century CE (i.e., 541), was called the Justinian Plague, which evolved in central Africa following spreading around the Mediterranean Sea. The second pandemic, occurring in the 14th century (i.e., 1347), was known as the Black Death, which started in Asia following spreading to Europe, and mainly affected the social, economic, cultural, religious, and political progression of the continents (Twigg, 1984). The third pandemic, occurring in the middle of the 19th century (i.e., 1894), known as the pneumonic plague, evolved in Yunnan, China following spreading to Hong Kong and India, and then finally throughout the world as well (Stenseth et al., 2008). Most of the plague epidemics were bubonic plague caused by the infection of lymph nodes. The other plague epidemics were of septicemic or pneumonic type (Gage and Kosoy, 2005).

All the recorded plague pandemics greatly affected the social and economic statuses of various nations and continents. Fig. 1−4 represents the global epidemiology of plagues all over the world since 1954, where the increased number of cases reported in recent years
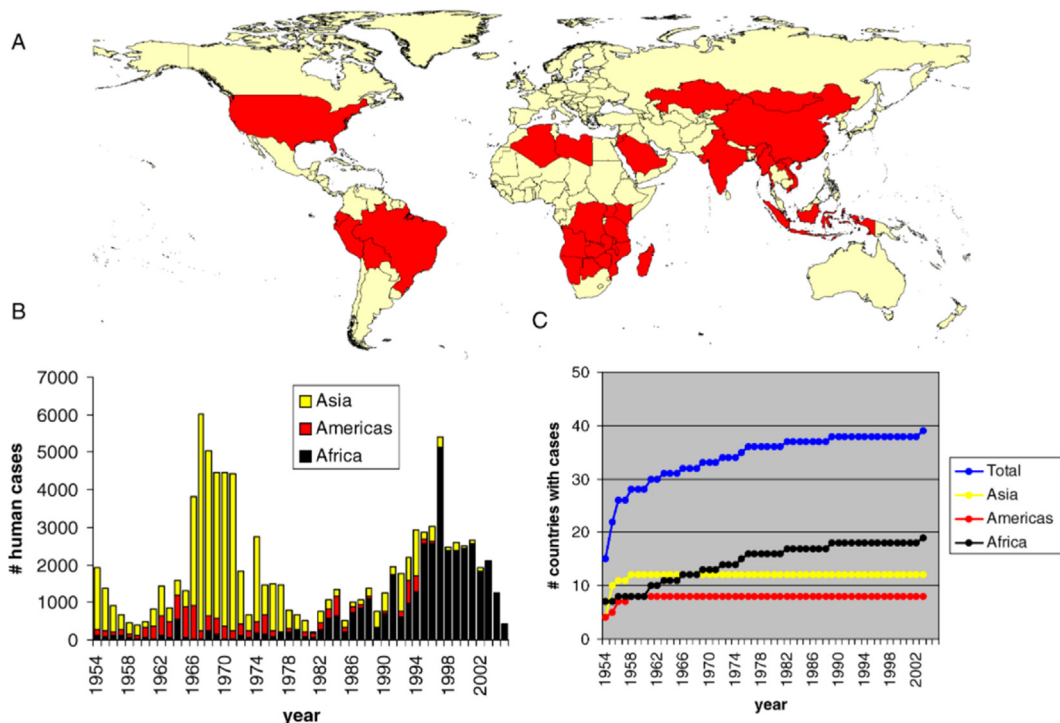
FIGURE 1–4 Plague distribution worldwide: (A) Map showing countries with known presence of plague in wild reservoir species (red), (B) Annual number of human plague cases over different continents, reported to the WHO in the period of 1954−2005, (C) Cumulative number of countries that have reported plague to the WHO since 1954. *Reproduced with permission from Figure 1, Stenseth, N. C. et al, Plague: Past, Present, and Future, 2008, PLoS Med 5(1), under the Creative Commons Attribution 4.0 license.*

indicates the plague as a reemerging as well as an endemic disease (Schrag and Wiener, 1995) that presently exists in some parts of South and North America, Africa, and Central Asia (Fig. 1.4A). Ultimately, the bubonic and pneumonic plague disease has shifted from Asia to Africa since the 19th century, where most cases and deaths occur in the Democratic Republic of the Congo (DRC), Madagascar, Mozambique, Malawi, Tanzania, and Uganda (Fig. 1.4B). Between 1900 and 2015, the number of infected plague cases in the United States was 1036 with an average of 9 cases/year. Furthermore, the number of plague cases in the United States including rural California, northern Arizona, northern New Mexico, southern Colorado, southern Oregon, and far western Nevada in 2015 was 16 (CDC, 2019b).

The total number of plague cases and deaths in the world was 3248 and 584, respectively, within the period of 2010−15, while the most affected countries were the DRC, Madagascar, and Peru (Stenseth et al., 2008). The DRC was the most affected country for over a decade since 2001. In the DRC, the large pneumonic plague outbreak occurred in October and November, 2006 (WHO, 2006). The host of regular plague epidemics has been Madagascar since 2012. In Madagascar, the major pneumonic and bubonic plague disease outbreak occurred in 2017, which led to more than 2417 infected plague cases and 209 deaths. As a result, the plague preparedness alert was imposed in nine countries and territories connected to Madagascar for trade and travel. As of July 2020, a bubonic plague case was reported in Bayannur, Inner Mongolia of China and Mongolia due to which a plague-prevention system has been activated throughout the year (Stenseth et al., 2008).

1.4.2 Influenza pandemic (H1N1 virus)

In the last 140 years, there have been five severe epidemics of influenza A virus that have emerged as different variants such as the bird flu, dog flu, H1N1 flu, H3N2 flu, horse flu, human flu, and swine flu (Fig. 1−5) (CDC, 2019a). Among these, the most deadly flu pandemic (category 5 influenza) was the 1918 flu (Spanish flu) caused by the H1N1-type influenza A virus that spread to the Arctic and remote Pacific islands (Potter, 2001). The death toll of the 1918

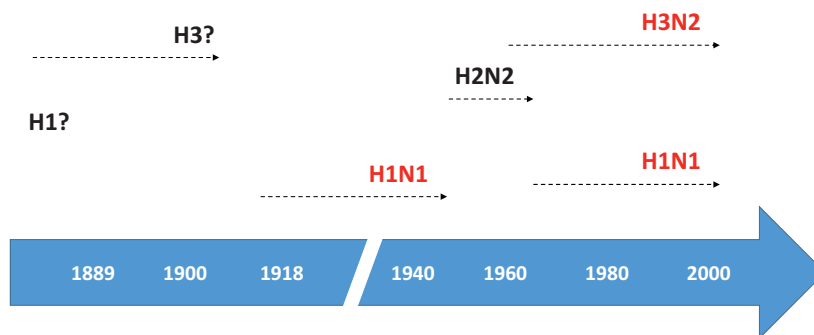

FIGURE 1–5 Types of influenza viruses evolved in humans causing recurring influenza pandemics since 1889. *Modified from Palese P (December 2004). "Influenza: old and new threats". Nature Medicine. 10 (12 Suppl): S82−87. doi:10.1038/nm1141.*

influenza pandemic was more than 50 million worldwide, similar to that of the Black Death, due to the extremely high infection rate caused by cytokine storms and lung infection (Patterson Kd Fau et al., 1991). As a result, the 1918 pandemic caused mental harm to numerous individuals, social disruption, and a sense of fear in the affected regions (NationalAcademiesPress, 2005).

The next influenza pandemic was the category 2 flu pandemic named the Asian flu, which emerged in Guizhou, China in 1956 and then spread to Singapore, Hong Kong, and the United States in 1957 (Mittal and Medhi, 2007). The death toll of the Asian flu worldwide was in the range of 1 million to 4 million. In the period between 1968 and 1969, a strain of the H3N2 influenza virus caused the category 2 Hong Kong flu pandemic, killing 1 million people worldwide (AssociatedPress, 2009).

The latest pandemic of the 21st century of the influenza A virus named swine flu was caused by a strain of H1N1 in 2009 (CDC, 2019a). According to the WHO, the number of infected cases and deaths during the influenza H1N1 pandemic were 482,300 and 18,000, respectively, in 199 countries. During the 2009 influenza pandemic, the main comorbidities were acute myocardial infarction and stroke, which significantly increased the number of deaths.

1.4.3 AIDS

One of the most annihilating diseases that has evolved in recent history is AIDS, an infection caused by a member of retroviruses called the human immunodeficiency virus (HIV) (Sepkowitz, 2001). According to the CDC, AIDS is defined as a disease at least moderately predictive of a defect in cell-mediated immunity, occurring in a person with no known cause for diminished resistance to that disease. The symptoms of AIDS are degrading immune function and unintended weight loss along with developing opportunistic infections. The major routes of transmission of the virus are contaminated blood transfusions, contaminated and used needles, unprotected sex, and pregnant and breastfeeding mothers (Cohen et al., 2011).

In 1981, the first five AIDS cases were reported in homosexual men due to a rare fungal infection caused by *Pneumocystis carinii* pneumonia, which was recognized by the CDC (Sharp and Hahn, 2011, Gallo, 2006). Since the first identification of AIDS cases in 1981, the number of HIV infections and the number of deaths has tremendously increased worldwide (Merson et al., 2008). Higher HIV/AIDS morbidity and mortality were observed in developing countries, while the highest prevalence rates were observed in sub-Saharan Africa (UNAIDS, 2020). As of 2019, the number of infected HIV cases was 38 million with 690,000 deaths, among which 20.6 million were from eastern and southern Africa. Thus HIV/AIDS is still actively spreading and is considered a pandemic (Kallings, 2008). The disease outbreak has caused large economic impacts, many controversies involving religion, and discrimination in society (UNAIDS, 2006).

1.4.4 Coronavirus epidemics

1.4.4.1 Severe acute respiratory syndrome coronavirus

The first coronavirus causing disease was severe acute respiratory syndrome (SARS), which is a relatively rare viral respiratory infection (CDC, 2017). The sign of SARS infection is similar to that of atypical pneumonia, and its symptoms are mainly breathing difficulties along with dry cough,

fever, and headache. The SARS virus is readily transmissible and thus can spread directly through air like the influenza virus and indirectly via surfaces touched by infected persons.

The SARS outbreak first emerged in Guangdong province, southeastern China on 16 November, 2002, and then spread to 29 countries in North America, South America, Europe, and Asia within about 8 months, from November 2002 to July 2003 (Routledge, 2003). According to the WHO, the total number of SARS infections was reported to be 8098, including 29 cases from the United States, while the total number of deaths was 774 (Fig. 1−6) (Routledge, 2003). The case fatality rate (CFR) of the SARS epidemic was 11% (Chan-Yeung and Xu, 2003) and it depends on the patient's age and gender (Routledge, 2003). Patients that were 65 years old and male were most likely to die (NationalAcademiesPress, 2004). The SARS outbreak mainly caused hospital-based as well as healthcare worker infections. Furthermore, the outbreak raised fear and economic instability across the world.

After the 2002−03 SARS outbreak, a few SARS infections were reported until May 2004 (WHO, 2004). Since May 2004, there have not been any known cases of SARS reported worldwide. In December 2019, the SARS-related virus strain called severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was detected, which caused the coronavirus disease 2019 (COVID-19) pandemic (Morens and Fauci, 2020).

1.4.4.2 *Middle East respiratory syndrome coronavirus*
Another coronavirus that appeared in Saudi Arabia in the Middle East region in 2012 was responsible for causing an epidemic called Middle East respiratory syndrome (MERS) (Parry, 2015).
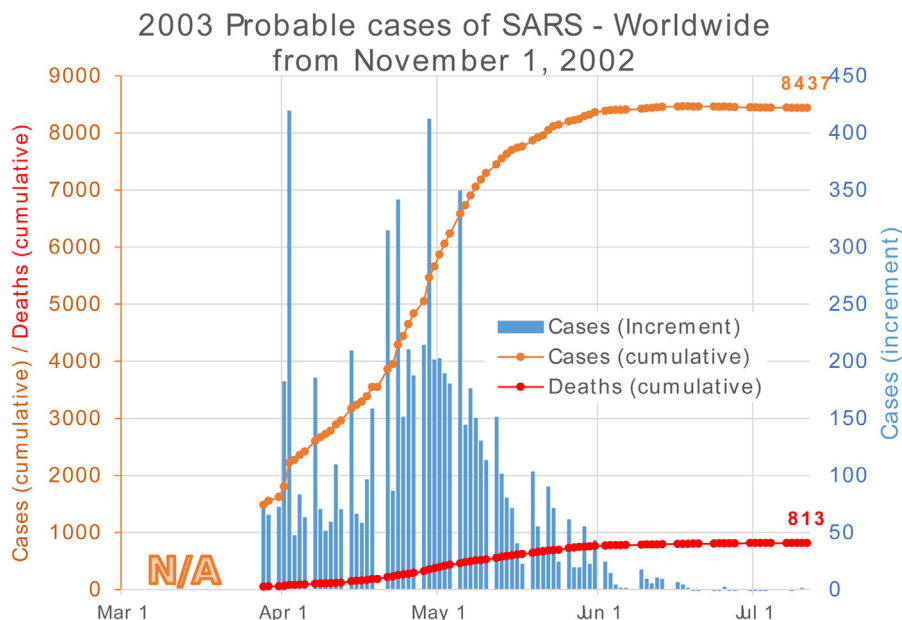

FIGURE 1–6 2003 Probable cases of SARS worldwide. *Courtesy: Cumulative number of reported probable cases of severe acute respiratory syndrome (SARS). WHO.* https://www.who.int/csr/sars/country/2003_05_28/en/.

MERS is also a viral respiratory disease like SARS. The MERS coronavirus (MERS-CoV) originated from bats and then was transmitted to humans via infected camels (Zumla et al., 2015).

The first MERS case was identified in June 2012 in Jeddah, Saudi Arabia, and Saudi Arabia was the most affected place in the Arabian Peninsula." (Zumla et al., 2015). In the period of 2012−13, the largest MERS epidemic spread fatally into Saudi Arabia, United Arab Emirates, and the Republic of Korea, while Saudi Arabia (approximately 80% of human cases) was the most affected country (Fig. 1−7) (Zumla et al., 2015). Since 2012, the countries that have reported MERS cases have been Algeria, Austria, Bahrain, China, Egypt, France, Germany, Greece, Islamic Republic of Iran, Italy, Jordan, Kuwait, Lebanon, Malaysia, Netherlands, Oman, Philippines, Qatar, Republic of Korea, Kingdom of Saudi Arabia, Thailand, Tunisia, Turkey, United Arab Emirates, United Kingdom, United States, and Yemen. Larger MERS outbreaks have been seen in South Korea and Saudi Arabia in 2015 and 2018, respectively (WHO, 2017).

According to the WHO, the number of MERS cases as of January 2020 was about 2500, while the death rate was 35% of the reported cases (Carmona et al., 2012). The spread of MERS-CoV mainly occurred in healthcare facilities among family members, patients, and healthcare workers before MERS-CoV was diagnosed and where infection prevention practices were inadequate. The patients with chronic lung disease, diabetes, immunodeficiency, and renal failure were at high risk of MERS severity. The impact of the MERS epidemic has been observed in the Republic of Korea in different aspects of life, such as travel, trade, and economies.(Al-Osail and Al-Wazzah, 2017)

1.4.4.3 Severe acute respiratory syndrome coronavirus-2

The most recent outbreak of coronavirus disease 2019 (currently known as COVID-19) caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) has been a potential threat to human health (Acter et al., 2020). The origin of the disease was Huanan
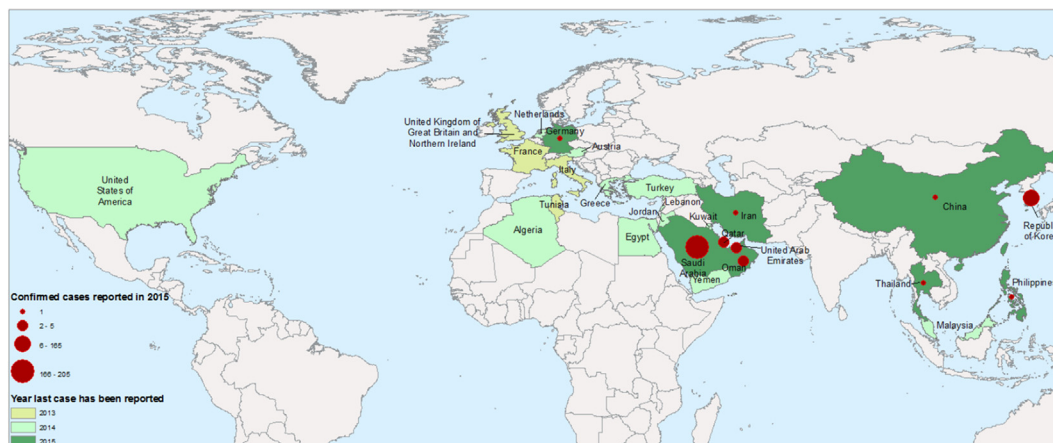

FIGURE 1–7 Confirmed cases of MERS-CoV worldwide in the period of 2012−15. *Courtesy: Global map of countries with confirmed cases of MERS-CoV and maps of previous years, WHO, Map date, 19 June 2015, https://www.who. int/csr/disease/coronavirus_infections/maps-charts/en/.*

Seafood Wholesale Market, located in Wuhan, Hubei, China, and then it subsequently spread to Thailand, Japan, and then other regions in Asia, Europe, North America, South America, Africa, and Oceania, developing into the global 2019−20 coronavirus pandemic by March. WHO declared this massive global outbreak as the sixth Public Health Emergency of International Concern on January 30 and a pandemic on March 11, 2020 as the disease spread worldwide.

According to figures compiled by US-based Johns Hopkins University, as of January 04, 2021, there are 85,603,740 confirmed cases, 23,188,005 active cases, 60,562,667 recoveries, and 1,853,068 deaths in about 191 countries/territories and 26 cruise/naval ships. The current scenario of the ten most affected countries in the world is presented in Table 1−3. As the number of confirmed COVID-19 infections is higher than the total number of suspected SARS cases, the SARS-CoV-2 virus is assumed to be more contagious than other coronaviruses, that is, SARS, MERS, and influenza. The natural reservoir of the SARS-CoV-2 virus is assumed to be bats. The human-to-human transmission of the virus mainly occurs via respiratory droplets produced from the coughs or sneezes of an infected person. The pandemic has caused global health impacts; social, economic, educational, and agricultural disruption; panic buying; widespread supply and food shortages; and postponement or cancellation of events (Cave and May, 2020, Horowitz, 2020, Larson, 2020, Litvinova et al., 2019, Maxmen, 2020).

1.4.4.4 The ebola epidemic

One of the most severe, deadliest, and most fatal viral diseases is Ebola virus disease (EVD) or Ebola hemorrhagic fever caused by a group of ebolaviruses such as Ebola virus (species *Zaire ebolavirus*), Sudan virus (species *Sudan ebolavirus*), Taï Forest virus (species *Taï Forest ebolavirus*), Bundibugyo virus (species *Bundibugyo ebolavirus*), Reston virus (species *Reston ebolavirus*), and Bombali virus (species *Bombali ebolavirus*) in human and nonhuman primates (such as monkeys, gorillas, and chimpanzees), among which the human disease-causing ebolaviruses are Ebola, Sudan, Taï Forest, and Bundibugyo viruses (WHO, 2016a).

Table 1–3   COVID-19 pandemic by location for ten most affected countries.

Country	Total COVID-19 cases	Total deaths due to COVID-19	Total recovered from COVID-19
United States	21,113,528	360,078	12,436,958
India	10,341,291	149,686	9,946,867
Brazil	7,733,746	196,018	6,813,008
Russia	3,260,138	58,988	2,640,036
Turkey	2,241,912	21,488	2,136,534
Colombia	1,675,820	43,965	1,542,353
Italy	2,155,446	75,332	1,503,900
Argentina	1,640,718	43,482	1,452,960
Germany	1,783,896	35,105	1,401,200
Mexico	1,448,755	127,213	1,098,431

Source: https://www.worldometers.info/coronavirus/. Updated as of 04 January, 2021.

The most likely sources of the ebolavirus are infected wild animals such as fruit bats; porcupines; and nonhuman primates such as chimpanzees, apes, and monkeys. The spreading of the virus may take place through direct contact with the infected blood, body fluids, or secretions of infected people; mucous membranes in the eyes, nose, or mouth; tissues of infected animals; and contaminated objects or surfaces (WHO, 2016a). Besides, the virus may exist in the semen or breast milk of an EVD-recovered person (WHO, 2015a). The incubation period of the disease is from 2 days to 3 weeks, while its major signs and symptoms are fever, sore throat, muscular pain, headaches, vomiting, diarrhea, decreased liver and kidney functions, sometimes internal and external bleeding, and low blood pressure from fluid loss (WHO, 2016a, Singh 2013). The Ebola epidemic overwhelmed the healthcare systems and caused a lack of routine diagnosis and treatment for endemic diseases such as malaria, HIV/AIDS, and tuberculosis. As a result, the nonebola diseases contributed to an estimated 10,600 additional deaths during the Ebola epidemic in Guinea, Liberia, and Sierra Leone of West Africa (Parpia et al., 2016). Besides, understaffing and fear of contracting the disease caused the closure of facilities that led to decreasing routine childhood immunization rates and routine healthcare in affected countries.

The Ebola virus first emerged with two simultaneous outbreaks in two tropical regions of sub-Saharan Africa named Sudan (in a village near Ebola river) and the DRC (formerly Zaire) in 1976, while the number of infections was 284 (with a mortality rate of 53%) and 318 (with a mortality rate of 88%) in the first and second outbreaks, respectively (WHO, 2016a). In the last 40 years, the Ebola virus has been mostly affecting several African countries with occasional outbreaks as well as a sparking alarm worldwide due to more than 25 deadly outbreaks (Table 1−4). The most severe EVD epidemic since 1976 that caused a large number of deaths occurred in West Africa (Guinea, Liberia, and Sierra Leone) from December 2013 to January 2016, with 28,646 cases and 11,323 deaths (WHO, 2016a). According to the WHO, the numbers of confirmed Ebola cases and deaths due to this disease were 2387 and 1590, respectively, from 1976 through 2020. The emergency alert for EVD was withdrawn on 29 March 2016. Recently, EVD has been reemerged in the DRC, Africa from May 2017 (K, 2017). The average CFR of EVD is about 50%, which indicates that the disease has a high risk of death (WHO, 2016a).

1.5 Assessing countries' readiness for coping with epidemics

In order to cope with an epidemic, five crucial stages are required to be followed: prediction of the novel pathogen; faster pathogen detection in animal reservoirs and human populations; disease containment at the beginning phases of transmission; control of the epidemic during its amplification; and elimination of the outbreak risk (CDC, 2006). Effective readiness of a country during an epidemic involves a disease surveillance system; early mitigation efforts; actual response measures such as case and contact tracing; identifying infected cases; and preventive measures in healthcare facilities and public health measures, such as clean water and handwashing etiquette (Gates, 2015).

Table 1–4   Chronology of previous ebola virus disease outbreaks.

Year	Country	EVD	Cases	Deaths	Case fatality
2020	Democratic Republic of the Congo	Zaire	Ongoing		
2018—20	Democratic Republic of the Congo	Zaire	3481	2299	66%
2018	Democratic Republic of the Congo	Zaire	54	33	61%
2017	Democratic Republic of the Congo	Zaire	8	4	50%
2015	Italy	Zaire	1	0	0%
2014	Spain	Zaire	1	0	0%
2014	United Kingdom	Zaire	1	0	0%
2014	United States	Zaire	4	1	25%
2014	Senegal	Zaire	1	0	0%
2014	Mali	Zaire	8	6	75%
2014	Nigeria	Zaire	20	8	40%
2014—16	Sierra Leone	Zaire	14,124*	3956*	28%
2014—16	Liberia	Zaire	10,675*	4809*	45%
2014—16	Guinea	Zaire	3811*	2543*	67%
2014	Democratic Republic of the Congo				
2012	Democratic Republic of the Congo	Bundibugyo	57	29	51%
2012	Uganda	Sudan	7	4	57%
2012	Uganda	Sudan	24	17	71%
2011	Uganda	Sudan	1	1	100%
2008	Democratic Republic of the Congo	Zaire	32	14	44%
2007	Uganda	Bundibugyo	149	37	25%
2007	Democratic Republic of the Congo	Zaire	264	187	71%
2005	Democratic Republic of the Congo	Zaire	12	10	83%
2004	Sudan	Sudan	17	7	41%
2003 (Nov-Dec)	Democratic Republic of the Congo	Zaire	35	29	83%
2003 (Jan-Apr)	Democratic Republic of the Congo	Zaire	143	128	90%
2001—02	Democratic Republic of the Congo	Zaire	59	44	75%
2001—02	Gabon	Zaire	65	53	82%
2000	Uganda	Sudan	425	224	53%
1996	South Africa (ex-Gabon)	Zaire	1	1	100%
1996 (Jul-Dec)	Gabon	Zaire	60	45	75%
1996 (Jan-Apr)	Gabon	Zaire	31	21	68%
1995	Democratic Republic of the Congo	Zaire	315	254	81%
1994	Côte d'Ivoire	Taï Forest	1	0	0%
1994	Gabon	Zaire	52	31	60%
1979	Sudan	Sudan	34	22	65%
1977	Democratic Republic of the Congo	Zaire	1	1	100%
1976	Sudan	Sudan	284	151	53%
1976	Democratic Republic of the Congo	Zaire	318	280	88%

Source: Ebola virus disease, World Health Organization, 10 February 2020, https://www.who.int/news-room/fact-sheets/detail/ebola-virus-disease.

In order to flatten the epidemic curve, nonpharmacological interventions such as using personal protective equipment (PPE; i.e., masks, gloves, etc.) and social distancing have been exercised in the affected countries (Stawicki et al., 2020). Vaccine production, as well as

the purchasing capability, is variable from country to country. For example, according to the WHO, 19 countries manufactured the influenza vaccine, while only the United States and France were the suppliers of the H1N1 vaccine in 2009 (CDC, 2019c).

Until now, different effective ways have been followed in the countries for coping with the epidemics, resulting in various impacts in the affected regions. The indices for measuring and identifying countries' preparedness and responses against the threats of epidemics worldwide are the Global Health Security (GHS) Index and the COVID-19 Safety, Risk and Treatment Efficiency framework and indices. There is a relationship between global health security and its ability to cope with pandemics. In this context, the GHS Index is an assessment index projected by the Nuclear Threat Initiative and the Johns Hopkins Center for Health Security (CHS) and developed with the Economist Intelligence Unit that benchmarks the capabilities of the health security of any nation affected by infectious disease outbreaks and thus encourages to upgrade the health facilities of the respective country. The GHS index usually is calculated based on 140 questions organized into six categories, namely the prevention of emerging diseases, the detection and reporting of confirmed cases and deaths, rapid response to the epidemic, the health system, the compliance with global norms, and the risk environment.

The 2019 GHS Index reported the rankings of 195 countries and territories, which finds that the average score is 40.2 out of 100, indicating the fundamental weakness of global healthcare systems and preparedness to face epidemics (LePan, 2020). The pre-COVID-19 GHS report highlights the global health security problems of the current world due to the following reasons:

- Worldwide weak national health security required for facing epidemic response
- Few efforts taken by countries for testing the capacities of health securities
- Inadequate funding for filling up the preparedness gaps of the countries
- Inadequate coordination and training among health professionals.

As shown in Fig. 1−8, 81% of the countries had a low score pertaining to the health security system in 2019, while 85% of countries did not exercise biological threat-focused simulation efforts along with the WHO. According to GHS, the score of the United States (98.2) was higher than that of Germany (84.6) and South Korea (92.1) in the case of detection, reporting, and infection control practices and availability of equipment, while the private sector of South Korea had sufficient protective equipment such as masks and developed and implemented test kits faster. Along with sufficient protective equipment, Germany had greater healthcare facilities such as hospital beds, intensive care beds, and ventilators (Lafortune, 2020). One of the limitations of GHS methodology in testing and the adaptability of health systems is that the index may over or underestimate the preparedness level of certain countries. One of the effective measures to flatten the epidemic curve is imposing lockdowns of nonessential economic activities, especially implemented by most Asian countries, including South Korea, and some European countries, including France and Germany. However, these shutdown approaches are responsible for the economic impacts of the affected regions.

Table 1−5 shows the ranking of the GSH index of the top ten countries that have adequate healthcare systems, which are best prepared to deal with a pandemic although there are still
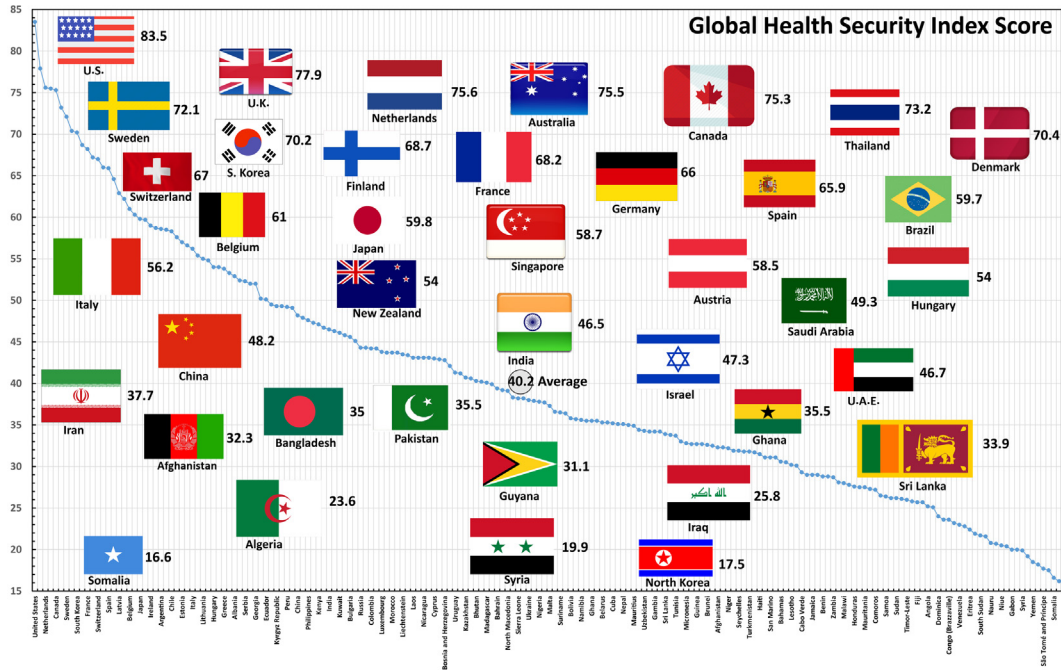
FIGURE 1–8 Global Health Security Index of countries with population of more than 5 million. (GHSI, 2019).

some gaps in their preparedness. Overall, the top 2019 GHS-ranked countries globally are the United States, the United Kingdom, and the Netherlands. In addition, Fig. 1−9 shows that numerous medical service frameworks have had their security tested with the episode of COVID-19 (Lafortune, 2020). The highest number of deaths per capita was reported in countries like Belgium, France, Italy, Spain, United States, and United Kingdom during the COVID-19 pandemic. The countries near the origin of the COVID-19 outbreak, such as South Korea, have started to release the lockdown measures due to effective management of the disease outbreak.

The COVID-19 Safety, Risk and Treatment Efficiency framework and indices have been released by the Deep Knowledge Group (a consortium of profit and nonprofit organizations) in March 2020, which cover 150 countries. This "Safety" index was calculated based on 72 metrics grouped into 3 indices, namely Safety, Risk and Treatment Efficiency, and 12 underlying quadrants. The data was collected from the WHO, Johns Hopkins University, Worldometer, and the CDC. Overall, the top COVID-19 Safety Indexed countries of 2020 are Israel, Germany, and South Korea.

Countries like Australia and South Korea performed well on both the November 2019 GHS Index and COVID-19 Safety Index. The top-ranked GHS Indexed countries such as the United Kingdom and the United States and Other OECD (Organisation for Economic Co-operation and Development) countries such as France, Spain, and Sweden were not in the list of the top 40 COVID-19 Safety Indexed countries. On the other hand, better ranked COVID-19 Safety countries were observed to be Austria, China, Hungary, Israel, Japan, New Zealand, Singapore,

Table 1–5   The top 10 highest-ranking countries in the Global Health Security index (GHSI, 2019).

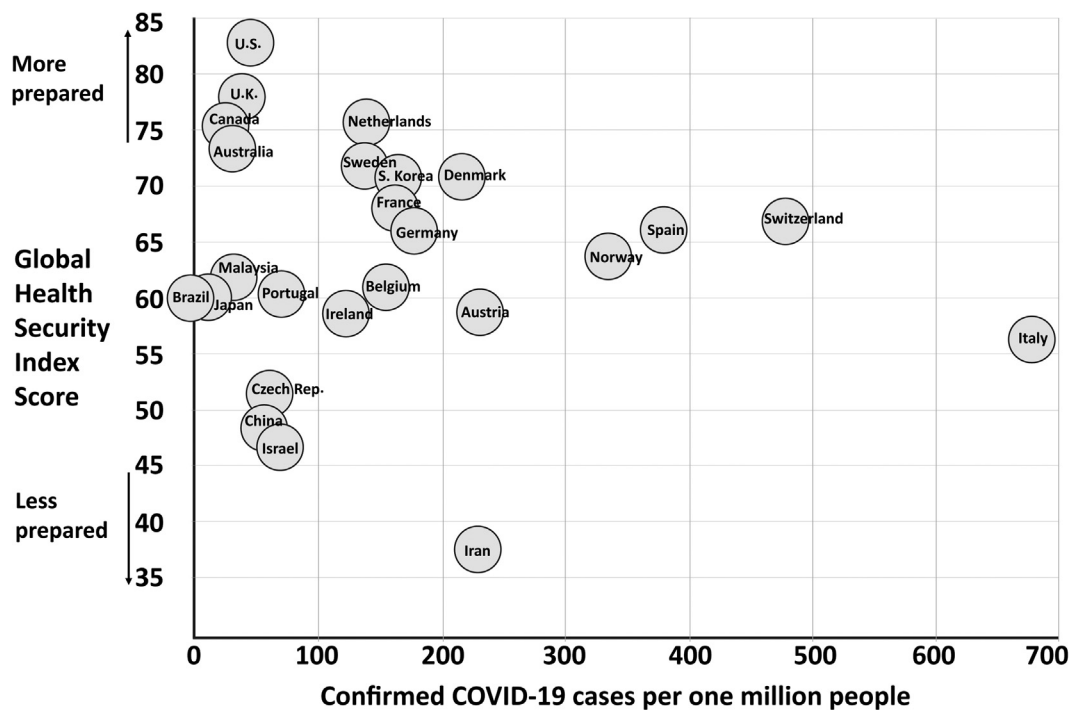| Ranking	Name of country	GHS index score
1	United States	83.5
2	United Kingdom	77.9
3	Netherlands	75.6
4	Australia	75.5
5	Canada	75.3
6	Thailand	73.2
7	Sweden	72.1
8	Denmark	70.4
9	South Korea	70.2
10	Finland	68.7

FIGURE 1–9 Confirmed COVID-19 cases versus Global Health Security score. (GHSI, 2019).

and the United Arab Emirates according to their GHS ranks. Besides, Germany ranked 2nd and 14th on the COVID-19 Safety Index and GHS Index, respectively. Asian countries performed well in the effective management of the COVID-19 crisis, such as massive testing, intense

reconnaissance frameworks, and quick detachment of tainted patients and the subsequent leveling of the epidemic curve (Lafortune, 2020).

1.6 Challenges in battling with epidemics

Epidemics of any disease put the resources of the health systems of the affected countries under pressure due to the admission of a large number of patients to hospitals. The most recent COVID-19 pandemic shows that the health and nonhealth impacts of a pandemic could be devastating even with good public health surveillance systems (Acter et al., 2020). All attention given to the emergency of medical supplies and supports may often be responsible for neglecting other regular health facilities. As a result, people with other diseases may not get healthcare services on time during an epidemic, and thus mortality rates get higher. The situation is worsening in poorer communities around the world and low-income countries, and countries facing severe epidemics faced mainly this type of difficulty. For example, the Ebola virus in West Africa spread rapidly in more than 2 months before diagnosis and thus caused the Ebola epidemics. Besides, the epidemic caused by any novel virus may generate fear among certain at-risk populations, which leads to the generation of inadequate decisions or inappropriate behaviors.

The rapidly evolving nature of known epidemic diseases, such as cholera, HIV infection, influenza, meningitis, malaria, and tuberculosis still remains a threat for the globe. It is sometimes difficult to effectively access public health measures even in cases of known epidemics. The major limitations of access to vaccines are inadequate production capacity for diseases, for example yellow fever and influenza; vaccines out of stock during explosive outbreaks (e.g., meningitis); and the absence of markets during emergencies (e.g., oral cholera vaccine). Unprepared health systems could be challenged during epidemics of infectious diseases. In the case of inadequately undertaken preventive measures such as triage and isolation, the hospitals could be a source of transmission for unknown and emerging pathogens (for instance, MERS) from infected patients. Healthcare workers are usually at high risk of infection, which results in shortages of them during emergencies of epidemics and thus further weakens the health workforce. Therefore training new healthcare workers is time consuming. The traditional containment measures like home quarantine are sometimes unacceptable, which should be reevaluated in the perception of people's freedom of movement. The term "infodemics" is a new health risk among the population in the era of epidemics, which includes the rapid spreading of unauthentic, misleading, and unreliable information through social media nationally and internationally.

1.7 Concerns about future pandemics

The 21st century has been vigorously attacked by so many major epidemics (Gates, 2015). People will always remember the West African Ebola outbreak in 2014. The coronaviruses, that is, MERS, are still active, and the recent COVID-19 pandemic is still ongoing. Viral

hemorrhagic fevers, that is, Ebola and Marburg viruses, causing disease could become pandemics. The history of pandemics occurring every decade tells us that the recurrences between pandemics become more limited as seen with SARS in 2003, influenza A H1N5 (bird flu) in 2007, H1N1 (swine flu) in 2009, MERS in 2012, and Ebola in 2014 (Morse and Schluederberg, 1990, Jones et al., 2008).

Multidrug-resistant strains of tuberculosis (MDR-TB) are a major concern. Without dynamic reconnaissance and regulation measures, the possibility of avian influenza (H5N1) infection joining with human seasonal infections is a concern to researchers. The emergence and spread of multidrug-resistant strains of the plague virus would pose a major concern to human health (Inglesby et al.). As plague can originate in wildlife rodent reservoirs, it could not be eradicated. Africa is particularly at risk due to possibly favorable contact between plague reservoirs and peridomestic rodents in poor rural communities (Stenseth et al., 2008). The plague is known to be affected by various environmental conditions such as hotter springs and wetter summers that may turn out to be more normal in the future (Parmenter et al.; Enscore et al.). Furthermore, plague bacillus may adapt to new ecological niches due to its genomic rearrangement capacity and antibiotic resistivity (Parkhill et al.; Galimand et al., 1997).

As the current world remains vulnerable to epidemic events, the possibility of the next global pandemic could not be ignored. Although the advancement of medical science has been progressing rapidly in recent years, the natural immunity of humans to a newly mutated disease would not develop, and thus there are still concerns about global, sustained, and threatening public health emergencies in the future (Ross et al., 2015). As diseases very rarely disappear, there is always space for new ones. There are some reasons behind emerging and reemerging new pathogens and the increasing transmissibility and severity of infectious diseases. The major potential factors that serve as the breeding grounds for concerns of the future transmission of respiratory and fecal-oral pathogens are overpopulation (Alirol et al.); weak populations along with malnourishment in low-to-middle-income countries (LMICs); quick and extreme mobility of individuals, with expanded vehicle offices; greater interconnectivity between megacities; poverty; globalization; relentless urbanization (Alirol et al.); swelling populations of city dwellers; global warming; environmental degradation; ecological changes; habitat destruction; close and rehashed interaction among individuals, animals, and livestock; domestic animals; drug resistance to entering pathogens and the existence of viral pathogens with high nucleotide substitution rate, poor mutation error-correction rate ability, and quick adaptation capacity to human hosts (Jones et al., 2008). Given the abovementioned contributing factors, it is almost certain that the following arising infection will likewise spread quickly and far.

1.8 Preparative measures for tackling future pandemics

It is impossible to create a pandemic-free world. But meticulous preparation and rapid response can be helpful to prevent, detect, and respond effectively and rapidly to most episodes from gaining out of power at the very start of a disease outbreak that represents

potential international threats. In order to make the world safer, the following pandemic preparation methods should be undertaken:

- Addressing the root cause of health insecurity and strengthening health systems with a strong focus on surveillance systems.
- Providing protected, compelling, and subjective wellbeing administrations prior to, during, and after scourges by long-term substantial investments.
- Building and sustaining versatile limits at public, local, and worldwide levels.
- Ensuring, improving, and implementing rapid accessibility of essential life-saving health services and interventions including medicines and vaccines and other countermeasures worldwide during crises.
- Early recognition of a new microbe and the beginning of human-to-human transmission during emergence by detecting unusual clusters of severe cases.
- Raising clinicians' awareness by training them effectively as detectors and first-line responders.
- Flexibility of preparedness to adapt to any novel agent.
- Employing risk communication and sophisticated skills among health specialists, offices, doctors, and health experts to limit the social, political, and monetary effects of a scourge.
- Permitting innovative work exercises in any event during pandemics to quickly track the accessibility of powerful tests, immunizations, and drugs.
- Empowering and engaging anthropologist communities for better understanding human ecology as well as addressing fear and trust issues.
- Empowering and engaging the health workforce community in creating and executing strong arrangements and techniques toward widespread health coverage.
- Adequate clinical management and better supportive care for patients by involving skilled, qualified, and dedicated health personnel.
- Recently, computational or artificial intelligence (AI) techniques have been playing a significant role in coping with global epidemics and addressing public health surveillance (Zeng et al., 2021, Dananjayan and Raj, 2020, Bansal et al., 2020). AI can help researchers in predicting the magnitude and impact of future epidemics. However, there are still some challenges regarding AI techniques, that is, unawareness, data sparsity, lack of skilled operating manpower, high cost, software malfunction, noninvincibility, algorithm bias, data breach, etc. (Harkut and Kasat, 2019). In order to explore AI techniques widely in the areas of global epidemics, some developments in AI techniques such as research on collaborative systems, fine-tuning of networks of neural network algorithms, generation of innovative ways to explore human intelligence, deep learning, development of neural biological networks, advent of reinforcement learning, limitations in the cost of high computational capacity, and wide availability of labeled data should be performed (Harkut and Kasat, 2019).

Furthermore, a number of hygiene measures are recommended in order to maintain health and prevent the spread of disease outbreaks in the future.

- Medical hygiene: The standard infection control precautions, that is, frequent handwashing; use and disinfection of PPE including masks, gowns, caps, eyewear, and gloves; prevention of sharp injury; disinfection of surgical equipment and environment; airborne and contact precautions; droplet precautions; isolation of infected patients; and safe removal of clinical waste, etc. should be practiced in medical care settings (WHO 2007).
- Home hygiene: Home hygiene may include frequent handwashing with soap and water, using hand sanitizer, food hygiene, water hygiene, cleaning common surfaces, care of domestic animals, using tissues or covering mouth during coughing, and disposal of used tissues after coughing (Bloomfield et al., 2009).
- Social hygiene: Social hygiene may include social distancing in public transport, educational institutions, workplaces, and markets; installment of handwashing set-ups; and frequent use of disinfectants in public places.

1.9 Review questions

1. What is the common origin of the continuously evolving epidemics hitting the globe and how does the transmission of any infectious disease take place?
2. How does a pathogen adapt to the human population?
3. How many times did the influenza viruses reemerge as variants until the 21st century?
4. Which coronavirus is the deadliest virus in history and why?
5. How many stages are essential for coping with an epidemic?
6. What are the popular nonpharmaceutical interventions that should be followed during an epidemic?
7. What is the relationship between countries' preparedness measuring index and its ability to cope with pandemics?
8. How can the Global Health Security (GHS) index be calculated for measuring the preparedness of a vulnerable country?
9. Write about the current health security problems worldwide.
10. Why are the health systems of any country the most affected part during any epidemic?
11. What are the major challenges faced during an epidemic?
12. Which factors contribute most to evolving novel pathogens in the human population?
13. How can an epidemic be responded to in a short time?
14. How can the challenges of computational or artificial intelligence (AI) techniques be overcome?
15. How can different hygiene practices be maintained?

1.10 Problem statements for young researchers

1. The countries with a good 2019 GHS Index score and COVID-19 Safety Index score performed effective management of epidemics. The top-ranked GHS Indexed countries

are not always the top-ranked COVID-19 Index countries. What is the reason behind this dissimilarity?

2. The number of cases and the usual frequency of any disease during an epidemic can vary according to the time and place of occurrence and the size and type of population exposed to the disease in an area. How is this statement true in terms of epidemic events that have occurred in history?

1.11 Discussion questions

1. All the epidemic events show the devastating health and nonhealth impacts even with good public health surveillance systems. The poorer communities are the main victims of this scenario. Besides, healthcare workers are at high infection risk even in developed countries. How can the resources of the health system be enriched in order to cope with an epidemic and reduce the infection risk of healthcare providers?

2. There have been many major epidemics since the early age of human evolution. The recent epidemics include the West African 2014 Ebola outbreak, 2012 MERS, and COVID-19. The history of pandemics occurring is a reflection of concern for future epidemics. What kind of key issues can be raised regarding the growing concerns of the future transmission of human pathogens?

3. Any novel microbe or pathogen, either newly emerging or reemerging, is considered an independent variable that causes disease in the susceptible human population. While most of the emerging human pathogens are of animal origin, discuss the main causes behind the triggering of an epidemic.

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