Received: 5 May 2023 | Revised: 24 July 2023 | Accepted: 1 August 2023

DOI: 10.1002/rmv.2475

REVIEW

WILEY

Dynamics of viral disease outbreaks: A hundred years (1918/19–2019/20) in retrospect - Loses, lessons and emerging issues

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Abstract

Infectious diseases continue to be the leading cause of morbidity and mortality, and a formidable obstacle to the development and well-being of people worldwide. Viruses account for more than half of infectious disease outbreaks that have plagued the world. The past century (1918/19–2019/20) has witnessed some of the worst viral disease outbreaks the world has recorded, with overwhelming impact especially in low- and middle-income countries (LMIC). The frequency of viral disease outbreak appears to be increasing. Generally, although infectious diseases have afflicted the world for centuries and humankind has had opportunities to examine the nature of their emergence and mode of spread, almost every new outbreak poses a formidable challenge to humankind, beating the existing pandemic preparedness systems, if any, and causing significant losses. These underscore inadequacy in our understanding of the dynamics and preparedness against viral disease outbreaks that lead to epidemics and pandemics. Despite these challenges, the past 100 years of increasing frequencies of viral disease outbreaks have engendered significant improvements in response to epidemics and pandemics, and offered lessons to inform preparedness. Hence, the increasing frequency of emergence of viral outbreaks and the challenges these outbreaks pose to humankind, call for the continued search for effective ways to tackle viral disease outbreaks in real time. Through a PRISMA-based approach, this systematic review examines the outbreak of viral diseases in retrospect to decipher the outbreak patterns, losses inflicted on humanity and highlights lessons these offer for meaningful preparation against future viral disease outbreaks and pandemics.

KEYWORDS
epidemics, infectious diseases, lessons, pandemics, viral outbreaks

Abbreviations: AIDS, Acquired Immune Deficiency Syndrome; CDC, Centre for Diseases Control; COVID, Coronavirus Diseases; DNA, Deoxyribonucleic Acid; EHF, Ebola Haemorrhagic Fever; FDA, Food and Drugs Authority; HIV, Human Immunodeficiency Virus; IHR, International Health Regulations; LMIC, Low- and Middle-Income Countries; MERS-CoV, Middle East Respiratory Syndrome Coronavirus; RNA, Ribonucleic Acid; SARS-CoV, Severe Acute Respiratory Syndrome Coronavirus; SEARO, South-East Asia Region; UNAIDS, Joint United Nations Programme on HIV/AIDS; US, United States; USA, United States of America; WHO, World Health Organisation.

1 | BACKGROUND

Globally, infectious diseases represent a formidable and major barrier to the development and well-being of people and economies, particularly in developing and underdeveloped nations.[1] For centuries infectious disease epidemics and pandemics have plagued the world with devastating outcomes. Viral infections contribute significantly to morbidity and mortality attributable to infectious diseases. The years 1918/1919 to 2019/2020 define a century that has witnessed some of the deadliest viral infectious disease outbreaks in history. The effects of these outbreaks continue to be severe in low- and middle-income countries (LMIC).[2]

Beginning in the year 1918/1919, the world recorded the outbreak of the flu pandemic (named Spanish flu) caused by the influenza A subtype H1N1 virus that became one of the most devastating viral disease outbreaks in history, having claimed between 50 and 100 million human deaths globally.[3,4] Subsequent to that, various subtypes of Influenza A virus have emerged, which caused epidemics and pandemics in various locations globally. These include the 1957–1958 Asian flu pandemic that began in East Asia and caused by a novel Influenza A subtype H2N2 virus, that resulted in approximately one to four million deaths globally.[5,6] That was followed by the 1968 H3N2 influenza pandemic, first detected in the United States (US), which also claimed approximately one million lives globally.[6]

Other viral disease outbreaks in the hundred years historical timeline include the 2003 severe acute respiratory syndrome coronavirus (SARS-CoV) epidemic, the 2009 swine flu pandemic, the 2012 Middle East respiratory syndrome coronavirus (MERS-CoV) outbreak, the 2013–2016 West African Ebola virus epidemic, the 2015 Zika virus outbreak, and the 2010–2011 H1N1 influenza pandemic.[6–10] In 2019, one hundred years after the Spanish flu, the world was stricken again with another pandemic, the Coronavirus disease of 2019 (COVID-19) pandemic that has killed millions of people, crippled healthcare systems and caused socioeconomic breakdown globally.[11,12] Of note, the continued life-threatening questions posed by outbreaks of viral infectious diseases necessitate continued exploration into causative agents, circumstances of their emergence and factors of their spread to inform the development of effective control measures. This is the drive and focus for this review.

This review on dynamics of viral disease outbreaks is presented in four major sections put under (1) background and introduction, (2) procedure for identifying relevant materials, (3) observations from analysis of the historical records obtained; and (4) discussion of the findings as well as emerging issues. The review concludes with a summary of the key findings and issues for consideration in effective preparedness against viral disease outbreaks.

2 | MATERIALS AND METHODS

The sources of information used in this review of hundred years of viral disease outbreaks were drawn from peer-reviewed articles retrieved from PubMed, National Library of Medicine, Scopus and Google scholar. The advanced search tool was utilised in conjunction with a variety of themes connected to viral diseases and outbreaks. The search was limited to outbreak of viral diseases as the inclusion criteria, and the period for the review materials searched was from 1918/19 to 2020. Even though the goal was to gather as many documents as possible, articles and documents judged unimportant based on the content were discarded. The keywords used to find review articles were a combination of the terms 'infectious disease outbreaks', 'viral pandemics', '20th century', 'fatality', 'severity', and 'disease burden.' These keywords were put together by use of 'OR' and 'AND' Boolean operators. For example, the search for articles on viral infectious disease outbreaks in premodern and modern times was set as follows: TS = ('infectious disease outbreak*' or 'influenza or 'Ebola' or 'COVID-19') AND TS = ('20th century*' or 'modern *' or 'losses' or 'lessons' or 'challenges').

In all, 2046 articles were found during the search. To optimise the quality of the information, the articles obtained were filtered using the title of the article, abstract, or full text; and articles that did not satisfy the inclusion criteria were rejected. Duplicate articles and those unrelated to infectious disease outbreaks were among the documents rejected. After the initial screening, 823 articles that satisfied the inclusion criteria were considered. The process employed in identifying suitable records for inclusion in the review included different document types, such as research articles, review articles and abstracts (Figure 1).

Records obtained were entered into excel and summarised for presentation in this review. Information of interest retrieved for each virus that caused an outbreak includes the year(s) of outbreak, countries or regions affected, extent of the outbreak/estimated number of deaths caused, mode of transmission and natural host. Where appropriate, these were presented in tables, bar graph and pie chart. Case fatality was evaluated solely on account of the number of deaths attributable to an outbreak. In some cases, the number of deaths was estimated over a range. In such cases, an approximation of the median, 75th or 100th percentile was used in further analysis as the case may be. Further information was derived that include the total number of years a particular virus caused an outbreak in the century under review and the total number of deaths caused by each virus in all its appearances over the period. The number of deaths per year was obtained by dividing the total number of deaths by the total number of years of outbreak. Where an outbreak continued for years consecutively, such as HIV that emerged in 1981 and has continued till today (42 years), or the current SARS-CoV-2 driven COVID-19 pandemic (2019–date), the outbreak was considered as continuous

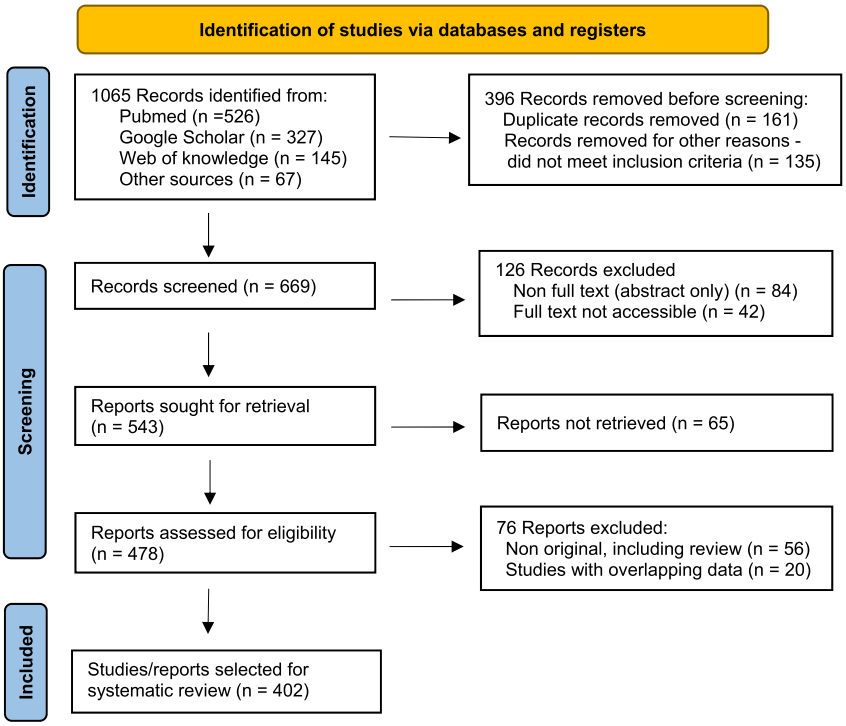

FIGURE 1 PRISMA 2020 flow diagram showing the search strategy, the number of records identified, and the number of included/excluded records.

and counted as one, irrespective of the duration of the outbreak. However, if an outbreak lasted for about 2 years followed by a year or two of silence and then reappeared a second time, it was counted as two, in that order. The findings and observations made from the analysis are presented and discussed in the following sections.

3 | RESULTS

3.1 | Viruses that caused epidemics and pandemics

There were a total of 51 viral outbreaks that resulted in epidemics and pandemics in the century under review. These outbreaks were caused by twenty-seven (27) viruses, including 5 subtypes of Influenza A (H1N1, H2N2, H3N2, H5N1 and H7N9). Figure 2 shows the viruses responsible for the outbreaks recorded. The figure displays the frequency of the viruses in terms of the number of outbreaks and the corresponding percentage of the total number of outbreaks recorded. Two percent (as in the case of Influenza A subtype H7N9) indicates this particular virus strain appeared once (1/51) in the century, and 12% indicates approximately 6 appearances over the period under review.

In all, 15 viruses appeared only once. The duration of these appearances ranged from as short as 1 year, in the cases of Hepatitis A (China, India, 1988), Hepatitis B (India, 2009), Influenza A (H7N9) of India (2015) and Japanese Encephalitis (India, 2017) to as long as 42 years (HIV, 1981) and 50 years in the case of Mpox (1970). The viruses that appeared once are those with a 2% frequency score, nine of which are grouped under 'Other' (9, 18%) in the pie chart (Figure 1). In terms of frequency of outbreaks, the six most significant viruses are Yellow fever (six times, 12%), Dengue (also six times, 12%), Ebola and Influenza A subtype H1N1 (four times or 8% each), followed by Poliomyelitis and Smallpox, each of which made three appearances (6% each) in the century. These frequencies underscore the outbreak potential of the viruses but not the fatality rate or duration of the outbreaks.

The details about the viruses with respect to years and duration of outbreak, regions affected and outcome of each outbreak in terms of the number of human deaths recorded or estimated among others are shown in Table 1. The record shows HIV has lasted the longest, from its detection in 1981 until present. Besides its frequent appearance, Dengue outbreak appears to last long, being the second longest outbreak, having lasted for 12 years in all, among the 26 viruses in the century. Dengue is followed closely by the three viruses, Hand, foot and mouth disease, MERS-CoV and Yellow fever with 11 years total duration. Four other viruses that recorded appreciably high numbers of deaths and demonstrated a propensity for frequent occurrence are Influenza A H1N1 (Spanish flu), Poliomyelitis, Measles and Ebola. SARS-CoV-2 falls under special consideration, in that, its appearance marks the end of the century under consideration. The century in focus thus began with the pandemic Influenza A H1N1 of 1918/1919 that lasted just for about two years but claimed tens of millions of lives; records another influenza pandemic in 1968 (the Hong Kong flu caused by Influenza A H3N2), exactly 50 years after the 1918/1919 outbreak, and ends with the COVID-19, which is now in its third year and has claimed close to seven million lives and counting.

With regards to extent of the outbreak, some viral outbreaks appear to be concentrated in certain regions more than others, causing epidemics in those regions, whereas others move across

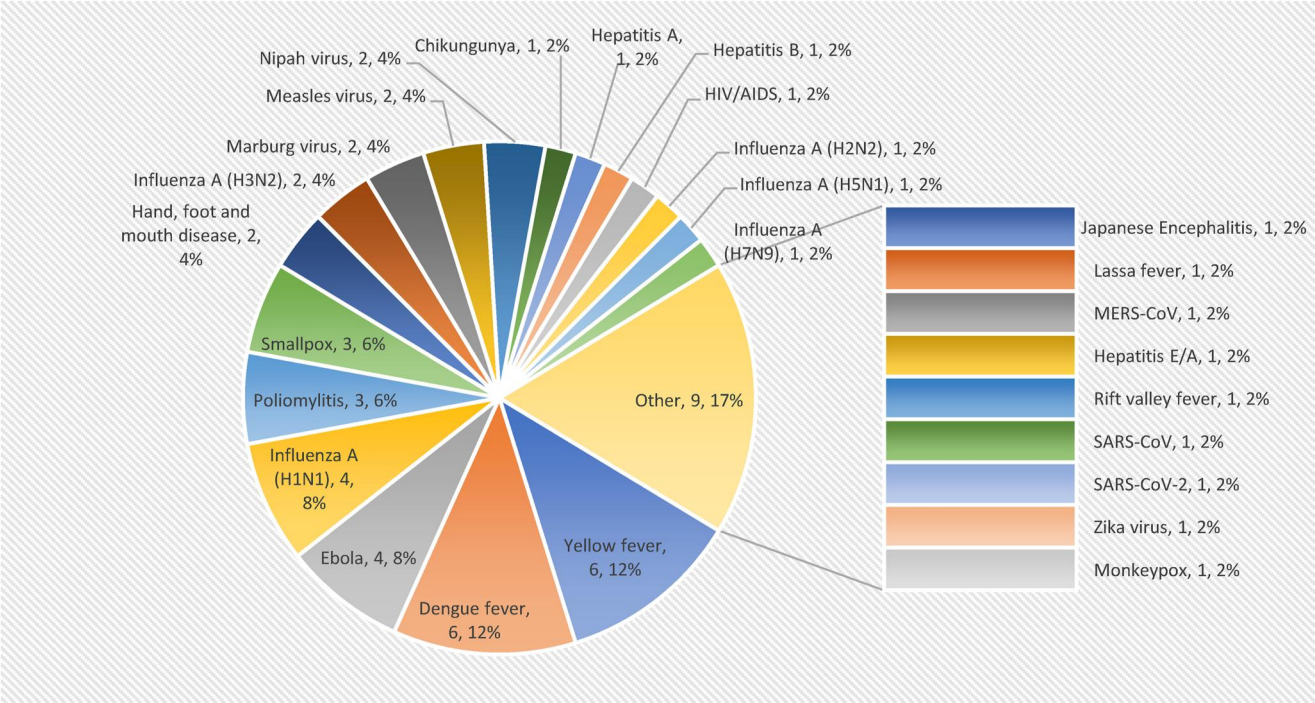

FIGURE 2 Frequency of 27 viruses that caused epidemics and pandemics in the hundred years, 1918/1919–2019/2020. Segments of the pie chart are labelled with the virus name, the number of outbreaks and the corresponding percentage out of the total of 51 outbreaks.

regions and continents–the cause of pandemics. Influenza A subtypes H1N1 and H2N2, HIV, the Coronaviruses (MERS-CoV and SARS-CoV, SARS-CoV-2), Poliomyelitis, Measles and Zika virus were responsible for most of the pandemics encountered. Dengue virus appeared mostly in parts of Europe and Asia but is less common in Africa. On the other hand, Yellow fever, Rift Valley fever, Marburg, Lassa fever and Ebola appeared to be restricted to Africa.

3.2 | Estimates of case fatality per year over the course/duration of viral outbreaks.

To evaluate case fatality, the cumulative number of deaths caused by the respective viruses over the duration presented in Table 1 were normalised by finding the number of deaths per year as indicated in the methods section. Figure 3 presents this data. Four viruses caused extremely high mortalities, the values of which are beyond the scale of the figure and so could not be shown in the graph. They are Influenza A H1N1, SARS-CoV-2, Influenza A H2N2 and HIV. These have been shown in the chart area of Figure 3 with their respective number of deaths per year. Further attention would be given to these again later. Besides these four viruses, Smallpox, Yellow fever and Poliomyelitis also accounted for an appreciably high number of deaths per year.

Determinations were done regarding the mode of transmission of the various viruses, the nature of the resulting outbreak and the natural hosts for viral emergence. Details of these are shown in Table 2. In all, 16 near-distinct modes were identified. Broadly, the transmission modes can be grouped under (1) bite of a mosquito (Aedes or Culex), (2) contact with infected blood/body fluids or organ of an infected person, (3) contact with respiratory droplets of an infected person, (4) contact with an infected animal such as pigs, poultry, bats, rats, and camels, and (5) contact with infected food or water.

Findings showed that viruses transmitted by the respiratory route, either person-to-person or contact with infected animal (such as bat, pig or poultry) or surfaces were commonly associated with pandemics. Exposure to faeces/urine, contaminated food, water, or surfaces were the common routes for the outbreak of epidemics. Correspondingly, pigs, poultry, birds and bats commonly served as natural hosts for respiratory viruses and were therefore commonly associated with pandemics, whereas human hosts and mosquito species are commonly associated with epidemics.

4 | DISCUSSIONS

Observations highlight some important factors that promote viral disease outbreaks, epidemics and pandemics. These include climate change, urbanisation, environmental degradation and hence destruction of natural habitats of viral pathogens, gene mutations to enhance adaptation to changed environment and consumption of wildlife meat among others. These consequently lead to changes in reservoir or intermediate host populations.[21,66] All the deadliest viral disease outbreaks have been linked in one way or another to these factors. Contact with respiratory droplets from infected person,

TABLE 1 Alphabetical list and impact of 27 viruses that caused outbreaks in the past century.

No.	Virus	Years of outbreak/Duration		Countries/regions affected	Estimated fatality (Cumulative)
		Years	Duration (years)		
1	Chikungunya[13,14]	2013–2015	2	Mozambique, Europe and the Americas	183
2	Dengue fever[15–17]	2000, 2004–2009, 2011, 2013, 2017, 2019–2020	12	Central America, Indonesia, Singapore, India/Pakistan/Philippines, Puerto Rico/Dominican republic/Mexico, Cambodia/Brazil, Bolivia/Queensland/Australia, Peshawar/Pakistan/Sri Lanka, Asia-Pacific/Latin America	7972
3	Ebola[18–20]	2004, 2007, 2013–2015, 2018–2020	8	Sudan, DR Congo/Uganda, West Africa, DR Congo/Uganda,	13,889
4	Hand, foot and mouth disease[21,22]	2008–2017, 2011	11	China, Vietnam	3492
5	Hepatitis A[23,24]	1988	1	Shanghai/China, India	40
6	Hepatitis B[25,26]	2009	1	India	49
7	HIV/AIDS[27–29]	1981 - present	42	*Worldwide*	37 million
8	Influenza A (H1N1)[4,7,30]	1918–1920, 1977–1979, 2003, 2009–2010	8	*Worldwide*, Southeast Asia/Egypt, worldwide	100 million
9	Influenza A (H2N2)[31,32]	1957–1958	2	*Worldwide*	4 million
10	Influenza A (H3N2)[33]	1968–1970, 1972–1973	3	United States	1027
11	Influenza A (H5N1)[34,35]	2013–2019	6	China	616
12	Influenza A (H7N9)[36]	2015	1	India	2035
13	Japanese Encephalitis[37,38]	2017	1	India	1317
14	Lassa fever[39]	2019 - present	3	Nigeria	247
15	Marburg virus[40]	1998–2000, 2004–2005	4	Democratic republic of the Congo, Angola	221
16	Measles virus[41]	2010–2014, 2019–2020	6	DR Congo, Vietnam, New Zealand, Philippines, Kuala Koh, Malaysia, Samoa	12,175
17	MERS-CoV[42,43]	2012 - present	11	Worldwide	941
18	Monkey pox[44–46]	1970 - present	50	Democratic republic of the Congo, West Africa	[a]4500
19	Nipah virus[47,48]	1998–1999, 2018	3	Malaysia, India	122
20	Poliomyelitis[49–51]	1937, 1948–1952, 1971	6	*Worldwide*, Australia, United States, Netherlands	16,150
21	Hepatitis E/A[52,53]	2014–2015	2	Inda	36
22	Rift Valley fever[54,55]	2006–2007	2	East Africa	394
23	SARS-CoV[56–58]	2002–2004	2	*Worldwide*	774
24	SARS-CoV-2[12,59]	2019 - present	3	*Worldwide*	7 million
25	Smallpox[60,61]	1924–1925, 1972, 1974	4	Minnesota (United States), Yugoslavia, India	15,535
26	Yellow fever[62]	1940, 1960–1962,1986–1987, 2012,2016, 2020 - present	11	Sudan, Ethiopia, Nigeria/Mali, Sudan, Angola/DR Congo, Nigeria	38,400
27	Zika virus[63–65]	2015–2016	2	*Worldwide*	53

[a]Mpox fatality estimated was obtained using a case fatality ration of 10% of an average of 1000 cases per year for 45 of the 50 years since the first human case was detected.

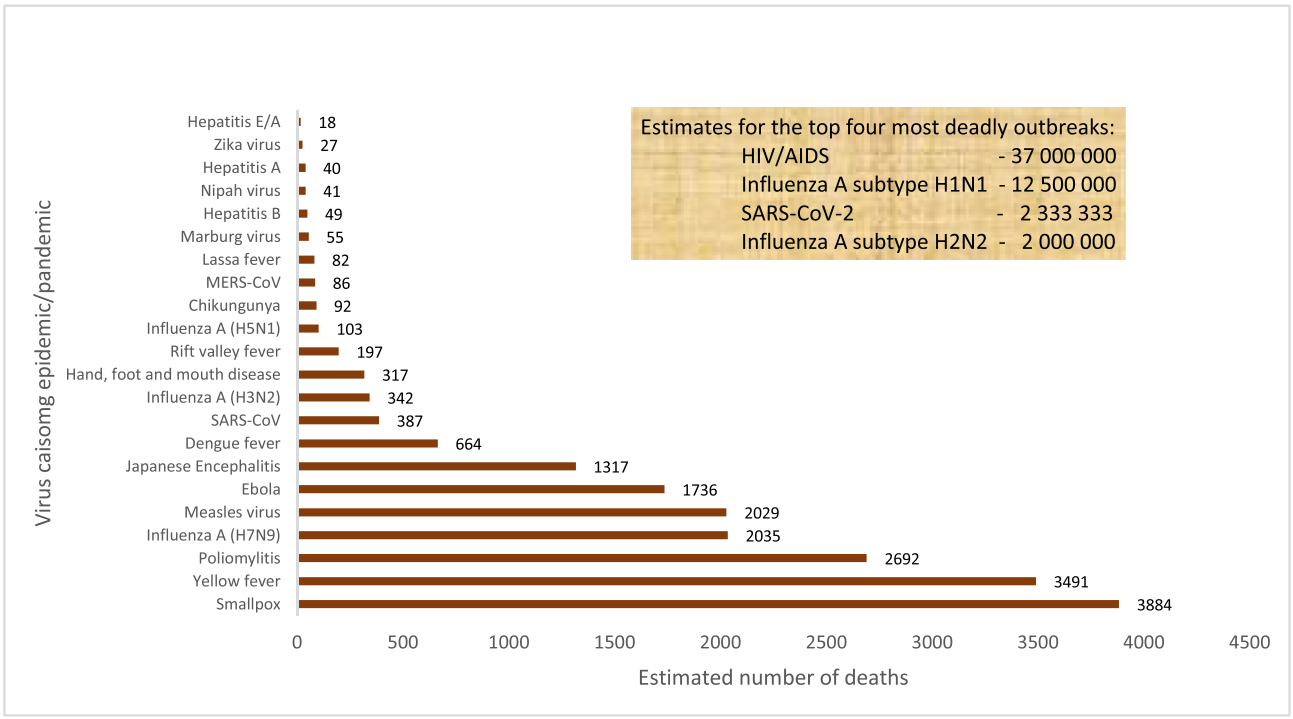

FIGURE 3 Cumulative number of deaths per year caused by viral outbreaks in the century 1918/1919–2019/2020. The number of deaths per year was determined for the duration of the epidemic/pandemic. Four viruses caused extremely high mortalities, such that the number of deaths caused per year are beyond the scale of the figure. These have been separated, embedded in the figure. They are Influenza A H1N1, SARS-CoV-2, Influenza A H2N2 and HIV.

contact with blood or body fluids from infected person, contact with infected animal or animal product, and bite of infected arthropod such as mosquito, are some of the routes of transmission of the viral outbreaks observed. Consequently, pandemics are more likely to occur where there is increasing interaction among human populations, and among human and animal ecological communities.[67–71] Furthermore, trade expansion, ease of local mobility and international air travel, which promote more frequent human-human interactions, represent important contributory factors for spread, once viral emergence has occurred.[66,72] It is noteworthy that several of the outbreaks recorded, such as the SARS coronavirus, spread to several other nations as a result of travelling before the transmission was brought under control.[73] Briefly, these factors have been illustrated below using some candidate viruses whose outbreak have inflicted severe wounds on humanity, and whose emergence appears to be on the rise and so deserves particular attention.

4.1 | Respiratory virus pandemics: Influenza A H1N1

Evaluation of viral outbreaks in the past century confirms the influenza pandemic of 1918–1919 as the most devastating pandemic in the century.[74–76] The cause of the outbreak and its association with avian influenza, however, was not known until the 1930s when it was confirmed to be caused by the H1N1 influenza virus with genes from avian sources.[3,77] Until now, at least 5 subtypes of Influenza A have been described that have caused epidemics and pandemics, mainly through human contact with infected respiratory droplets or contact with infected animals such as poultry (H5N1), pig (H3N2, H1N1, H7N9) or birds (H2N2, H1N1) (Table 2).

4.2 | Blood-borne pandemics: HIV/AIDS

The human immunodeficiency virus (HIV) was first reported in July 1981, by doctors in New York and California, as a rare form of cancer predominantly among homosexual men.[78] As the cause of this outbreak was initially unknown, the disease was referred to as Kaposi's sarcoma, before it was later named acquired immune deficiency syndrome (AIDS).[79] In 1983, the retrovirus HIV was identified as the causative agent for AIDS.[80,81] AIDS, which started as an epidemic in 1981, soon became an important global public health issue. Today, Africa south of the Sahara carries the heaviest burden of the disease.[82] Contact with infected blood and sexual contact remain the modes of transmission of the virus.[83]

4.3 | Zoonosis associated epidemics: Ebola

Ebola virus is a zoonotic pathogen that infects both human and nonhuman hosts, causing Ebola haemorrhagic fever (EHF). The

TABLE 2 Viral outbreaks by transmission mode.

No.	Transmission mode	Viruse(s)	Extent of outbreak	Natural host
1	Bites of infected Aedes mosquito species	Dengue	Epidemics	Aedes aegypti mosquito sp.
		Chikungunya		Aedes aegypti mosquito sp.
		Yellow fever		Aedes and haemogogus sp.
		Zika virus		Aedes aegypti mosquito sp.
2	Contact with blood/body fluids of infected persons	Ebola	Epidemic	Fruit bats, some non-human primates (wild animals)
		Hand, foot, and mouth disease	Epidemic	Humans
3	Fecal-oral transmission -contact with infected food/water	Hepatitis A	Epidemic	Humans
		Hepatitis E	Epidemic	Humans
4	Contact with infected blood	HIV/AIDS	Pandemic	Chimpanzees
5	Person-to-person; respiratory droplet of infected persons	Influenza A (H1N1)	Pandemic (Spanish flu)	Wild aquatic bird and duck
		Influenza A (H2N2)	Pandemic (Asian flu)	Birds, ducks
6	Pigs-to-human; respiratory droplets of infected persons or infected surfaces	Influenza A (H3N2)	Pandemic (Hongkong swine flu)	Pigs
		Influenza A (H1N1)	Pandemic (Russian swine flu)	Pigs
		Influenza A (H7N9)	Epidemic (Indian swine flu)	Pigs
7	Human contact with infected birds or virus-contaminated environment	Influenza A (H1N1)	Epidemic (South East Asia and Egypt)	Wild aquatic birds
8	Exposure to infected poultry	Influenza A (H5N1)	Epidemic (avian influenza)	Poultry
9	Bite of infected culex mosquitoes sp. (Culex tritaeniorhynchus)	Japanese encephalitis virus	Epidemic (India)	Pigs and birds
10	Exposure to urine and faeces of infected animals, body secretions of infected persons	Lassa fever	Epidemic (Nigeria)	Mastomys rats
11	Contact with infected bats, close contact with infected foods and persons (nipah)	Marburg virus	Epidemic (DR Congo, Angola)	African fruit bats
		Nipah virus infection	Epidemic	Fruit bat
12	Contact with respiratory droplets of infected persons, or by airborne spread through coughs	Measles	Epidemics	Humans
13	Contact with dromedary camels	Middle East respiratory syndrome coronavirus (MERS-CoV)	Pandemic	Dromedary camels, bats
14	Contact with blood or organs of infected animals	Rift Valley fever	Epidemic	Aedes mosquito species
15	Respiratory droplet of infected persons	SARS-CoV	Pandemic	Bats
		SARS-CoV-2	Pandemic	Bats
16	Contact with infected persons (person-to-person)	Smallpox	Epidemic	Humans
		Monkey pox	Epidemic	Unknown

first confirmed case of Ebola was detected in Guinea, Africa.[20] The 2014 Ebola outbreak in West Africa was one of the deadliest outbreaks in recent times.[19] The outbreak mostly affected West African countries including Guinea, Liberia and Sierra Leone–the three most heavily affected countries, as well as Nigeria, Senegal and Mali. Other nations affected are Spain, the United Kingdom, Italy, Senegal, Mali and the United States.[18,84] The Ebola virus was initially suspected to be transmitted through contact with the meat of infected animals; but once it is established in the human population, it can then be transmitted through direct contact with the body fluids of infected individuals whether dead or alive.[85]

4.4 | Arthropod-borne epidemics: Arboviruses

For decades, Arboviral diseases were thought to play minor roles in global cases of morbidity and mortality. As such, little attention was given to research into Arboviruses, particularly in Africa. However, the unprecedented surge in emergence of Arboviral disease outbreaks in recent decades[86] necessitated increased attention. Arthropods such as mosquito species are the source of emergence of various Arboviral outbreaks, including Yellow fever, Zika virus, Dengue and Chikungunya. Globalisation and climate change appear to be major factors promoting their spread.[87,88] These findings underscore the need for greater attention to Arboviral disease surveillance and research to help reduce the increasing frequency of their infections.

4.5 | *Coronavirus pandemics: MERS-CoV, SARS-CoV and SARS-CoV-2*

Like influenza viruses, Coronaviruses are partly responsible for the seasonal respiratory diseases observed. The alpha coronaviruses cause normal colds. Three beta-coronaviruses that have caused outbreaks in man in the century under review include the SARS-CoV in 2003, MERS-CoV in 2012, and SARS-CoV-2 in 2019.[56,57] The SARS-CoV-2 virus was discovered in a group of patients in Wuhan in early December 2019 as the causative agent of what was initially known to be a rare form of pneumonia, but which was later identified as a new coronavirus responsible for COVID-19. Bats have been suggested to be the animal reservoirs, but pangolins are also thought to have transmitted the virus to humans.[89–91] The COVID-19 pandemic persists despite the implementation of preventive strategies and deployment of vaccines.

4.6 | Human-to-human spread: The special case of monkey pox epidemic

The human monkeypox (Mpox) virus outbreak was first detected in Denmark in 1958 in captive cynomolgus macaque monkeys.[46] In 1970, the first human case was discovered in the Democratic Republic of the Congo (then known as Zaire), nine months following the eradication of smallpox in the Democratic Republic of the Congo.[44,92] Since then, Mpox has remained endemic in the Democratic Republic of the Congo from where it has spread mostly to some Central and West African countries.[93] In 2003, the United States of America became the first location outside of Africa that reported human monkeypox cases. The first global outbreak of the virus occurred in early May 2022. On 24 July 2022, the World Health Organization declared the M pox outbreak as a public health emergency of international concern in view of its rapid global spread.[94] Transmission of the virus can occur by person-to-person through direct contact with infectious skin or contact with fluids from other body parts such as the mouth and the genitals. The natural host is not yet known.

4.7 | Losses caused as a result of viral disease outbreaks

In the past century, the world experienced several epidemics and pandemics that have caused devastating effects. Outbreaks, epidemics and pandemics such as Spanish flu, HIV/AIDS, Ebola and COVID-19 have caused extremely high mortalities. The Spanish flu, one of the worst outbreaks of the 20th Century, killed an estimated 50 to 100 million people within a short space of two years (1918–1920), and, like the COVID-19, overwhelmed the world's healthcare system.[95] Ebola killed over 11,000 people. Globally, as of 12 April 2023, there have been 762, 791, 152 confirmed cases of COVID-19, with at least 6.8 million deaths reported to WHO.[96] Besides the precious lives claimed, many who survived these outbreaks were left with various degrees of morbidity. For instance, many of the survivors of the Ebola outbreak suffer from chronic, long-term health issues such as muscle and joint pains, eye problems and headaches.[97] Furthermore, these outbreaks indirectly affect the health system by reducing resources available, both material and human, for routine healthcare. The economies of nations were also affected as a result of increase in mortalities that led to shortage of labour. Lockdowns reduced the availability of organised labour, and travel and border restrictions also drastically decreased revenue.[98,99] The burden and loses incurred by nations due to viral disease outbreaks cannot be described in full.

4.8 | Lessons from viral disease outbreaks over the past century

Findings showed an increase in the number of viral disease outbreaks in the past century. The gravity of the adverse effects of these outbreaks and demands for measures to control the outbreaks present some lessons to better equip humankind in preparation for future outbreaks. First, the records show that most of the viruses that caused major outbreaks are zoonotic pathogens (Table 2). Universally, there is no consensus regarding where the 1918/1919 H1N1 influenza virus originated[100]; the 2009 H1N1 outbreak was thought to emerge from pigs[101]; and the 2014–2015 Ebola outbreak was thought to have been caused by the fruit bats and some non-human primates.[20] Again, bats were implicated in the 2019 SARS-CoV-2 outbreak,[102] while the emergence of MERS was also facilitated by the interactions between camels and humans.[103,104] These make the surveillance of infections at the human-animal-environment interface very crucial and thus underscore the essence of a One Health approach to controlling infectious diseases.

Second, viral disease outbreaks such as Influenza A, Ebola, MERS and COVID-19 have emphasised the importance of public health measures and infection control practices in public settings such as the markets, hospitals and schools, and for populations at risk. Practices such as quarantine, wearing of masks and protective clothing, regular handwashing and the use of sanitisers contributed immensely in controlling or ameliorating some viral outbreaks such as Influenza A and COVID-19.[105] In the case of the 1918–1919

pandemic flu for example, with no preventive vaccination and no medications to treat secondary infections at the time, strategies such as isolation, personal hygiene, mask wearing and disinfectant use, as well as restrictions in public gatherings or social distancing represented the major control measures.[106] Interestingly, besides the availability of vaccines currently, these interventions are still relevant in the 21st century, as they served as milestones for the prevention and control of COVID-19.

Another important outcome of viral disease outbreaks in the past century is the advancement in research into vaccine development and production. Vaccine production and deployment are crucial in the fight against infectious disease outbreaks and in the protection of human populations against future pandemics. In response to the 1918 Spanish flu pandemic, the first influenza A virus vaccine based on inactivated influenza was developed. The vaccine was approved for use in the 1940s[107] Subsequently, other flu vaccines were developed that target other strains of the virus.[108] Currently, there are vaccines developed for viral diseases such as Ebola, Polio, Yellow Fever and COVID-19.[109] Several technologies such as viral vector-, DNA-, mRNA- and protein-based approaches have been developed for the production of vaccines.[110]

Lastly, to a large extent, viral outbreaks and pandemics have put countries in a position to have an outbreak preparedness plan against infectious diseases.[111,112] The pressing need for early warning systems to strengthen preparedness against viral disease outbreaks are also highlighted.

4.9 | Emerging challenges

Global efforts toward the control and prevention of viral disease outbreaks over the past hundred years have led to significant breakthroughs. However, several challenges exist that hamper the progress of control measures and also pose a threat to a successful fight against viral disease emergence and spread. These may be viewed as challenges and would be discussed from three perspectives. The first challenge involves the forces of nature, which are not directly under the control of mankind; the second is awareness of the viral outbreaks and preparedness, and the third is vaccines.

Climate change: The selection and availability of suitable vectors is a necessary requirement for the emergence of vector-borne pathogens.[113] A complex interaction of environmental factors influences the ecological niche for hosts of vector-based pathogens. Population growth and expansion, urbanisation, changes in land use and environmental degradation ultimately lead to climatic changes,[114] which consequently affect disease-causing pathogens that have part of their life cycle in the environment (that is, outside the host). The increasing frequency of viral disease outbreaks may partly be attributable to climate change. Infectious pathogens such as viruses with pandemic potentials are zoonotic; so, they are affected to a large extent by human engagements with the environment and interactions at the human-animal interface. For example, climate change may affect the distribution of arthropod vector-borne viral diseases such as outbreaks due to Yellow fever, Zika virus, Dengue and Chikungunya, whose emergence in recent decades has been unprecedented.[115,116] This constitutes a challenge, in view of the fact that the constant human interactions with animals and the environment, as well as activities that lead to climate change, can only be controlled to some extent, but cannot be stopped entirely. Viral pathogens, on the other hand, unless they get extinct, will continue to adapt to living in new hosts if their natural hosts are endangered. Thus, they should be expected to emerge and re-emerge–the cause of persistent outbreaks that humankind may have to contend with at all times. Thus, the need for proper preventive and control measures remains imperative.

Outbreak preparedness: The importance of viral infectious disease outbreak preparedness and response systems cannot be overemphasized. The essence of the International Health Regulations (IHR) is thus underscored.[117] However, though many member countries of the IHR have implemented pandemic preparedness systems, and others are at different stages of preparedness,[118] most resource-limited, developing countries do not meet the basic criteria for compliance with the IHR. As such, what could otherwise be localized outbreaks easily lead to epidemics and pandemics and become difficult to control.[119] It is therefore important that the global community operates viral disease control and prevention strategy in concert–working together towards the same goal.[120] During the 2014 West Africa Ebola epidemic for instance, inadequacies of diagnostics, infection control processes, response strategies and access to basic health care[85] caused the lives of over 11,000 people. Globally, the unpreparedness of public health systems caused a delay in response during the COVID-19 outbreak, which contributed to high mortalities, led to the breakdown of economies and healthcare systems, and caused the closure of educational and other public institutions.[121]

Vaccine research and development: Though there has been an appreciable success in the development and deployment of vaccines in response to some viral diseases, access to these vaccines is still a challenge. Timely development, efficacy and distribution of vaccines continue to be one of the weaknesses in epidemic and pandemic response.[121,122] For instance, during the 2009 H1N1 pandemic, though vaccines were developed within a short time, distribution and coverage were much lower than expected. While vaccination began earlier in the USA, it took a longer period to begin in other countries.[123,124] Vaccine supply remains a challenge particularly in developing countries.[125] Furthermore, the extent of immunity the vaccines confer and their potency against new variants are concerns that remain unaddressed.[126] Hence, despite the progress made so far, a great deal needs to be done in vaccine research to produce vaccines for infections not yet covered, and optimize the quality, safety and efficacy of those already developed but with some shortcomings.

5 | CONCLUSION

In the past century humankind has experienced some of the deadliest viral infectious disease outbreaks in history. Knowledge of the triggers of pandemics as well as advances in prevention strategies

constitutes a vital tool for reducing the impact of disease outbreaks. Evidence from the analysis of the outbreaks reviewed, indicates that respiratory viruses have the highest pandemic potential and therefore should deserve great attention in pandemic preparedness. The role of governments in implementing and maintaining effective public health emergency preparedness plans is crucial. As human activities and factors that influence viral disease outbreaks persist, continued research and monitoring are needed to better understand the dynamics of viral disease outbreaks. The importance of vaccines in mitigating viral epidemics and pandemics cannot be overemphasised, but inadequacies in vaccine production and deployment call for intensified vaccine research. An integrated, interdisciplinary approach involving all stakeholders in government, public health, research and academia, and drug manufacturing companies is warranted to help in the control and prevention of viral disease outbreaks. This review evaluated and assessed the dynamics of viral infectious disease outbreaks in retrospect and highlighted the causes, losses and lessons learnt. The review also discussed the emerging issues considerable for a meaningful preparedness to successfully face future viral disease outbreaks and pandemics.

AUTHOR CONTRIBUTIONS

Nicholas I. Nii-Trebi: conceptualisation; methodology; formal analysis; investigation; project administration; writing – original draft; writing – reviewing and editing. **Thomas S. Mughogho:** conceptualisation; methodology; writing – original draft; writing – reviewing and editing. **Anisa Abdulai:** formal analysis; investigation; writing – original draft; writing – reviewing and editing. **Francis Tetteh:** conceptualisation; methodology; writing – original draft; writing – reviewing and editing. **Priscilla M. Ofosu:** conceptualisation; methodology; writing – reviewing and editing. **Mary-Magdalene Osei:** conceptualisation; writing – original draft; writing – reviewing and editing. **Akua K. Yalley:** conceptualisation; methodology; writing – reviewing and editing.

ACKNOWLEDGEMENTS

This work was facilitated through lectures on Dynamics of Infectious Diseases. The contributions and encouragement of the 2022 first year PhD students of the Department of Medical Microbiology of the University of Ghana Medical School is acknowledged. No funding was received for this work.

CONFLICT OF INTEREST STATEMENT

No conflict of interest declared.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the supplementary file for this article.

ETHICS STATEMENT

Ethics approval was not necessary.

PATIENT CONSENT STATEMENT

No patients were involved.

PERMISSION TO REPRODUCE MATERIAL FROM OTHER SOURCES

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How to cite this article: Nii-Trebi NI, Mughogho TS, Abdulai A., et al. Dynamics of viral disease outbreaks: a hundred years (1918/19–2019/20) in retrospect - loses, lessons and emerging issues. *Rev Med Virol*. 2023;e2475. https://doi.org/10.1002/rmv.2475