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# Understanding the epidemiology of COVID-19

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**ABSTRACT:** COVID-19 caused by SARS-CoV-2 was reported in December, 2019 in Wuhan city of Hubei province, China, in people who had visited seafood market. Its symptoms were similar to pneumonia but its infectivity was very high. The main modes of transmission of SARS-CoV-2 were identified as spread by nasal droplets and oral-fecal route and COVID-19 was found to be infectious in incubation and asymptomatic period. Hence, by the time real potential of its pathogenicity was realized, it had spread to many regions of China, other Asian countries, European countries, United States etc. and by April 20, 2020, it had spread to 185 countries all over the world. By this time, China had contained the virus, due to strict social distancing measures, and there was decline in the number of positive cases but in many other countries, especially U.S. and European countries, the cases continued to rise. United States showed the sharpest rise in COVID-19 cases in April, 2020 and also reported the highest number of deaths from the disease. As most of the countries are facing first-wave of COVID-19 by April, 2020, there are fears of second-wave of COVID-19 as China plans to relax social distancing norms to resume business, other work etc. to combat economic losses.

**Keywords:** SARS-CoV-2; COVID-19; Pandemic; Social distancing.

## 1. INTRODUCTION

Coronaviruses belong to the largest group of viruses that belong to the order *Nidovirales*. They are RNA viruses with a 26 to 32 kb genome [1]. There are four genera of coronaviruses i.e. alpha, beta, gamma and delta, of which alpha and beta coronaviruses are human coronaviruses (HCoV i.e. they infect humans). As of now, bats are considered to be the reservoirs of coronaviruses [2]. Coronaviruses are known to cause diseases in animals, which may be severe in livestock. Coronaviruses have a history of getting transmitted to humans and causing mild respiratory infections. The first case of corona virus infecting humans severely was reported from Guangdong province in south China in November, 2002, probably transmitted through bats and affected 26 countries with 8000 cases [3]. The disease was called as severe acute respiratory syndrome (SARS) and the causative agent was beta HCoV (SARS-CoV). During the 2002-03 corona virus outbreak, there were 8098 positive cases with 774 deaths. The mortality rate was higher in elderly people [4]. SARS-CoV was an example which demonstrated that CoV can jump from animal to human and cause pandemic. There was another outbreak of beta CoV in 2012 which caused the disease 'Middle East respiratory syndrome (MERS)' and the virus was named MERS-CoV. MERS did not cause community spread [2].

The latest outbreak of corona virus-2 was in Wuhan city of Hubei Province in China, in December, 2019 [5]. Most of the early reported cases in Wuhan were thought to be due to visits to the seafood market. However, later there were cases of human-human transmission as people who had no contact with the sea food market also contracted the infection including the medical professionals. Soon it was found that the exposure to the virus can cause infection in all people, even the healthy ones. However, in initial phase of spread mostly the infected people were from the age group of 35-55 years, although people as elderly as 89 years and children and infants were also reported to be infected. More males (59%) were infected than females [5, 6]. It was also found out that elderly people were more at risk which might be due to poor immune system and also people who were immune-compromised like people having medical conditions such as renal or hepatic issues were also at risk [5]. The first death reported due to SARS-CoV-2 was from China on January 10, 2020 [7]. By this time, the infection had spread to hundreds of people in various cities of China.

Soon the infection spread to other parts of the globe including Asia, Europe and America. On January 30, 2020, WHO Director-General declared SARS-CoV-2 outbreak as the Public health Emergency of International Concern [8] and on March 11, 2020 as a pandemic [9]. World Health Organization announced that the disease caused by this corona virus would be called Corona Virus Disease- 19 (COVID-19) and the virus was named as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [6, 9].

The spread of SARS-CoV-2 was very quick. By January 30, 2020, there were reports of 9976 confirmed positive cases from at least 21 countries with China having most number of cases [10]. By January 31, 2020 the virus had spread to many countries, affecting 11,791 people and causing 213 deaths. By February 16, 2020, the confirmed cases in China were 70,548 and 683 in other countries [11]. By March 9, 2020, 104 countries reported 109,577 cases of COVID-19 with China having the highest cases i.e. 80,904 cases. Apart from China, other countries with major cases were South Korea (7382 cases), Italy (7375 cases) and Iran (6566 cases) [12].

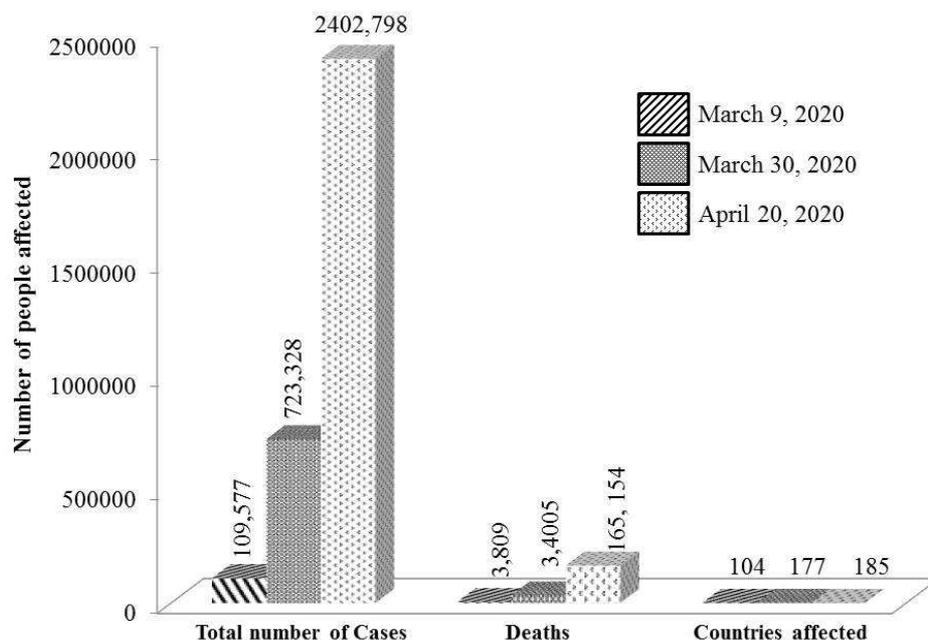
By March 30, 2020, the number of cases rose to 723,328 from 177 countries all over the world. With 143,025 positive cases, United States was at the top of the chart followed by Italy (97,689) and China (82,152) [10]. On April 1, 2020, there were 857,957 confirmed cases globally affecting 180 countries with U.S. having most number of positive cases (188,547). On April 20, 2020, the number of global confirmed cases was 2,402,798 with highest number of cases in U.S. followed by Spain and Italy and the pandemic had spread to 185 countries [10].

## 2. METHODOLOGY

The latest research papers pertaining to COVID-19 published all over the world and those listed by the Centers for Disease Control and Prevention (CDC), US Department of Health and Human services, were considered for this article. The article was divided into four sections which included discussion on the epidemiology of SARS CoV-2 in China, Asian countries (other than China), Europe and United States. The incubation period and reproduction rate ( $R_0$ ) of SARS-CoV-2 from different regions have been tabulated.

## 3. EPIDEMIOLOGY OF SARS-COV-2

The number of COVID-19 cases has been increasing globally since January, 2020. However, there has been steep rise in the cases in April, 2020 (Figure 1). This review discusses selected cases of COVID-19 from different countries. The discussion on the epidemiology of COVID-19 has been divided into following four sections which include the initiation and spread of the SARS-CoV-2 in different regions of the world.



**Figure 1.** Global status of COVID-19 between March, 9, 2020 and April, 20, 2020 (numbers shown above the bars) [10, 12].

### 3.1. Understanding the epidemiology of COVID-19 in China

The initial information about COVID-19 came to light when the local health authority in Wuhan, Hubei Province, China issued an epidemiological alert on December 31, 2019 following cases of some patients who developed pneumonia and had history of visits to sea food market in Wuhan. Soon, the Chinese Center for Disease Control and Prevention (China, CDC) sent off a rapid response team to assist local health authorities in epidemiological and etiological investigations. It all started like this: on December 27, 2019, three adult patients were admitted to a hospital in Wuhan showing symptoms of severe pneumonia. Among the patients were a 49 year old woman (Patient 1: a retailer in seafood market), a 61 year old man (Patient 2: a frequent visitor to seafood market) and a 32 year old man (Patient 3). Patient 1 had no chronic medical condition and she reported fever and cough with discomfort in chest on December 23, 2019. After four days, her cough and chest discomfort worsened but fever was reduced. Patient 2 had reported cough and fever on December 20, 2019. He developed respiratory distress 7 days after onset of illness which worsened further after next two days. Patients 1 and 3 recovered after treatment and were discharged on January 16, 2020. However, Patient 2 died on January 9, 2020 [13].

Between Jan 1-22, 2020, about 425 laboratory-confirmed cases of novel coronavirus infected pneumonia (NCIP) were reported in Wuhan, China in the age range of 15-89 years [5]. Initially there was a lot of difficulty in identifying patients of SARS-CoV-2 as the symptoms appeared similar to common cold. It took time to identify such patients, isolate them and many of them could not be hospitalized due to several factors. At this stage, the cases doubled every 5.4 days in Wuhan, China. There was human to human transmission among close contacts throughout December, 2019 which remained unnoticed leading to gradual spread of the disease. By January 2, 2020, 41 patients were hospitalized in Wuhan, 27 of whom had visited the seafood market in Wuhan and 73% of the patients were men. Between Jan 1-22, 2020, 99 patients (men outnumbered women) were reported to be admitted in hospitals in Wuhan with 49 having travel history to seafood market [14]. Fifty patients had comorbidities. Forty seven patients had long term exposure to market

while 2 had short term exposure. By January 25, 31 patients were discharged after treatment while 11 had died. It was observed that men are affected more easily than women. This could be due to the protective role of X chromosome and the sex hormones which strengthen women's immune system [15]. So, it was hypothesized that SARS-CoV-2 had more chances of infecting older men with chronic comorbidities as they have weaker immune system [16, 17]. Further, 835 confirmed cases were reported by January 24, 2020 in Wuhan of which 25 died [18] and by Jan 26, 2020, 62 more patients (19-65 years) were admitted in Zhejiang province, China and none of them were had visited seafood market in Wuhan [19]. All these observations implied at a rapid spread of COVID-19 through human-to-human transmission in initial phase.

Some more reports of COVID-19 confirmed cases were reported from Wuhan [20, 21] and Beijing [22] in late January to early February, 2020. By January 28, 2020 there were more than 5900 confirmed cases of COVID-19 and more than 9000 were suspected across 33 provinces in China [20]. By February 4, 2020 approximately 20,471 confirmed cases of COVID-19 and 425 deaths had been reported by National Health Commission of China [23]. The Chinese Center for Disease Control and Prevention, Beijing, China [24] reported 42,672 confirmed cases of SARS-CoV-2 till February 11, 2020 from mainland China. The age ranges of the majority of confirmed cases were 30-79 years and were reported from Hubei province with 1023 deaths. By February 11, 2020, 1386 counties in 31 provinces were affected due to SARS-CoV-2. Along with the patients, 1716 medical workers were also infected, 5 of whom died.

### 3.2. Cluster spread

SARS-CoV-2 has shown that it can spread in clusters. In an article by Chan et al. [25], it was reported that on Jan 10, 2020, five (age: 36-66 years) of the six persons of a family from Shenzhen, Guangdong province, China, showed unexplained symptoms of pneumonia after their visit to Wuhan. Later, one more family member, who had not visited Wuhan, became infected after several days of contact with the infected persons. None of these members visited seafood market in Wuhan but they visited hospital in Wuhan. From this incident, it was hypothesized that the virus is capable of human-to-human transmission by merely coming in contact with the infected person. The incubation period for SARS-CoV-2 was 3-6 days and showed cluster spread of the disease. In another case of cluster spread, 355 of the 3711 people on board the Diamond Princess cruise ship were found COVID-19 positive between January 10, 2020 and Feb 16, 2020 [11]. Thus, COVID-19 can attain the capability of super spreading due to such cluster cases which may prove perilous.

### 3.3. Comparison of epidemiology of SARS-CoV-2 with SARS and MERS

In two initial studies in Shanghai, China and Germany it was observed that the COVID-19 was infectious during the incubation period [26, 27]. This revelation was very precarious as it would make the identification of the infected extremely difficult in early stages. In the absence of identification, there would remain a constant threat of the exponential spread of the disease. Thus, unlike SARS and MERS which were infectious only during the symptomatic period, SARS-CoV-2 is infectious even during the incubation and asymptomatic period [28, 29]. Also, while SARS and MERS infected the intrapulmonary epithelial cells more than the cells in the upper respiratory tract [30, 31]. SARS-CoV-2 is capable of infecting even the upper respiratory tract [29] making it easier to spread through nasal droplets [26]. Hence, SARS-CoV-2 is more infectious and dangerous than SARS and MERS and has full potential to spread infection during incubation and asymptomatic period from person-to-person through close contact. The incubation period and reproduction number of SARS-CoV-2 from different regions and different studies has been summarized in Table 1.

**Table 1.** Incubation period and reproduction number ( $R_0$ ) of SARS-CoV-2 in different regions of world.

S. No.	Country	Incubation period (in days)	Mean $R_0$	Reference
1	China	5.2	4.08	[21]
2	Korea (26 patients)	3.9	0.48	[7]
3	Wuhan, China (425 patients)	5.2 (Doubling time: 7.4)	2.2	[5]
4	Wuhan, Hubei province, China	8 (Range: 2-14)	2.6-4.71	[6]
5	Wuhan, China (138 patients)	-	2.2	[32]
6	Wuhan, China (7 pregnant women)	5.5 (Range: 2-9)	-	[26]
7	Diamond Princess cruise ship (355 patients)	5.2	2.28	[11]
8	Zhejiang province, China (62 patients)	4	-	[19]
9	Shenzhen, Guangdong province, China (6 patients)	4.5 (Range: 3-6)	-	[25]
10	Mainland China (1099 patients)	4.5 (Range: 2-7)	-	[33]
11	Outside China	-	2.2 to 3.3	[34]
12	China, Outside Wuhan (88 patients)	6.4	-	[35]
13	Global	5.5	-	[36]
14	Global	Doubling time: 6.4 days	2.68	[37]
15	Global	8 (Range: 2-14)	1.4-6.49	[38]
16	Global	8.5 (Range: 3-14)	2-2.8	[12]
17	Europe (38 patients)	7.5 (Up to 14 days)	-	[39]
	Mean	5.85	2.96	

\* $R_0$  refers to reproduction time i.e. the number of healthy persons infected by an infected person; if  $R_0 \geq 5$ , it is known as 'super spreading'.

### 3.4. Causes of spread of COVID-19

Apart from its ability to be infectious during asymptomatic period, there was another reason for the rapid spread of SARS-CovV-2. Generally, in late January or early February, every year, the Chinese people celebrate their new year. In late January, 2020, a large number of people were returning to their respective cities after a visit to Wuhan to celebrate Chinese lunar New Year. During this time of the year there was mass movement of people all over the world. So, it was expected that there would be more cases of COVID-19 in China and worldwide [19]. Further, the virus has the capability of surviving in various environmental conditions, thus making it even more dangerous for transmission. For example, it can tolerate pH in the range of 3-10 at room temperature, it is very stable at 4°C (i.e. in refrigerators) but can't tolerate temperatures beyond 70°C. The virus does not remain infective after remaining on printing and tissue papers for some time but it is more stable on smooth surfaces. Since, the virus can survive outside the host for quite some time, it poses a significant hazard of transmission through contact. However, the good thing is that it is susceptible to standard methods of disinfection, if followed rigorously [40].

### 3.5. Recurrence of COVID-19

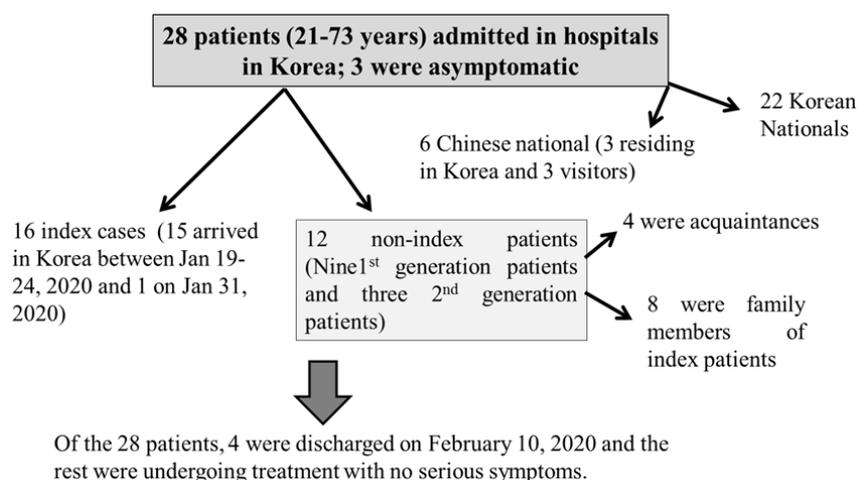
Strict social distancing measures were taken by government in China after the initial outbreak in Dec. 2019-Jan. 2020. This helped in reducing the number of cases in China during February-March, 2020 and the situation was still the same as of in April, 2020. The epidemiologist fear that as there is no herd immunity in China, there are chances that the COVID-19 cases might surge as soon as the social distancing measures are withdrawn and businesses and other essential sectors resume work [41]. Thus, the situation is very critical.

The same may be said for other countries of the world as majority of them are currently facing first-wave of COVID-19.

### 3.6. Epidemiology of COVID-19 in Asian countries (Outside China)

As the world was struggling to understand the SARS-CoV-2 which had infected thousands of people in China and had spread to many regions in China, soon it was reported that there were positive cases of COVID-19 in other countries as well. COVID-19 initially spread to other Asian countries outside China. The cases were reported from countries like Thailand, Japan, South Korea, Malaysia and Singapore [20]. On January 13, 2020 the first positive case of SARS-CoV-2, outside China, was reported from Thailand. The patient did not have any history of visiting seafood wholesale market in Huanan, China. Further, on January 15 and January 20, 2020, the first positive cases were reported from Japan and Korea respectively [42].

A report by Ki et al. [7] mentioned about 28 patients in Korea, between January 20, 2020 and February 10, 2020 (Figure 2). The patients were exposed to some areas in Korea before they were diagnosed and isolated. The epidemiological characteristics of the disease were considered to be similar to severe acute respiratory syndrome (SARS) and Middle-East respiratory syndrome (MERS).



**Figure 2.** A case of COVID-19 spread in Korea [7].

A curious case was reported from Vietnam where a 65 year old man and his wife returned from Wuchang district of Wuhan, China to Hanoi, Vietnam. The man had history of medical conditions like hypertension, type 2 diabetes, lung cancer and coronary heart disease. He became ill after 4 days of his return from Wuchang i.e. on January 17, 2020. This was the time when cases of COVID-19 were being reported from Wuhan. He was admitted in hospital due to low grade fever and fatigue on January 22, 2020. He confirmed that he did not visit sea food market in Wuhan. After his treatment, his fever disappeared by January 25, 2020. Surprisingly his wife had no symptoms of the infection and she was perfectly alright till January 28, 2020. Further, his 27 year old son, who had not travelled to any region having COVID-19 or came in contact with any person having the infection, met him on January 17 and shared a bedroom with his parents for three days in a hotel room which had air conditioner. On January 20, son also reported dry cough and fever and was tested positive for SARS-CoV-2. The son might have contracted the infection from the father but the report said that the report is awaited to confirm if both the strains of virus are the same. The family had travelled to four cities in Vietnam using various modes of transport like planes, trains and taxis. They came in close contact with 28 people, however, none of them had symptoms of upper respiratory tract infection [43].

This case showed different incubation periods for the virus: 3 days for the son while 10 days for the mother. It again raises question over the infectivity of the virus. It has been believed since long that people with strong immune system are less prone to get infected than people with weak immune system. In this case, either the son did not have strong immune system as compared to his mother (which could be possible due to many factors like environment, diet, physical activity etc.) or certain factors like sex could have protective role against the virus or the son might have been infected with a more virulent strain of the virus. Studies are needed to further look into the way SARS-CoV-2 infects and its pathogenicity.

On March 12, 2020, Pongpirul et al. [44] described the first case of a taxi driver infected with the disease in Thailand. The taxi driver was 51 year old. On January 20, 2020 he experienced fever, cough and myalgia. He took some medicine from the local shops as at that time there were no reported cases of SARS-CoV-2 in Thailand. However, the symptoms persisted. On January 23, 2020 he visited a private clinic and he was given more medicines and sent off home. From January 24-27, 2020, he was not able to drive the taxi. On January 28, 2020 when he visited public hospital, he was identified as PUI and isolated. Later after tests, he was found positive for SARS-CoV-2. He disclosed that he had hypertension and type 2 diabetes. Further, he also revealed that he was in close contact with Chinese tourist passengers who had cough and were wearing mask. He had no history of travel to China. He lived with his family in the same house and all of the family members tested negative for SARS-CoV-2. Thus, there was no human-to-human transmission of the virus in spite all of the family members living in close contact with the taxi driver for 8 days, a long enough period for the transmission during the symptomatic period. This is again a curious case, as the taxi driver got infected very easily just by ferrying the passengers while his family members did not get infected even after remaining in close contact with him.

Taiwan has around 3 million Taiwanese people who work in China and out of them 2000 work in Wuhan. So there is a high risk of the infection being transferred from China to Taiwan. By January 29, 2020 there were 7 positive cases imported from China. Out of these 7 cases, one woman got infected in a return flight from China to Taiwan and also infected her husband who did not visit Wuhan or came in contact with any other person having COVID-19 [45].

### 3.7. Epidemiology in Europe

The COVID-19 cases started from Wuhan, China in Dec. 2019 and reached Europe in mid-January, 2020. The first case of SARS-CoV-2 was reported from France. The first of the five patients in France, was diagnosed with SARS-CoV-2 infection on January 24, 2020 [39]. Five patients, all of Chinese origin, were admitted to two different hospitals in Paris, France. The patients included 3 men (age: 31, 48 and 80 years) and 2 women (age: 30 and 40 years). All of them had travelled from China to France around mid January, 2020. The 80 year old patient died on Feb. 14, 2020 of illness while all other patients recovered and were discharged from hospital by Feb 19, 2020 [36].

In Munich, Germany, on Jan 24, 2020 there was a case of human to human transmission from a Chinese business partner to a 33 year old German businessman as they attended the same meetings on Jan 21 and 22, 2020. During her stay in Germany, from Jan 19-22, 2020, the Chinese business partner was asymptomatic but showed symptoms in the flight and was tested positive on Jan 26, 2020 in China. The German businessman had no travel history in the past 14 days. On Jan 28, 2020, three more persons in his office tested positive for SARS-CoV-2. Of the three infected only one had a direct contact with index patient. This incidence is another example of human-to-human transmission of the disease [27].

By Feb. 21, 2020, there were 47 confirmed cases of COVID-19 in the European Region i.e. France (12 positive cases), Germany (16 cases), Belgium (1), Finland (1), Italy (3), Spain (2), Russia (2), Sweden (1) and UK (9) [39]. By March 6, 2020, there were 5,544 COVID-19 cases and 159 deaths in EU and UK [34]. Of all the European countries, Italy was the worst affected. By March 11, 2020, Italy had 12,462 confirmed cases of COVID-19 and 827 deaths, only second after China in mortality and the increase in the COVID-19 cases showed an exponential curve [46]. A large number of people affected by SARS-CoV-2 were asymptomatic but were infectious. On March 19, 2020, there were 427 deaths in 24 hours in Italy alone. By March 23, 2020, the number of deaths reported from Italy rose to 3405 which exceeded 3245 from China. Thus, Italy became the worst COVID-19 affected country in the world [47]. The spread of COVID-19 in the EU and UK has been very rapid from February 21, 2020 to April 19, 2020 and so have the deaths increased [48] (Figure 3).

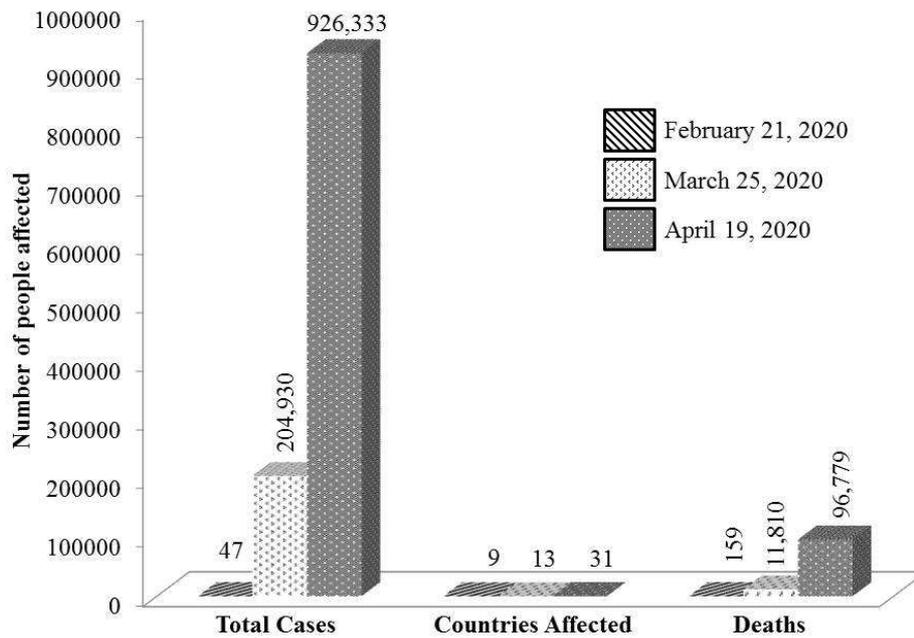


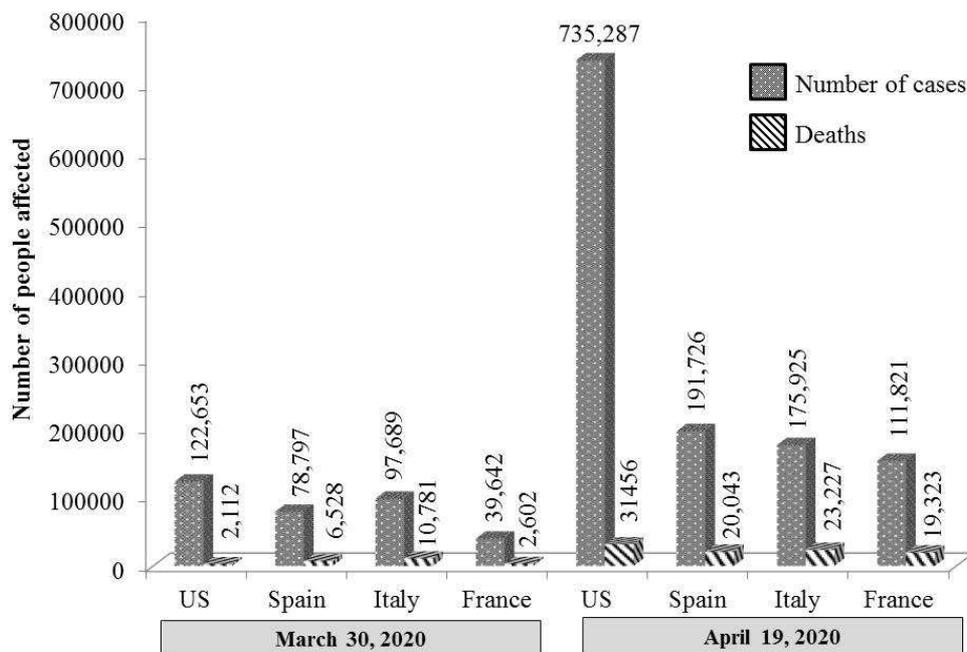
Figure 3. Status of COVID-19 in EU/UK from February 21, 2020 to April 19, 2020 (numbers shown above the bars) [48].

### 3.8. Epidemiology of COVID-19 in United States

The threat of COVID-19 spread globally and the governments became vigilant for the people who traveled to other countries. The Chinese health authorities had confirmed about the relationship between unexplained pneumonia like symptoms in Chinese people with SARS-CoV-2 on January 7, 2020. On January 20, 2020 the state and local health departments in United States and Centers for Disease Control and Prevention (CDC), started identification and monitoring of all the persons who came in close contact with SARS-CoV-2 positive cases [49]. The first positive case of SARS-CoV-2 infection from United States was reported on January 20, 2020. The patient was a 35 year old man who had a four day history of cough and fever and approached a clinic in Snohomish County, Washington on January 19, 2020. He reported that he travelled to Wuhan, China and returned to Washington State on January 15, 2020. The patient decided to report for a check-up after he developed some symptoms as he had seen alerts from US CDC about the coronavirus outbreak in China. The patient was an otherwise healthy person apart from a history of hypertriglyceridemia. Due to the travel history of patient, the local and state health departments were

immediately notified. The patient received due treatment in an isolated ward. The patient remained hospitalized by January 30, 2020 and all his symptoms vanished except cough [50].

The U.S. Department of Health and Human Services (HHS) declared SARS-CoV-2 as the U.S Public Health emergency on January 31, 2020. Aggressive measures were taken by CDC, many federal agencies, state and local health departments and other organizations to slow down the transmission of the virus [8]. By January 31, 2020, there were 650 persons under investigation (PUI) for SARS-CoV-2. As per CDC criteria, 210 symptomatic persons were tested for the virus, out of which 148 (70%) had travel related risk of contracting infection, 42 had close contact with either PUIs or ill laboratory confirmed patients and 18 (9%) had travel or contact related risks. The health departments issued guidelines that it was very crucial to identify people who had a travel history to the affected region or came in close contact with COVID-19 suspected [51]. By February 4, among 210 PUIs, 11 were found positive for SARS-CoV-2 [8, 50]. Thus, in U.S., the epidemiologic risk factors for SARS-CoV-2 did not only include travel to Wuhan, China but also close contact with a positively infected person or a person who was being evaluated for SARS-CoV-2. By Feb 6, 2020, there were total 61 cases in U.S. [48]. By March 30, 2020, U.S became the country with the most number of COVID-19 cases with a brisk increase in the number of cases as compared to European countries from March 30, 2020 to April 19, 2020 [10, 52] (Figure 4).



**Figure 4.** Status of COVID-19 in U.S. and some worst affected countries of EU between March 30, 2020 and April 19, 2020 (numbers shown above the bars) [10, 23].

#### 4. CONCLUSION

COVID-19 caused by SARS-CoV-2, originated in Wuhan, China and has now become the pandemic. The origin of the disease is yet not known. By the time we could assess the potential pathogenicity of the virus, the infection had already spread far and wide. China had to take extremely difficult steps of quarantine and isolation to contain the virus. However, the disease spread to several countries through human-to-human transmission including European countries, Asian countries, United States etc. Most of the countries, especially developing countries, did not have testing kits for the virus and the rate of its spread was extremely

quick, hence almost all the countries went into lock down for designated periods to contain the virus. By April 20, 2020, 185 countries had reported the cases of COVID-19 with U.S. reporting highest number of cases. In the mean-time, the medical fraternity which was directly dealing with the disease was under severe threat from the virus and in many countries, including Italy, many medical professionals also died due to SARS-CoV-2. Due to decline in the number of cases in China as a result of strict social distancing measures, the government is planning to lift curbs on certain sectors and resume work but epidemiologists warn of second-wave of COVID-19 while other countries still struggle with the first-wave of COVID-19.

**Conflict of Interest:** The author declares no conflicts of interest.

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