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Automated analysis of fatality rates for COVID 19 across different countries

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Abstract One of the significant parameters that helps in the reporting the highest risk areas, which have COVID 19 pandemic is case fatality rate (CFR). In this work, automated analysis was carried out to evaluate fatality rate (CFR) across different countries. Furthermore, a state of art algorithm is proposed to estimate CFR and it is possible to make it applicable in the mobile phone. This application will enable us to monitor the status level of the patients (suspected, exposed and infected) to save time, efforts and get a high quality of the recordings. All data were obtained from (https://www.worldometers.info/coronavirus/) and pointed at the period between 27th March and 27th May 2020. Results present Spain and Egypt have a highest score of the fatality rate (approximately 24%) compared with previous research, which Italy was the highest score of the case fatality rate (CFR). On the other hand, Australia has had the lowest of the (CFR) in the current and previous researches. Furthermore, Spain has the highest percentage score of the total active cases and death rate: 0.41% and 0.00073% respectively. Documentation and comparison fatality rate of COVID 19 pandemic across different countries could assist in illustrating the strength of this pandemic, speed spreading and risk area which infected of this disease.

1. Introduction

COVID-19, also known as the coronavirus disease 2019, is an infectious disease that transmitted from animal to human. The first case was discovered at Wuhan city, China, in December 2019 and spread worldwide to most countries. The first identified case was reported in December 2019 and since then it has spread rapidly. The virus causes a range of the symptoms, from fever, coughs, sore throats, headaches with difficulty in breathing and sometimes death more severe cases [1,2]. COVID-19 spreads by droplets of saliva from the nose and mouth of an infected person to healthy contacts. Also contact with contaminated hard surfaces could transmitted the infection as the virus will survive up to 4–5 days on hard objects. If a person, who is infected with the coronavirus, comes into close contact with another person, it is likely that that person will become infected. Furthermore, droplets of saliva that are ejected out of the mouth and the nose when sneezing or coughing. It may contain the virus, and will allow the virus to spread if it lands on surfaces where it could stay for up to five days[3–6].

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Despite continues efforts by many nations, the fatality rate for COVID-19 is still souring as the virus spread through air born and airdropped. However, banning large crowds and practicing social-distancing are able to slow its spread and avoid exposure to higher viral load. Quarantine could reduce the incidence rate of COVID-19 and lower the fatality rate [7–9].

Fatality rate is a metric, which has been used to evaluate the COVID-19 effects on human by measuring the ratio between the total number of dead to total number of closed cases (the number of dead patients with the number of recovered patients) [10–12]. In order to report a realistic worldwide fatality rate, many problems were addressed. Firstly, the lack of necessary laboratory test for all COVID-19 patients. Secondly, the hesitance of some COVID-19 patients to report their illness to the hospital. There are many problems in obtaining the honest real values of the fatality rate. This is due to the lack of the capabilities to carry out the necessary laboratory tests for all people who’s have virus symptoms to detect the virus and sometimes hesitation of patients to go hospital when they feel virus symptoms.

Many researches have been concerned with calculating or estimating the fatality rate because coronavirus has become a global pandemic and its importance in analysis of virus impact. In the first article, predicting mortality rate has been performed based on using machine learning tool [13] and deep learning [14]. This gives an efficient procedure in identifying mortality rate shortly and accurately.

Construction a mathematical model to represent lockdown of COVID-19 has been introduced and applied [15]. This model illustrates three types of quarantine. Optimization of this model based on the analysis of all conditions, which impact on the spreading and could reduce the number of the infected people. Moreover, a real time mathematical model has been carried out to detect fatality rate of severe cases of COVID-19 [16]. It is very powerful to involve this algorithm, but in the same time it has a kind of complexity to make it applicable for all people. The rapid increase in the number of COVID-19 cases adversely affects the quality of the healthcare services, which provided by hospitals. Therefore, presenting an early plan to assess patient’s stage of COVID-19 could support in decreasing the pressure on other healthcare services and help to decide patient priorities.

In this research, we conducted a study to calculate the fatality rate for the period between 27th March and 27th May 2020 across different countries (USA, Spain, Italy, Iraq, Iran, Uzbekistan, Egypt and Australia) based on the data which were collected from [17]. In addition, in this work a novel and flexible algorithm has been proposed and it is likely to be applicable on the mobile phone for everyone to improve the performance of the fatality rate calculation and obtain more accurate statistics.

This paper comprises four sections. Firstly, complete the rest of the Section 1. Secondly in the Section 2 presents material and methods. Discussions and results are illustrated in the Section 3, while the fourth section introduces conclusions and future works.

1.1. Case fatality rate (CFR)

A patient with symptoms similar to COVID-19 is suspected patient, however; a patient is still exposed to infected even though the results of the laboratory tests are reported negative. In this case a patient is considered to be exposed to infection until proven to be recovered or infected after 14 days based on the World Health Organization (WHO) report. Therefore, either discharged a patient from hospital or consider as infected patient, this is basically depends on the symptoms at period between (1–14) days. Infected patients could be recovered and discharges or died due to severe complication of COVID-19, see Fig. 1.

To know if a person is infected with coronavirus or not, they get tested. There two types of tests for COVID-19 are viral tests and antibody tests. A viral test denotes if you have a current infection, where an antibody test indicates if you had a previous infection. Only people that have shown known symptoms of coronavirus should be tested, since, worldwide, there is a scarcity of COVID-19 tests. This has a large impact on the number of the cases and the number of the deaths. For example, in Iraq and Egypt, there is a significant shortage of tests, and therefore there may be people infected with COVID-19 but still not have been tested. Equation (1) has been utilized to determine case fatality Rate (CFR) [18–21].

\[
CFR(\%) = \frac{ND}{NCC} \times 100
\]

where ND is a number of deaths due to COVID-19 and NCC is a number of closed cases of COVID-19. The number of the closed cases is the sum of the number of the death number and the number of recovered patients, see Fig. 2. This figure reflects a brief description of the COVID-19 virus journey developing across time. There are four stages a patient may go through: (suspected, exposed, infected and dead). The first stage presents a patient who may suffer from symptoms that could be a corona virus symptom or not, or patient has not any symptoms, but he or she in contact with the confirmed person with the virus. In the second stage, patient is still exposed to the infection, but if a patient has severe symptoms with proof, patient could be infected. Infected confirmed patient may be recovered or died depends of the level of virus load and immunity of the body. Fatality rate is related with number of recovered and dead patients.

If we examine the fatality rate for the coronavirus in different countries, for example, USA, Spain and Italy, some of the greatly affected countries, we can see that these countries, despite their advanced healthcare systems that they have established, have a much higher fatality rate in comparison to some poorer countries, for example Iraq, Egypt and Sudan that do not have very progressive health systems, but regardless of that, have lower deaths.

Fig. 1 Illustrate three types of patients across corona virus.
2. Material and method

2.1. Source of data

The data were obtained from accurate databases including Worldometer [17]. It was collected form a set of countries across different continents (USA, Spain, Italy, Iraq, Iran, Uzbekistan, Egypt and Australia) at the period between 27th March and 27th May 2020. The main reason is to observer the impact and spreading of the COVID-19 at different regions.

Moreover, the values of the fatality rate of COVID-19 can be vary considerably across different places. The purpose of the comparison is to estimate possible effects of the demographic characteristics of population and ethnic origin on the epidemic outcomes. This data includes population, total daily active cases, total daily of dead infected patients and total daily recovered patient from COVID-19.

2.2. Automated evaluation of daily fatality rate

Case fatality rate (CFR) was evaluated using Eq. (1) for a set of countries across different continents in two months. Furthermore, a state of art algorithm has been proposed to determine daily CFR.

Algorithm. An algorithm is introduced to show the sequence of the instructions to evaluate case fatality rate (CFR). This algorithm consists of a set of variables which are defined below:

\[ X_{\text{ij}} : \text{patient} \quad (i = 1,2, \ldots, m, j = 1,2, \ldots, n) \], when \( n \) is a number of patients during a day and \( m \) is a number of days

\( X_{\text{Si,j}} : \text{Suspected patient} \)

\( X_{\text{Ei,j}} : \text{Exposed patient} \)

\( X_{\text{Fi,j}} : \text{Infected patient} \)

\( X_{\text{Di,j}} : \text{Dead patient} \)

\( \text{CFR}_{\text{ij}} : \text{Fatality rate} \)

\( k_1 \) and \( k_2 \) are number of recovered and dead patients respectively

1. Start
2. Start a new day
3. \( i = 0, k_1 = 0, k_2 = 0, j = j + 1 \)
4. Charge patient \( (X_{\text{ij}}) \) into hospital
5. \( i = i + 1 \)
6. If \( X_{\text{ij}} \) suffer symptoms similar to COVID-19 then \( X_{\text{ij}} \) is \( X_{\text{Si,j}} \) and patient should do the required laboratory tests.
7. If laboratory tests are positive then \( X_{\text{Si,j}} \) will be \( X_{\text{Fi,j}} \) and go to step 9. In the case of these tests are negative then \( X_{\text{Si,j}} \) will be \( X_{\text{Ei,j}} \), then stay \((1–14)\) under quarantine
8. If \( X_{\text{Ei}} \) still has negative laboratory test after 14 days of suspecting with COVID-19 then go to step 9, but in the case \( X_{\text{Ei}} \) has series symptoms and laboratory tests read positive then \( X_{\text{Ei}} \) will be \( X_{\text{Fi,j}} \)
9. If \( X_{\text{Fi,j}} \) recovered then \( k_1 = k_1 + 1 \), but when \( X_{\text{Fi,j}} \) died, a patient will be \( X_{\text{Di,j}} \) and \( k_2 = k_2 + 1 \)
10. Discharge patient
11. go to step 4
12. Evaluation of daily Fatality rate \( (\text{CFR}_{\text{ij}}) \) using equation(1)
13. At the end of the day go to step 3

3. Discussion and results

The fatality rate values depend on the accumulation the number of the dead patients and the total number of closed cases. The most significant factor in this equation is the strength of the health system to provide a standard health care to a large number of COVID-19 patients. People awareness about viral spread and their commitment to health authority advice to prevent that is the major factor in limiting the spread of the disease. For example, through these two months (27th March to 27th May) there are countries that do not have a developed health system such as Iraq which was recorded lower values of fatality rates than developed countries. However, through the time, while adhering to the World Health Organization (WHO) instructions in these countries, the virus can gradually fade, despite the difference in its variation strength of the virus. Therefore, adherence to safety rules which are mentioned above is the primary driver that fights COVID19. In addition, we do not forget the availability of adequate health services is essential to reduce the high percentage of the deceased patients.

In this work, case fatality rate (CFR) has been evaluated and reported in the Fig. 3, which demonstrates evaluation across different 8 countries. Fig. 4 demonstrates the disparity of the fatality rate across different countries (evaluation of standard deviation). On the other hand, the mean values of the CFR are illustrated in the Fig. 5. Spain and Egypt scored the highest on the fatality rate approximately 24%, while the lowest score was 0.6% for Uzbekistan, Iraq was 5% and Australia 7%. In the previus reserches [18,22,23] the highest fatality rate was in Italy. However, in the our research the statistical analysis are evaluated across course of two months (27th March to 27th May), the world highest CFR rate is in Spain, Egypt and Spain have approximatively the same score. On the other hand, Australia, in the current and previous reserch still has the lowest score of the death and fatality rate. Iraq, Uzbekistan and Iran come from the same continet, meaning that there is similarity in ethnic origins. Therefore, they are grouped togerther in the same figure to observe the difference in the fatality rate. In this research Iraq and Uzbekistan approximately have the close score of the fatality rate, see Fig. 6. At the same reason, European countries are grouped in the Fig. 7.

The low incidence of the deaths recorded in the epidemic may be due to insufficient testing and the presence of different copies of the virus [24–27]. Furthermore, evaluation total active cases of COVID19 at the period (27th March –27th May) across different countries are illustrated in the Table 1.

The percentage of the death of introduced countries (USA, Spain, Italy, Iraq, Iran, Uzbekistan, Australia and Egypt) to its population are illustrated in the Table 2. Obviously, during these two months, Spain has the highest death rate compared to other countries in the list of the Table 2. On the other hand, Uzbekistan has the lowest score, it is \( 0.007*10^{-5}\% \).

During these two months, Spain, USA and Italy have the highest percentage of infected of COVID19 patients, while Australia and Iraq have the lowest score. The low percentage in Australia and Iraq compared with other countries could be due to people adhere to the appropriate prevention rules or the virus was on the early stage. Where it is possible to answer of this during the next days after two months. The first
**Fig. 2** Shows the pipeline of evaluation of fatality rate of coronavirus.

**Fig. 3** Illustrates evaluations of fatality rates (CFR) across 8 different countries.

**Fig. 4** Presents evaluations of standard deviation of fatality rates (CFR) values across different countries at two months.

**Fig. 5** Shows mean values of fatality rates (CFR) across different countries through two months.

**Fig. 6** Comparison of fatality rates (CFR) values of Spain and Italy across course of two months (27th March to 27th May).

**Fig. 7** Shows different values of fatality rates (CFR) across three countries (Iraq, Uzbekistan and Iran) through two months.

**Table 1** Shows total active cases to the population across different countries.

| Region      | Total active cases | Population       | Percentage  |
|-------------|--------------------|------------------|-------------|
| USA         | 1,304,073          | 331,002,651      | 0.394%      |
| Spain       | 194,524            | 46,754,778       | 0.416%      |
| Italy       | 179,705            | 60,461,826       | 0.297%      |
| Iraq        | 4,662              | 40,222,493       | 0.0115%     |
| Iran        | 111,531            | 83,992,949       | 0.132%      |
| Uzbekistan  | 3,239              | 33,469,203       | 0.009%      |
| Australia   | 2,819              | 25,499,884       | 0.0110%     |
| Egypt       | 19,232             | 102,334,404      | 0.0187%     |
factor is the adherence of people to the basic rules of social separation in terms of the distance from one person to another, wearing masks and paws.

In this paper we also introduced an algorithm to perform more accurate calculations for fatality rate. This algorithm works to classify a patient to a suspect if he or she suffers from symptoms of the virus, but if the laboratory test appears positive, a patient is infected and if the appears negative, the patient remains exposed to infection for 14 days until it is proven that he is infected or cured. Based on the data which were collected at the period between 27th March and 27th May, there are some countries that do not have a developed health system, but have recorded lower casualties compared to developed countries.

In the case of the worsening of the symptoms of the virus, through this algorithm or application, the health monitoring body is contacted to take appropriate measures. Therefore, the main goal of this algorithm is to reduce the momentum on hospitals and shrink the rate of the infection, when the infected person goes to the hospital or health centre will be a carrier of the virus.

4. Conclusions

People's awareness of the virus's risk and pursuing proper prevention instructions can limit its spread. This is observed in the results in the previous section. Hospital capabilities to incubate and manage cases according to a well-thought-out protocol that influences the fatality rate reduction and virus control as well.

In this research, an algorithm proposed that can be programmed to be application in the mobile phone, through which information are collected by circulating it as an application using the mobile phone. The Patient Information Based Algorithm estimates the fatality rate of COVID19 in real-time to save time, efforts and get a high quality of the recordings.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table 2: Illustrates total death to the population across different countries.

| Region       | Total death | Population | Percentage |
|--------------|-------------|------------|------------|
| USA          | 1251.82     | 331,002,651| 37*10^-5%  |
| Spain        | 344.83      | 46,754,778 | 73*10^-5%  |
| Italy        | 390.177     | 60,461,826 | 64*10^-5%  |
| Iraq         | 2.209       | 40,222,493 | 0.5*10^-5% |
| Iran         | 84.822      | 83,992,949 | 10*10^-5%  |
| Uzbekistan   | 0.258       | 33,469,203 | 0.007*10^-5% |
| Australia    | 1.225       | 25,499,884 | 48*10^-6%  |
| Egypt        | 12.596      | 102,334,404| 1.23*10^-5%|

References

[1] Q. Li, X. Guan, P. Wu, X. Wang, L. Zhou, Y. Tong, et al, Early transmission dynamics in Wuhan, China, of novel Coronavirus-Infected Pneumonia, New Engl. J. Med. 382 (2020) 1199–1207, https://doi.org/10.1056/NEJMoa2001316.
[2] C. Huang et al, Clinical features of patients infected with 2019* novel coronavirus in Wuhan, China, Lancet 395 (2020) 497–506.
[3] T.G. Ksiazek, D. Erdman, C.S. Goldsmith, et al, A novel coronavirus associated with severe acute respiratory syndrome, N. Engl. J. Med. 348 (2003) 1953–1966.
[4] N. Lee, D. Hui, A. Wu, et al, A major outbreak of severe acute respiratory syndrome in Hong Kong, N. Engl. J. Med. 348 (2003) 1986–1994.
[5] N. Chen, M. Zhou, X. Dong, J. Qu, F. Gong, Y. Han, Y. Qiu, J. Wang, Y. Liu, Y. Wei, J. Xia, T. Yu, X. Zhang, L. Zhang, Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study, Lancet 395 (2020) 507–513, https://doi.org/10.1016/S0140-6736(20)30211-7.
[6] Z. Xu et al, Pathological findings of COVID-19 associated with acute respiratory distress syndrome, Lancet Resp. Med. 8 (2020) 420–422.
[7] M. Chung, A. Bernheim, X. Mei, N. Zhang, M. Huang, X. Zeng, et al, CT Imaging Features of 2019 Novel Coronavirus (2019-nCoV), Radiology 295 (2020) 202–207.
[8] H.A. Rothan, S.N. Byrareddy, The epidemiology and pathogenesis of coronavirus disease (COVID-19) outbreak, J. Autoimmun. (2020).
[9] P. Wu, X. Hao, E.H.Y. Lau, J.Y. Wong, K.S.M. Leung, J.T. Wu, et al, Real-time tentative assessment of the epidemiological characteristics of novel coronavirus infections in Wuhan, China, as at 22 January 2020, Euro. Surveil. 25 (2020).
[10] A. Ghan, A. Donnelly, D. Cox, J. Griffin, C. Fraser, T. Lam, M. Ho, W. Chan, R. Anderson, J. Hedley, G. Leung, Methods for Estimating the Case Fatality Ratio for a Novel, Emerging Infectious Disease, Am. J. Epidemiol. 162 (5) (2005) 479–486.
[11] M. Iosa, S. Paolucci, G. Morone, Covid-19: A Dynamic Analysis of Fatality Risk in Italy, Front. Med. 7 (2020) 185, https://doi.org/10.3389/fmed.2020.00185.
[12] S. Ghisolfi, I. Almás, J. Sandefur, T. Carnap, J. Heitner and T. Bold, Predicted COVID-19 Fatality Rates Based on Age, Sex, Comorbidities, and Health System Capacity, CGD Working Paper 535.Washington, DC: Center for Global Development, 2020.
[13] L. Yan, H. Zhang, J. Goncalves, et al, An interpretable mortality prediction model for COVID-19 patients, Nat. Mach. Intell. 2 (2020) 283–288, https://doi.org/10.1038/s42256-020-0180-7.
[14] P. Arora, H. Kumar, B. Panigrahi, Prediction and analysis of COVID-19 positive cases using deep learning models: A descriptive case study of India, Chaos, Solitons Fractals (2020).
[15] D. Vega, Lockdown, one, two, none, or smart. Modelling containing covid-19 infection. A conceptual model, Sci. Total Environ. (2020) 730.
[16] L. Wang, Real-time estimation and prediction of mortality caused by COVID-19 with patient information-based algorithm, Sci. Total Environ. 727 (2020).
[17] https://www.worldometers.info/coronavirus/.
[18] M. Khafai, F. Rahim, Cross-Country comparison of case fatality rates of COVID-19/SARS-COV-2, Osong Public Health Res. Perspect. 11 (2) (2020) 74–80.
[19] R. Timothy, et al. Estimating the infection and case fatality ratio for coronavirus disease (COVID-19) using age-adjusted data from the outbreak on the Diamond Princess cruise ship, February 2020, Euro Surveil (2020) 25(12).
[20] R. Porcheddu, C. Serra, D. Kelvin, N. Kelvin, S. Rubino, Similarity in case fatality rates (CFR) of COVID-19/SARS-COV-2 in Italy and China, J. Infect. Dev. Ctries 14 (2) (2020) 125–128.

[21] K. Mizumoto, K. Kagaya, G. Chowell, Early epidemiological assessment of the transmission potential and virulence of coronavirus disease 2019 (COVID-19) in Wuhan City, China, January–February, 2020, BMC Medicine, 2020.

[22] G. Giangreco, Case fatality rate analysis of Italian COVID-19 outbreak, J. Med. Virol. (2020) 1–5, https://doi.org/10.1002/jmv.25894.

[23] A. Remuzzi, G. Remuzzi, COVID-19 and Italy: what next?, Lancet 395 (2020) 1225–1228, https://doi.org/10.1016/S0140-6736(20)30627-9.

[24] L. Lan, D. Xu, G. Ye, C. Xia, S. Wang, Y. Li, et al. Positive RT-PCR test results in patients recovered from COVID-19 [published online ahead of print February 27, 2020]. JAMA. https://doi.org/10.1001/jama.2020.2783.

[25] W.J. Guan, Z.Y. Ni, W.H. Liang, C.Q. Ou, J. X. He, et al., Clinical characteristics of coronavirus disease 2019 in China [published online ahead of print February 28, 2020]. N. Eng. J. Med. https://doi.org/10.1056/NEJMoa2002032.

[26] X.L. Md el al, Risk factors for severity and mortality in adult COVID-19 inpatients in Wuhan, J. Allergy Clin. Immunol. 146 (1) (2020).

[27] L.J. Carter, L.V. Garner, J.W. Smoot, Y. Li, Q. Zhou, C.J. Saveson, J.M. Sasso, A.C. Gregg, D.J. Soares, T.R. Beskid, S.R. Jervey, C. Liu, assay techniques and test development for COVID-19 diagnosis, ACS Cent. Sci. 6 (5) (2020) 591–605.