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Predictions of FluSurge 2.0 methodology on hospital utilization during the Covid-19 outbreaks in several countries

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Abstract

Application of the Flusurge 2.0 methodology to predict the needs of conventional hospital treatment, intensive care, and respiratory support resources as a consequence of coronavirus disease (COVID-19) in several countries. Different countries of the following continents have been selected: Europe, Asia, Africa, North America, South America, and Oceania. Variables: Total population and age distribution; Number of COVID19 infections; Number of deaths from COVID19; Number of non-ICU hospital beds; Number of ICU beds; Number of ventilators. Method: The proposed possible scenario planning is based on the application of FluSurge 2.0 Software, developed by The Johns Hopkins Center for Health Security (CHS/CDC). Saturation of conventional hospitalization is expected in India, Uganda, Nepal, and Haiti; there is a forecast of saturation for ICU beds in all sample countries except Turkey. Ventilator saturation is expected in all countries of the sample except Argentina, Austria, Brazil, France, United Kingdom, Japan, South Korea, Norway, Poland, Turkey and the USA. The model shows, for a percentage greater than 50% of the countries, difficulties related to the saturation of their ICU units, and the use of ventilators.

Keywords

Covid19, ICU beds, hospital beds, ventilators, saturation

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Background

On March 11, the WHO declared the global pandemic caused by COVID-19, which was first identified in December 2019 in Wuhan, China,[1] and advised health systems around the world to prepare for the effects of the virus on the care structures of the health services in the different countries. SARS-CoV-2 infection can develop coronavirus disease 2019 (COVID-19), which has resulted in high rates of hospitalization and intensive care unit (ICU) admission. At the end of December 2020, the official number of those affected in the world is more than 96 million, with more than 2 million deaths. This virus is now known to be especially lethal in those over 70 and worse for men than women.[2]

With the growth in the number of those affected by Covid-19 comes an increased concern for the possible saturation and collapse of the health system due to lack of hospital beds, ICU space or mechanical ventilators. The period of the resource shortage may vary from country to country, as this depends on the existing availability of healthcare resources and the actions implemented, as well as the moment of onset of the contagion and the observed transmission rate.[3]

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Resources such as hospital beds, intensive care units and ventilators are fundamental in the treatment of patients with serious diseases: for this reason, in the light of possible future outbreaks, it is of vital importance to be able to project the amount of beds and intensive care units required at the peak. Ajao et al.,[4] carried out a mathematical modeling and observed that the limiting factor in a pandemic crisis would be the number of respiratory ventilators.

The current emergency situation allows a reasonable estimation of foreseeable hospitalization and critical care needs at a national level. It should be noted that calculations performed at the time of publication may be re-evaluated according to the evolution of the pandemic in the near future and the real time knowledge acquired.

As it will take considerable time to fully understand the epidemiology of COVID-19, it is reasonable to make forecasts using a model that has been extensively studied for decades and that appears similar to COVID-19: pandemic influenza.

Various studies have evaluated hospital capacity in different countries. One of the main conclusions is that if no action is taken to expand the supply of beds or contain the virus, the rapid saturation of health systems is highly probable.[5–12]

The demand for hospitalization of COVID-19 patients is influenced by various factors such as age and preexisting conditions, with different effects on societies as the pandemic progresses. There are examples that have shown the importance of developing models for estimating resource requirements in the event of emerging epidemics. Sophisticated real-time models with simple models have traditionally been used to quickly check health decision guidelines. Mathematical models are proving instrumental in studying the current COVID-19 pandemic[13,14] as well as in driving governmental actions. A hallmark of the latter was the radical shift in the initial “herd immunity” strategy of the United Kingdom, as models produced by the Imperial College London projected a death toll of 500,000 in order to reach this scenario.[14] Substantial insights on the dynamics of disease spread can be gained by using compartmentalized models such as the 3-compartment SIR (susceptible-infected-recovered).[2,15,16]

There are examples that have shown the importance of developing models for estimating resource needs in emerging epidemics. Real time simulations with simple models rather than sophisticated models have been habitually used to quickly orientate decision making policies in healthcare matters.[17]

Another possibility would be to evaluate the hospital resource capacity during a pandemic using a standard model, which would offer a simple and immediate application. With the intention of providing a tool that allows this simple and rapid evaluation, following Burke, Centers for Disease Control and Prevention[18] developed a model to predict the behavior of the influenza pandemic and the response of critical hospital resources for recurrent influenza pandemics: FluSurge 2.0.

According to the census data and the estimate of hospital resources (hospital beds, ICU beds and mechanical ventilators) provided by the software user, FluSurge 2.0 calculates the number of hospital admissions and deaths for an influenza pandemic and compares the number of patients hospitalized, the patients requiring ICU and the number of patients requiring respiratory help during a pandemic and relates them to the existing hospital capacity. It is one of the most used software tools.[17] The Johns Hopkins Center for Health Security has recommended that all healthcare systems use the CDC model for influenza increase to better prepare for the coming influx of patients.[19]

Two other examples of software development that provide simple and accessible tools to simulate the behavior of an influenza pandemic and its impact on healthcare resource demand, in particular ICU beds and ventilators, are SimFlu, developed by Ahn et al.[20] and the AsiaFluCap Simulator by Stein et al.[21]

Using the time-series sequences of influenza A viruses, we developed a simulation tool for influenza virus, named SimFlu, to predict possible future variants of influenza viruses. SimFlu can create variants from a seed nucleotide sequence of influenza A virus using the codon variation parameters included in the SimFlu package. SimFlu supports three operating systems—Windows, Linux, and Mac OS X. SimFlu is publicly available at http://lcbb.snu.ac.kr/simflu.[20]

The AsiaFluCap Simulator is a combination of a resource model containing 28 health care resources and an epidemiological model. The tool was built in MS Excel© and contains a user-friendly interface which allows users to select mild or severe pandemic scenarios, change resource parameters and run simulations for one or multiple regions. Besides epidemiological estimations, the simulator provides indications on resource gaps or surpluses, and the impact of shortages on public health for each selected region. It allows for a comparative analysis of the effects of resource availability and consequences of different strategies of resource use, which can provide guidance on resource prioritizing and/or mobilization.[21]

The factors that influence the credibility of a simulation model are its capacity to adapt its operativity to a local level and the coherence of the results with the restrictions imposed by regional and state authorities.[22] It is for this reason, together with the recommendation of the John Hopkins Center, that we have decided to base the present work on the predictive capacity of FluSurge 2.0.

The objective of this study is to use the CDC methodology to predict the needs of conventional hospital treatment, intensive care and respiratory support resources that have been required as a consequence of coronavirus disease (COVID-19) in several countries belonging to Europe, Asia, Africa, North America, South America and Oceania, in order to verify its usefulness and suitableness on future occasions.

Material and methods

Different countries from the following continents have been selected: Asia (Mongolia, India, Japan, Nepal, South Korea and Turkey); Africa (Uganda and South Africa); Europe (Spain, Norway, Portugal, Italy, France, Austria, Sweden, Poland and the United Kingdom); North America (Canada and USA) and South America (Argentina, Brazil, Haiti and Mexico) and Oceania (Australia and New Zealand).

The criteria followed in selecting the countries have been to try to choose for each continent, at least one country with scarce resources and another with a greater supply of resources. With regard to European and North American countries, choose examples of countries with social security health systems and countries with National Health Systems.[23,24] The calculation of possible scenarios requires several initial assumptions about the characteristics of the pandemic. It should be noted that these assumptions cannot be based on the current moment, but are derived from the bibliography previously published and expounded in the text, which is very limited and susceptible to interpretation. To carry out the model, the following assumptions have been considered:

a) Total population and age distribution (0–14, 15–65, over 65 years)[25];
b) Number of COVID19 infections[25];
c) Number of deaths from COVID19[25];
d) Number of non-ICU hospital beds[25];
e) Number of ICU beds[3,26–33]
f) Number of ventilators[28–34]
g) Need for admission to hospital:

Hospitalizations occurred in 32% of cases reported from 26 countries; Severe illness (requiring ICU and/or respiratory support) accounted for the 2.4% cases reported from 16 countries.[35]

With the data accumulated so far in the European Union and the United Kingdom, among the confirmed cases, 30% of people with COVID-19 required admission.[35]

h) Need for admission to the ICU:

About 20% to 30% of SARS patients required admission to an intensive care unit (ICU), and most of them required mechanical ventilation.[36]

i) Average length of stay in the ICU due to COVID-19-related disease:

This has been estimated at 14 days based on the average of the case series published by Yang et al.[39]

j) Average length of hospital stay (not in the ICU) for COVID-19-related disease:

We propose 11 days, as this is the approximate median time referred by Guan et al.[40] for non-severe patients and, furthermore, is similar to the experience provided by Marín-Corral et al.[41] of 2,205 patients with influenza virus.

k) Average percentage of hospitalized patients requiring admission to Intensive Care Medicine: Around 71% of the patients required mechanical ventilation.[39]
l) Average percentage of hospitalized patients requiring invasive mechanical ventilation:

Between 20% and 30% of SARS patients required mechanical ventilation.[39]

m) Average duration of use of invasive mechanical ventilation:

The aggressiveness and precocity of the respiratory symptoms in the course of the disease and the high mortality in ventilated patients allow us to estimate an average duration of invasive ventilation very close to the ICU stay itself, as occurred in critically ill patients with influenza A, where the quartiles of time practically coincide in ICU stay and mechanical ventilation time.[37] It has therefore been maintained at 14 days.

n) Duration of the pandemic:

Estimates for 6, 8 and 12 weeks can be made with the software used. It should be borne in mind that the results for the for 12-week duration estimate suppose a longer estimate that reduces the concentration of cases in the period considered without altering the estimated absolute number of cases.

o) Average percentage of patients who die in the hospitalization setting:

Using modeling, the fatality among hospitalized cases has been estimated to be 14% (95% CI 3.9–32%).[38]

For a series in the Seattle Region (U.S.) the fatality rate for hospitalized patients has been 50%.[39]

However, a study conducted in New York, shows that almost all COVID19 ventilated patients have died in hospital.[40]

p) Daily percentage increase in the cases that arrive compared to the previous day:

This percentage has been calculated from the daily increase in COVID-19 contangions and the average percentage of hospital inpatients for each country of the sample. Severe illness was reported in 9.2% (3,567 of 38,960) of hospitalized cases from 19 countries (median, IQR: 15%, 3.8–35%); Death occurred in 1,005 of 9,368

(11%) hospitalized cases from 21 countries (median, IQR: 3.9%, 0–13%).[41]

The Johns Hopkins Center for Health Security (CHS / CDC) has published an article to propose guidelines to prepare for a COVID-19 pandemic, similar to those published in 2006 in relation to pandemic influenza.[42]

The proposed possible scenario planning is based on the application of FluSurge 2.0 Software, developed by the CDC. This is a model based on a free downloadable spreadsheet that allows a series of approximate calculations to be made of the increase in demand for hospital-based services during an influenza pandemic and which can be used to plan for both a moderate and serious pandemic situation. The tool allows modifying the population at risk, the available hospital resources and the assumptions of the epidemiological course of the pandemic process, resulting in a rough estimate of needs in this context: thus, it estimates the number of people hospitalized, the number of people requiring care in the ICU, the number of people requiring mechanical ventilation and the degree of saturation of the services available to attend them. FluSurge 2.0 has been specifically designed to assess the possible effect of a pandemic caused by influenza virus and validated only in this area.

FluSurge 2.0 is used to calculate the percentage of hospital capacity needed, demand on hospital-based resources such as hospital beds, ventilators, ICU capabilities, and potential health outcomes (e.g. morbidity and mortality rates). FluSurge 2.0 requires a list of inputs and primary data. Users are asked to provide estimates of their local population in 3 age groups (0–19, 20–64, and 65+ years). Population in FluSurge is divided into three age groups: school-aged children, working adults, and retirees, (0–19 years, 20–64 years, and 65+ years).

Once the primary data section is complete the user is then instructed to determine pandemic duration (duration refers to the number of weeks users assume the pandemic wave to last) of 6, 8, or 12 weeks, and pandemic attack rate (attack rate refers to the percentage of the population that becomes clinically ill due to a pandemic) of either 15, 25, or 35%. FluSurge then calculates the data and provides estimates of hospital admissions and hospital (non-ICU), ICU, and ventilator capacity needed over the course of the pandemic (by week). FluSurge is also used to estimate the number of hospital admissions and deaths due to a pandemic. Hospital admissions can be estimated for 3 different pandemic impact scenarios: minimum or the best-case scenario (fewest possible number of hospital admissions); mean or the most likely scenario (number of hospital admissions most likely to occur); and maximum or the worst-case (1918-type) scenario (largest number of hospital admissions).[43]

Its application for a pandemic due to the COVID-19 virus must be carefully evaluated in relation to two facts: a) the impossibility of real time validation; b) the introduction of the necessary data for its application being based on a bibliographic review, still insufficient and, in some cases in the absence of sufficient information, based on approximations.

Table 1. Hospital non-ICU beds, ICU beds and ventilators per 1,000 inhabitants.

Country	Hospital non-ICUbeds/ 1000 inhabitants	ICU beds/ 1000 inhabitants	Ventilators/ 1000 inhabitants
Argentina	2.01	0.19	0.13
Australia	3.84	0.09	0.28
Austria	7.37	0.22	0.28
Brazil	1.96	0.17	0.25
Canada	2.50	0.12	0.13
France	5.98	0.12	0.14
Haiti	0.70	0.01	0.01
India	0.53	0.02	0.03
Italy	3.18	0.13	0.09
Japan	13.05	0.05	0.26
Korea, Republic of	12.27	0.10	0.19
Mexico	1.38	0.01	0.02
Mongolia	6.88	0.12	0.06
Nepal	0.10	0.01	0.01
New Zealand	2.71	0.03	0.11
Norway	3.60	0.08	0.15
Poland	6.62	0.07	0.27
Portugal	3.32	0.04	0.14
South Africa	1.77	0.07	0.03
Spain	2.03	0.05	0.05
Sweden	2.22	0.06	0.06
Turkey	2.81	0.47	0.21
Uganda	0.09	0.004	0.002
United Kingdom	2.54	0.06	0.08
United States	2.77	0.29	0.21

Results

Table 1 shows the distribution of hospital resources (non-ICU hospital beds; ICU beds and ventilators) per 1,000 inhabitants, for the different countries selected for this study.

The results of the simulation study show the expected demand for hospital beds, ICU beds, and non-ICU ventilators. In India, the saturation of the conventional resource of hospital beds appears in the 5th week with 120% of utilization and the saturation peak of 160% is reached in the 7th and 8th weeks, with this peak being brought under control in the 10th week. In Uganda the respective figures would be 125% of hospital occupancy observed in the 2nd week, with a peak of 725% in the 7th and 8th week and the saturation not exceeding this in the rest of the following 12 weeks. In the case of Nepal, the model calculates a saturation in the 2nd week with an occupation of 137% and a peak of 707% in the 7th week and without saturation for subsequent weeks. In Haiti, resources were saturated in the 7th and 8th weeks with

Table 2. Predicted saturation of ICU beds and ventilators.

Country	1st week ICU bed saturation	Week peak ICU bed occupancy	Week overcoming ICU bed saturation	1st week ventilator saturation	Week peak ventilator saturation week	Week overcoming ventilator saturation
Argentina	5 (131%)	7 (180%)	11 (90%)	N	N	N
Australia	3 (126%)	7 (344%)	N	4 (142%)	7 (252%)	12 (84%)
Austria	5 (120%)	7 (163%)	11 (83%)	N	N	N
Brazil	5 (122%)	7 (161%)	11 (85%)	N	N	N
Canada	3 (103%)	7 (286%)	12 (94%)	7 (105%)	7 (105%)	9 (94%)
France	4 (139%)	7 (255%)	12 (81%)	N	N	N
Haiti	2 (336%)	7 (2109%)	N	2 (259%)	7 (1627%)	N
India	2 (185%)	7 (1233%)	N	3 (129%)	7 (391%)	N
Italy	4 (140%)	7 (251%)	12 (82%)	5 (113%)	7 (151%)	11 (79%)
Japan	2 (137%)	7 (844%)	N	N	N	N
Mexico	2 (323%)	7 (2001%)	N	2 (101%)	7 (625%)	N
Mongolia	4 (110%)	7 (194%)	12 (66%)	5 (126%)	7 (164%)	11 (88%)
Nepal	2 (333%)	7 (1998%)	N	2 (290%)	7 (1738%)	N
New Zealand	2 (164%)	7 (1003%)	N	6 (114%)	7 (125%)	10 (90%)
Norway	3 (148%)	7 (416%)	N	N	N	N
Poland	3 (176%)	7 (505%)	N	N	N	N
Portugal	2 (142%)	7 (909%)	N	6 (104%)	7 (119%)	10 (81%)
South Africa	2 (164%)	7 (1003%)	N	6 (114%)	7 (125%)	10 (90%)
South Korea,	3 (112%)	7 (307%)	N	N	N	N
Spain	3 (220%)	7 (624%)	N	4 (134%)	7 (246%)	12 (78%)
Sweden	3 (189%)	7 (551%)	N	4 (128%)	7 (241%)	12 (74%)
Turkey	N	N	N	N	N	N
Uganda	1 (157%)	7 (5320%)	N	1 (106%)	7 (3601%)	N
United Kingdom	6 (113%)	7 (134%)	10 (87%)	N	N	N
United States	7 (113%)	7 (113%)	9 (94%)	N	N	N

an occupancy of 103% and were exceeded in the 9th week, so it saw its conventional hospitalization resources saturated at some point in the 12 weeks that the simulation study is planned.

Table 2 shows the length of saturation of ICU beds indicating the week in which saturation is reached, the percentage by which demand saturates available resources, the peak of demand and the week in which supply adjusts to demand. This simulation has been performed for the most likely scenario. All countries in the study, except Turkey, reach saturation at some point in the 12 weeks projected by the simulation.

The same data for the use of ventilators is also expressed in Table 2. For this resource, there is no saturation in the occupation for Argentina, Austria, Brazil, France, United Kingdom, Japan, South Korea, Norway, Poland, Turkey and USA.

The country with the earliest (the first week) ICU collapse is Uganda, while the other selected country on the African continent, South Africa, will saturate its ICUs in the third week. The remaining countries that see ICU resources saturated earlier (in the second week) are, in Asia: Nepal, India, Japan and New Zealand; in Europe: Portugal, in the Americas: Mexico and Haiti. None of these countries that have previously collapsed ICUs will recover their operation during the 12 weeks covered by the simulation.

The rest of the countries will see their ICUs collapse between the 3 rd and 5th week, except the United Kingdom, which reaches saturation in the 6th week, and the USA, which will do so in the 7th week. Of all of them, the United Kingdom, USA, Mongolia, Italy, France, Canada, Brazil, Austria and Argentina will regain slack; almost all of them between the 11th and 12th week of the simulation. The peak of saturation in all the countries of the sample analyzed occurs in week 7, which may be a bias in the model.

Regarding ventilators, approximately 60% will experience a collapse, 64% of which will recover capacity in the period simulated, almost all of them between the 10th and 12th week. The same possible bias toward the peak of saturation in the 7th week is observed in the result for the ventilators.

Discussion

The results obtained with this model indicate difficulties in the healthcare systems regarding saturation of ICUs and ventilator in a period of between 7 and 8 weeks.

Regarding the variable "need for admittance to ICU," a discrepancy has been observed between the different studies published to date concerning the percentage of patients requiring admittance to the ICU: 7.7% according to Yang et al.[39] and 5% in the series of Guan et al.[40] For this study we have chosen the results from Peiris,[38] for whom it seems evident that of those hospitalized patients who develop pneumonia, between 20 and 30% need ICU support.

Regarding the variable "average length of stay in hospital," this was 12 days (10–14 days) for all patients, while the average increased to 13 days (11.5–17 days) in patients with serious disease, according to data obtained from Guan et al.[40] The time for the average stay in the ICU has not been defined in the published literature to date. According to Yang et al.,[39] for patients who died, the average time from admittance to the ICU to their death was 7 days for 61.5% of the patients. For those patients who recovered from the disease, 60% remained hospitalized after 28 days from admittance to the ICU.[44]

For the variable "average percentage of patients hospitalized requiring admission to ICU," this study uses the 11% derived from Italian data, clearly higher than the percentage published by Yang et al.[39] and Guan et al.[40] in China.

Regarding the variable "need for mechanical ventilator," Guan et al.[40] indicate that this was required by 71% of the patients. However, following the recommendation by the Spanish Society for Intensive Medicine,[45] the estimation for the data corresponding to the variable "average percentage of hospitalized patients requiring invasive mechanical ventilation" has been chosen as if all patients were assisted with invasive mechanical ventilation, using a percentage of 6.5% in hospitalized patients.

The results coincide with the projections published by Meng et al.,[46] which underline the importance of not collapsing ventilator resources, although their projection for demand is lower than that assumed by the present work. For Grasselli et al.,[47] the projections for ICU bed use made from a retrospective study carried out between the end of February and the beginning of March 2020 in the Lombardy region show similar expectations to the present study.

There is agreement with the work of Murthy et al.[48] on the lack of capacity in low-income countries regarding their provision of ICU beds and ventilators and the fragility of their healthcare structures, especially the public, to face a pandemic that could collapse these resources. Thus, the expectation for Haiti is for a virtually complete collapse in the first week of pressure on ICU admittance.[31] However, the results of the ongoing study for the USA do not coincide with other analyses, which believe that a situation of collapse may occur both in ICU beds and in respirators[18,49] with the exception of the work of Roberton et al.,[50] who considers that the problem is not counting the set of resources for the entire country, but the unequal distribution of these among the states, which will cause some of them to suffer congestion problems.

Qventus,[19] using the FluSurge 2.0 methodology, obtains the result that, at the peak, there will be a lack of 9,100 ICU beds and 115,000 Med-Surg beds in the USA and shows that the states that can be expected to experience the greatest shortage of capacity (higher demand than supply) in ICU beds are: Vermont (151% capacity), Hawaii (138%), Maryland (136%), New York (136%) and Delaware (133%). Similarly, it is expected that the most populated states have a high number of patients unable to access ICU beds. In the moderate scenario, in the fifth week New York will have a shortage of 1,110 ICU beds, California 1,107, Florida 630, Texas 528 and Pennsylvania 402.

An analysis of scenarios, carried out by Marcia C Castro et al.,[51] shows that if no changes in trajectory are observed, at the beginning of April Brazil will begin to face a shortage of hospital beds, ventilators and above all ICU beds in line with the results obtained with FluSurge.

Putra et al.,[52] using a Monte Carlo simulation, predict that COVID-19 in pregnant women will seriously affect obstetric hospital care. They also predict that the peak in the USA will be reached at the beginning of April, while in our study this would be at the end of April.

The authors of the study assume that the Monte Carlo analyses have an inherent limitation, in that they can only be carried out in accordance with the precision of underlying assumptions, which is also the case with FluSurge 2.0.

Ruoran et al.[53] estimates the probability of being in a critical state at the peak of the epidemic for each age and hypertension group, using the COVID-19 mortality rates by age and hypertension from Wuhan. They apply these calculations of healthcare rates to the population structures in USA cities based on the crude prevalence of hypertension in adults in 2017 and the proportion of adult population over 65 in these cities, as well as using USA data for ICU bed resources, hospital beds and population structure to estimate the bed capacity for hospitalized patients per 10,000 adults. They concluded the need to implement early strict disease control measures to mitigate the demand for hospitalization and ICU beds during an outbreak of COVID-19 and avoid healthcare resource saturation in the USA.

What are our research's implications toward theory, practice, or policy?

This study shows how to evaluate the hospital resource capacity during a pandemic using a standard model, which would offer a simple and immediate application. Compared to more sophisticated mathematical models, the model proposed by FluSurge 2.0 allows, in a simple and accessible way, to obtain a simulation of the probabilities of saturation of resources such as hospital beds, ICU beds and mechanical ventilators, with an approximate indication of time future in which such saturation is expected to occur. In any case, in the current emergency situation, it allows a reasonable estimate of the foreseeable hospital and critical care needs at the national level.

The saturation of health resources appears to be early in time relative to population, for low-income countries, due to the fragility of their public health systems. This aspect is exacerbated by income disparities, which may explain the uneven saturation of health resources between countries.

Although we have carried out our evaluation at the country level, the tool developed by John Hopkins University allows its use at decision-making and care levels such as a health region or a hospital.[43]

It is true that, recently, applications have been developed that work with more complex algorithms[44,45,54] but, precisely, the value of this study has been to test a tool for use in situations such as the current one, simple to use and that offers data on the capacity of the physical resources of the hospital (and by derivation, of human resources) that allow a rapid design of the immediate and medium-term scenario as well as management decision-making; particularly in view of the data that the second and third waves of the virus spread have produced.[18,49]

Conclusions

The model shows, for a percentage greater than 50% of the countries, difficulties related to the saturation of their ICU units, and the use of ventilators. The predictions of collapse shown by this methodology must be confirmed by the real data, once verified, in order to evaluate its usefulness in helping with similar problems

The saturation of healthcare resources appears to be in line with a low proportion with respect to the number of inhabitants, especially in low-income countries, due to the fragile state of their public health systems. This aspect is exacerbated by inequality of income, which may explain the unequal saturation of healthcare resources between countries.

This study shows how FlueSurge 2.0 is a tool, available to any interested and needy user that allows, in an easy and fast way, to obtain a diagnosis of the response of their hospital resources, in particular ICU beds and hospitals. ventilators, to the spread and effects of a pandemic such as SARS-COV-2.

A limitation for this study, has been the accessibility of information related to the following variables: total population and age distribution; number of COVID19 infections; number of deaths from COVID19; number of non-ICU hospital beds; number of ICU beds and number of ventilators.

In other sense, one limitation with the model used by John Hopkins is that it takes into account healthcare resources but not the evolution of the contagion of the disease in scenarios of a large, medium, or weak confinement of the population to avoid contact.

It should be noted that the calculations made at the time of publication of this text can thus be re-evaluated based on the evolution of the pandemic in the near future, and the knowledge acquired in real time.

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