PM520 Computational Statistics: Epidemic models

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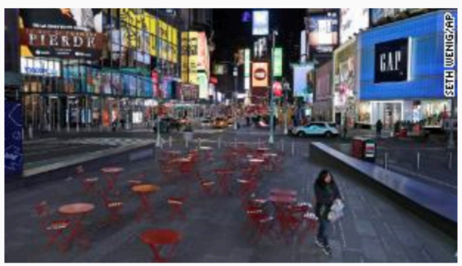
US, UK coronavirus strategies shifted following UK epidemiologists' ominous report

By **Nick Paton Walsh**, CNN

Updated 4:01 PM ET, Tue March 17, 2020

(CNN) — A study by UK epidemiologists predicts that attempts to slow, or mitigate -- rather than actively halt, or suppress -- the novel coronavirus could overwhelm the number of intensive care hospital beds and lead to about 250,000 deaths in the UK and more than a million in the United States during the course of the current pandemic.



Related Article: Sweeping restrictions take effect in coronavirus response as health officials warn US is at a tipping point

The study, which has not been published in a peer-reviewed journal, was released on Monday by London's Imperial College COVID-19 Response Team, which says it is advising the UK government on its response strategy. The study says it used modeling that has informed the approach of the British government in recent weeks; on Monday, the government abruptly called on vulnerable and elderly Britons to isolate themselves for 12 weeks, and introduced a variety of social distancing and quarantine recommendations that days earlier seemed distant prospects.

Sir Patrick Vallance, chief scientific adviser to the UK, confirmed Tuesday that the Imperial College study was among those the UK government was looking at.

16 March 2020 — Imperial College COVID-19 Response Team

Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand

Neil M Ferguson, Daniel Laydon, Gemma Nedjati-Gilani, Natsuko Imai, Kylie Ainslie, Marc Baguelin, Sangeeta Bhatia, Adhiratha Boonyasiri, Zulma Cucunubá, Gina Cuomo-Dannenburg, Amy Dighe, Ilaria Dorigatti, Han Fu, Katy Gaythorpe, Will Green, Arran Hamlet, Wes Hinsley, Lucy C Okell, Sabine van Elsland, Hayley Thompson, Robert Verity, Erik Volz, Haowei Wang, Yuanrong Wang, Patrick GT Walker, Caroline Walters, Peter Winskill, Charles Whittaker, Christl A Donnelly, Steven Riley, Azra C Ghani.

On behalf of the Imperial College COVID-19 Response Team

Summary

The global impact of COVID-19 has been profound, and the public health threat it represents is the most serious seen in a respiratory virus since the 1918 H1N1 influenza pandemic. Here we present the results of epidemiological modelling which has informed policymaking in the UK and other countries in recent weeks. In the absence of a COVID-19 vaccine, we assess the potential role of a number of public health measures – so-called non-pharmaceutical interventions (NPIs) – aimed at reducing contact rates in the population and thereby reducing transmission of the virus. In the results presented here, we apply a previously published microsimulation model to two countries: the UK (Great Britain specifically) and the US. We conclude that the effectiveness of any one intervention in isolation is likely to be limited, requiring multiple interventions to be combined to have a substantial impact on transmission.

Extended the model in this paper:

PNAS

Modeling targeted layered containment of an influenza pandemic in the United States

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Edited by Barry R. Bloom, Harvard School of Public Health, Boston, MA, and approved January 15, 2008 (received for review July 23, 2007)

Planning a response to an outbreak of a pandemic strain of influenza is a high public health priority. Three research groups using different individual-based, stochastic simulation models have examined the consequences of intervention strategies chosen in consultation with U.S. public health workers. The first goal is to simulate the effectiveness of a set of potentially feasible intervention strategies. Combinations called targeted layered containment (TLC) of influenza antiviral treatment and prophylaxis and non-pharmaceutical interventions of quarantine, isolation, school closure, community social distancing, and workplace social distancing are considered. The second goal is to examine the robustness of the results to model assumptions. The comparisons focus on a pandemic outbreak in a population similar to that of Chicago, with ≈8.6 million people. The simulations suggest that at the expected

and 1.7–2.0 (6). Based on past experience, one might assume for a newly emergent pandemic influenza that R_0 = 1.7–2.0 and T_g is as short as 3 days. Hence, although an influenza pandemic may be explosive, it is also potentially containable, because reducing transmission by as much as half might achieve an $R_0 < 1$.

Epidemic models represent a powerful tool for gaining insight into how the dynamics of an epidemic are affected by interventions (8). Small- (9, 10) and large-scale (6, 11, 12) individual-based stochastic simulations have previously examined the potential effectiveness of various interventions. However, different research studies seldom examine the same interventions, so results are difficult to compare.

In this article, three groups supported in part by the National Institutes of General Medical Sciences MIDAS network co-

The simulations suggest that at the expected transmissibility of a pandemic strain, timely implementation of a combination of targeted household antiviral prophylaxis, and social distancing measures could substantially lower the illness attack rate before a highly efficacious vaccine could become available.

Fundamental to the dynamics of an epidemic is:

The basic reproduction number, R_0,

The generation time, T_g, of the pathogen.

R_0 is the average number of secondary cases produced by each primary case at the start of an epidemic in a previously unaffected population;

T_g is the average time between infection of an index case and infection of the secondary cases they produce.

Although the R_0 of a future newly emergent influenza strain is unknown, previous estimates are 1.89 from the pandemic in 1968 in Hong Kong (5), and 1.5–1.7 in 1957 in Great Britain (6). The reproductive number of the first wave of the 1918 pandemic A(H1N1) in the United States was estimated as 2–3 (7)).

Based on past experience, one might assume for a newly emergent pandemic influenza that R_0 1.7–2.0 and T_g is as short as 3 days. Hence, although an influenza pandemic may be explosive, it is also potentially containable, because reducing trans- mission by as much as half might achieve an R_0 1.

In this article, three groups supported in part by the National Institutes of General Medical Sciences MIDAS network co- ordinated their efforts to use their own stochastic simulation models to examine the same set of intervention strategies.

Intervention Options

We considered a set of interventions consisting of antiviral treat- ment and household isolation of identified cases, prophylaxis and quarantine of their household contacts, closure of schools, social distancing in the workplace, and social distancing in the community at large.

Ascertainment: How many of the cases are detected?

Ascertainment of cases is key for targeted interventions, especially the use of influenza antivirals, case isolation, and quarantine of contacts. Rapid, specific diagnosis will be important.

- We assume that only 67% percent of influenza infections are symptomatic.
- We considered two levels of ascertainment of symptomatic influenza cases, namely, 60% and 80%.

Intervention

Interventions within the households of ascertained cases include the following:

- **Treatment of ascertained cases**. All ascertained cases are treated with one course of antiviral drug for 5 days beginning one day after the onset of symptoms. In the UW/LANL model, 5% of treated cases stop taking the drug after 1 day.
- **Targeted antiviral prophylaxis** (TAP) of household contacts. All household contacts receive one course (10 days) of prophylaxis beginning 1 day after the onset of symptoms of the index case. In the UW/LANL model, 5% of individuals who receive prophylaxis stop taking drug after 2 days.
- **Home isolation of cases**. Ascertained cases are isolated in the home, but not isolated from the people with whom they live, with a compliance rate of 60% or 90%.
- **Quarantine of household contacts**. Household contacts of ascertained cases are quarantined within the home for 10 days with a compliance rate of 30%, 60%, or 90%.

Three models were compared

The social structure of each of the three models was constructed differently, with implications for the effects of interventions. [For example] in the UW/LANL model

The population is geographically distributed among census tracts to closely represent variation in actual age and spatial distribution according to publicly available 2000 U.S. Census data (2).

- Each tract is in turn organized into 2,000-person communities.
- The household size distribution corresponds to that in the 2000 U.S. Census data.
- There are eight mixing groups within which individuals can associate and be infected by others in these groups.
- Each person belongs to a household, neighborhood, a cluster of four households, and a community. School children go to primary school, middle school, or high school.
- Preschool children go to small day care centers or play in small play groups.
- Most adults go to work at workplaces.

Deterministic or stochastic models?

Deterministic models are based on differential equations and work for large populations in which individual-level variation averages out.
Stochastic models simulate each individual thereby allowing for individual-level variation. They probably better assess the uncertainty in early stages of epidemics.

The models used here are stochastic.

R_0: the basic reproduction number

Transmissibility and Case Fatality Ratio. One uncertainty of a future pandemic strain is how transmissible it will be.

It is generally expected that the R_0 in a new pandemic will be 2.

Interventions work better at lower R_0 values.

Here, the focus was on where interventions would break down, which required studying improbably high R_0 values. We were interested in examining interventions at R_0 values near 2.0, 2.4, and 3.0.

Case fatality ratio [CFR]

Another uncertainty of a future pandemic is the case fatality ratio.

The estimated 2 in 100 case fatality ratio in the 1918 pandemic (7, 15) is two orders of magnitude larger than the estimated 2 in 10,000 in the 1957 and 1968 pandemics (16).

Because the number of deaths that occur will be a fairly linear function of the number of cases and the case fatality ratio, we present only the illness attack rates, and not the number of deaths.

Simulation models

All three models are stochastic, spatially structured, individual- based discrete time simulations.

In a stochastic, individual-based model, the chance that any susceptible individual will be infected by a contact with an infected person is random and related to the transmission probability for the situation of the contact.

Antiviral prophylaxis is assumed to reduce the probability of becoming infected by a contact by 0.3, and if infected, to reduce the probability of developing illness by 0.60.

Antiviral treatment or prophylaxis is assumed to reduce the prob-ability of an infected person transmitting by 0.62.

Social distancing can lower the number of effective contacts or the transmission probabilities.

Many other aspects of each simulation model occur stochastically; for example, whether a person develops symptoms, or whether a person complies with an intervention strategy.

Transmission

The probability of transmission from an infectious person to a susceptible person during a contact (colocation) of duration t is given by the formula $p_{trans} = 1 - (1 - q)^t$, where q is a parameter that can be set independently in different locations, for different infectious or susceptible people.

The overall R_0 is adjusted by changing the value of q.

Scenarios

6 scenarios were considered, numbered in increasing order of 'effectiveness':

- **Scenario 1** (baseline): no intervention.
- **Scenario 2**: interventions initiated after 1% of the population has developed symptomatic influenza, 60% case ascertainment, 30% compliance (quarantine and children staying home) 60% compliance with isolation.
- **Scenarios 3 and 5:** interventions at illness attack rate threshold of 0.1%, 60% of cases ascertained, 60% (Sc 3) or 90% (Sc. 5) compliance.
- **Scenarios 4 and 6**: initiate interventions at threshold of 0.01% illness attack rate and 80% of cases are ascertained, and 60% (Sc 4.) versus 90% (Sc. 6) compliance.

Results - Illness attack rates

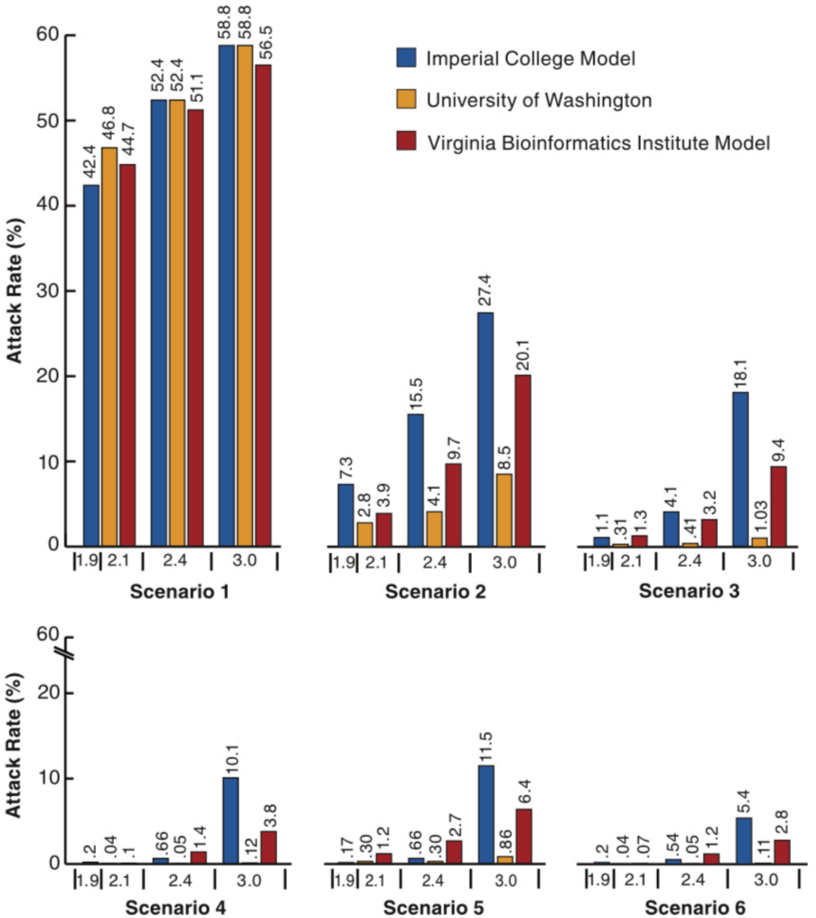

Fig. 1. Influenza illness attack rates for three R_0 values without intervention and with five scenarios of TLC intervention by using the three different models (Chicago population). See Table 1 for a description of scenarios. The R_0 values of 1.9 and 2.1 are considered as a single comparison.

'Attack rate' by place

Table 3. Percentage of infections by place and scenario, R_0 = 1.9 (2.1) in the Chicago population

	Scenario 1. No intervention			Scenario 2			Scenario 3		
	Imperial	UW	VBI	Imperial	UW	VBI	Imperial	UW	VBI
Illness attack rates	42.4	46.8	44.7	7.3	2.8	3.9	1.1	0.31	1.3
Places									
Home	33.1	39.4	41.1	48.3	58	45.9	50.4	59	36.9
Work	21.8	14.5	28.6	12.9	10	27.8	13.5	10	18.7
School	16.0	18.8	23.3	11.7	11	9.6	9.0	11	2.7
Day care	–	1.1	–	–	0	–	–	0	–
Play group	–	0.8	–	–	0	–	–	0	–
College	–	–	3.3	–	–	12.3	–	–	40.0
Shopping	–	–	2.0	–	–	2.4	–	–	1.0
Neighborhood	–	17.7	–	–	15	–	–	15	–
Neighborhood clusters	–	7.7	–	–	5	–	–	4	–
Other/Community	29.0	0	1.7	26.6	0	2.0	23.8	0	0.8
Totals									
Primary Groups*	70.9	72.7	93.0	72.9	79	83.3	72.9	79	58.3
Community†	29.0	25.4	3.7	26.6	20	4.4	23.8	19	1.8

*Includes home, school, workplace, and for the UW/LANL model, day care and play groups.
†Includes groups subject to community social distancing.

Sensitivity to intervention threshold

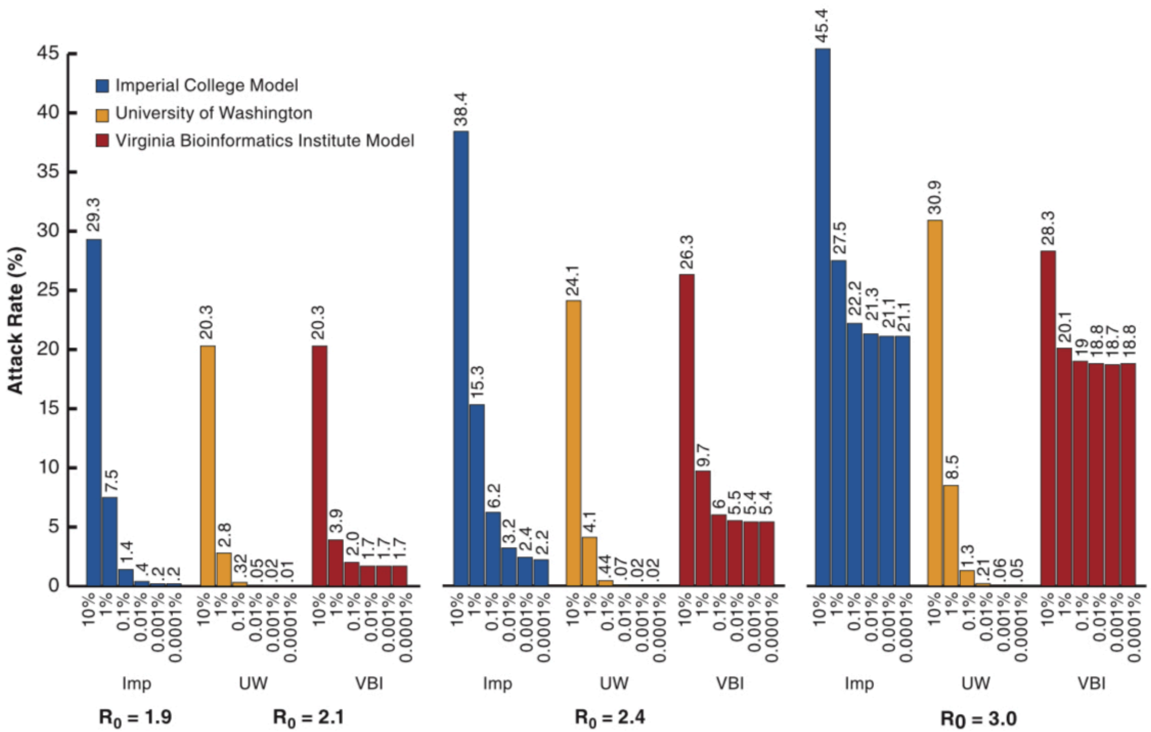

Fig. 3. Sensitivity to changing thresholds for all interventions simultaneously for the three models. Scenario 2 and three R_0 values, with threshold for triggering all measures being varied between 10% and 0.0001% cumulative illness attack rates. Chicago population.

What causes the reduction in infection rates?

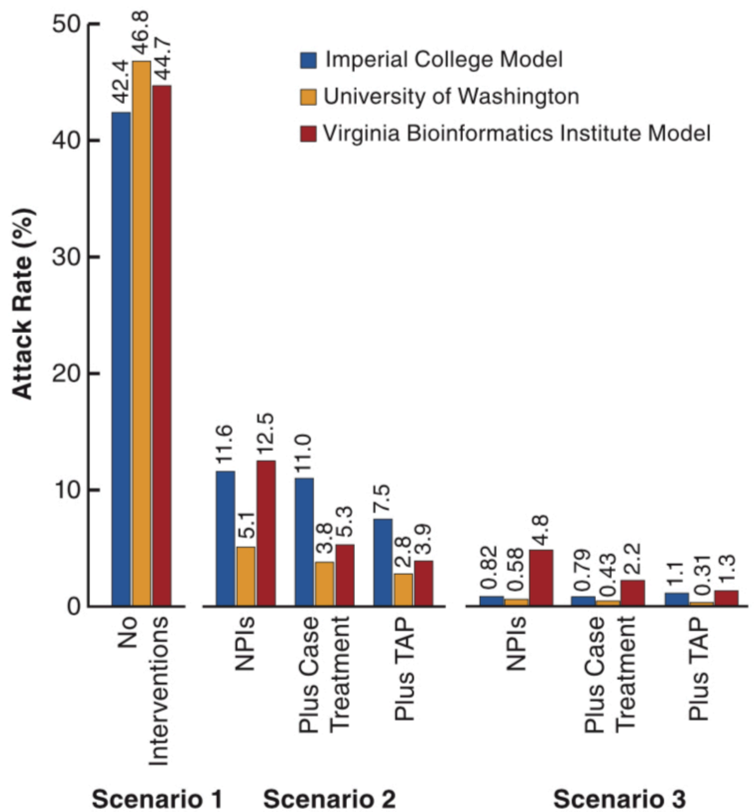

Fig. 4. Comparison of no intervention with intervention scenarios 2 and 3 using just NPIs, NPI with addition of just treatment of ascertained cases (Plus Case Treatment), and NPI with addition of treatment of ascertained cases and targeted antiviral prophylaxis (Plus TAP) of their household contacts. Scenario 1: no intervention; scenario 2: just NPI, with treatment only; with TAP (base case scenario 2); scenario 3: just NPI, with treatment only; with TAP and treatment (base case scenario 3); R_0 of 1.9 (2.1). Chicago population.

Overwhelmingly due to NPI (Non-pharmaceutical interventions)

"The effects of home and school interventions are more robust across the three models than the effects of community social distancing."

Discussion

"Especially at values of R_0 2 or below, the more probable values for a pandemic strain, the interventions are similarly, although not identically, effective in all three models."

"School closure plays an important role in all three models."

"If one could achieve these levels of compliance, ascertainment, and social distancing, then there would be a possibility of considerably mitigating a pandemic until a vaccine were available."

"However, whether the ascertainment and compliance levels modeled here are realistic has yet to be demonstrated. Whether public health officials would actually choose to implement such measures will eventually depend on the lethality and transmissibility (R_0) of the pandemic strain."

Discussion

"We caution against overinterpretation of the modeling results, even where the three models suggest similar effectiveness of interventions. Because of the uncertainties in the models, the results need to be viewed more as helping to structure thinking about pandemic planning, rather than being predictive of the precise effectiveness of different policies."

"Other simulation results (6, 9, 11) have demonstrated that use of even poorly matched, low-efficacy vaccines would greatly enhance the effectiveness of other intervention measures."

Back to the COVID paper…

16 March 2020 *Imperial College COVID-19 Response Team*

Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand

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On behalf of the Imperial College COVID-19 Response Team

Historical precedents

- 1918-19 H1N1 influenza pandemic. S
  - Some communities, in US, responded with a variety of non- pharmaceutical interventions (NPIs) - e.g., closing schools, churches, bars and other social venues.
  - Cities in which these interventions were implemented early were successful at reducing case numbers while

    the interventions remained in place and experienced lower mortality overall.
  - Transmission rebounded once controls were lifted.

Two fundamental strategies

Suppression. Aim to reduce the reproduction number, R_0, to below 1 to reduce case numbers to low levels or (as for SARS or Ebola) eliminate human-to-human transmission. Main challenge: NPIs (and drugs, if available) need to be maintained – at least intermittently - for as long as the virus is circulating in the human population, or until a vaccine becomes available. For COVID-19, it will be at least 12-18 months before a vaccine is available.

Mitigation. Aim to use NPIs (+ vaccines or drugs) not to interrupt transmission completely, but to reduce the health impact of an epidemic. In the 2009 pandemic, for instance, early supplies of vaccine were targeted at individuals with pre-existing medical conditions which put them at risk of more severe disease. In this scenario, population immunity builds up through the epidemic, leading to an eventual rapid decline in case numbers and transmission dropping to low levels. (R_0 reduced, but still >1)

The model

"We modified [our existing] simulation model developed to support pandemic influenza planning."

"Basic structure of the model remains as previously published:

Individuals reside in areas defined by high-resolution population density data.

Contacts with other individuals in the population are made within the household, at school, in the workplace and in the wider community.

Census data were used to define the age and household distribution size.

Data on average class sizes and staff-student ratios were used to generate a synthetic population of schools distributed proportional to local population density.

Data on the distribution of workplace size was used to generate workplaces with commuting distance data used to locate workplaces appropriately across the population.

Individuals are assigned to each of these locations at the start of the simulation."

The model

"Transmission events occur through contacts made between susceptible and infectious individuals in either the household, workplace, school or randomly in the community. […] Per-capita contacts within schools were assumed to be double those elsewhere in order to reproduce the attack rates in children observed in past influenza pandemics. [This means that], approximately one third of transmission occurs in the household, one third in schools and workplaces and the remaining third in the community."

They assume:

Incubation period of 5.1 days.

Infectiousness occurs from 12 hours prior to onset of symptoms for those that are symptomatic

Infectiousness occurs from 4.6 days after infection in those that are asymptomatic

Baseline is that R_0=2.4, but examine values between 2.0 and 2.6.

Symptomatic individuals are 50% more infectious than asymptomatic individuals.

Individual infectiousness is assumed to be variable, described by a gamma distribution

On recovery from infection, individuals are assumed to be immune to re-infection in the short term.

The model

- Further assumptions:
  - 40-50% of infections are not identified as cases (cf. data from China).
  - Two-thirds of cases are sufficiently symptomatic to self-isolate (if required by policy) within 1 day of symptom onset.
  - A mean delay from onset of symptoms to hospitalisation of 5 days.
  - Age-stratified proportion of infections that require hospitalisation and the infection fatality ratio (IFR) were obtained from cases from China. These estimates, when applied to the GB population result in an IFR of 0.9% with 4.4% of infections hospitalised (Table 1).
  - Based on expert clinical opinion, we assume that 50% of those in critical care will die and an age-dependent proportion of those that do not require critical care die (calculated to match the overall IFR).
  - We calculate bed demand numbers assuming a total duration of stay in hospital of 8 days if critical care is not required and 16 days (with 10 days in ICU) if critical care is required. With 30% of hospitalised cases requiring critical care, we obtain an overall mean duration of hospitalisation of 10.4 days.

Estimated case severity

Table 1: Current estimates of the severity of cases. The IFR estimates from Verity et al.[12] have been adjusted to account for a non-uniform attack rate giving an overall IFR of 0.9% (95% credible interval 0.4-0.14). Hospitalisation estimates from Verity et al.[12] were also adjusted in this way and scaled to match expected rates in the oldest age-group (80+ years) in a GB/US context. These estimates will be updated as more data accrue.

Age-group (years)	% symptomatic cases requiring hospitalisation	% hospitalised cases requiring critical care	Infection Fatality Ratio
0 to 9	0.1%	5.0%	0.002%
10 to 19	0.3%	5.0%	0.006%
20 to 29	1.2%	5.0%	0.03%
30 to 39	3.2%	5.0%	0.08%
40 to 49	4.9%	6.3%	0.15%
50 to 59	10.2%	12.2%	0.60%
60 to 69	16.6%	27.4%	2.2%
70 to 79	24.3%	43.2%	5.1%
80+	27.3%	70.9%	9.3%

IFR: Infection fatality rate

Intervention scenarios

Table 2: Summary of NPI interventions considered.

Label	Policy	Description
CI	Case isolation in the home	Symptomatic cases stay at home for 7 days, reducing non-household contacts by 75% for this period. Household contacts remain unchanged. Assume 70% of household comply with the policy.
HQ	Voluntary home quarantine	Following identification of a symptomatic case in the household, all household members remain at home for 14 days. Household contact rates double during this quarantine period, contacts in the community reduce by 75%. Assume 50% of household comply with the policy.
SDO	Social distancing of those over 70 years of age	Reduce contacts by 50% in workplaces, increase household contacts by 25% and reduce other contacts by 75%. Assume 75% compliance with policy.
SD	Social distancing of entire population	All households reduce contact outside household, school or workplace by 75%. School contact rates unchanged, workplace contact rates reduced by 25%. Household contact rates assumed to increase by 25%.
PC	Closure of schools and universities	Closure of all schools, 25% of universities remain open. Household contact rates for student families increase by 50% during closure. Contacts in the community increase by 25% during closure.

Results - no mitigation

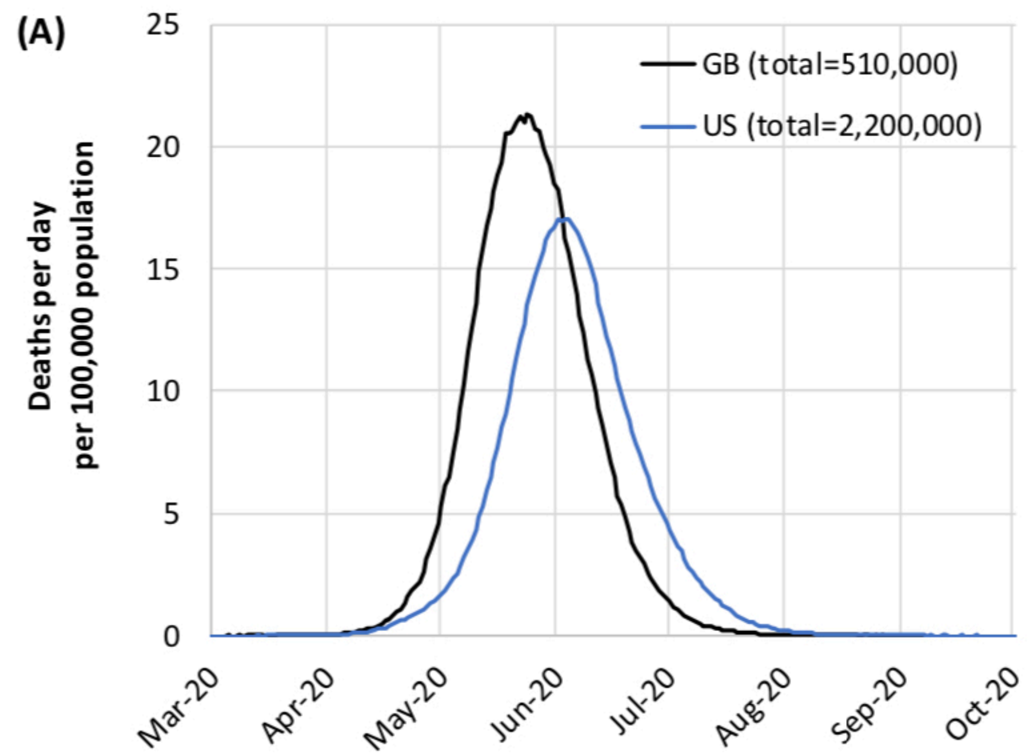


Figure 1: Unmitigated epidemic scenarios for GB and the US. (A) Projected deaths per day per 100,000 population in GB and US.

ICU bed needs as function of mitigation/intervention

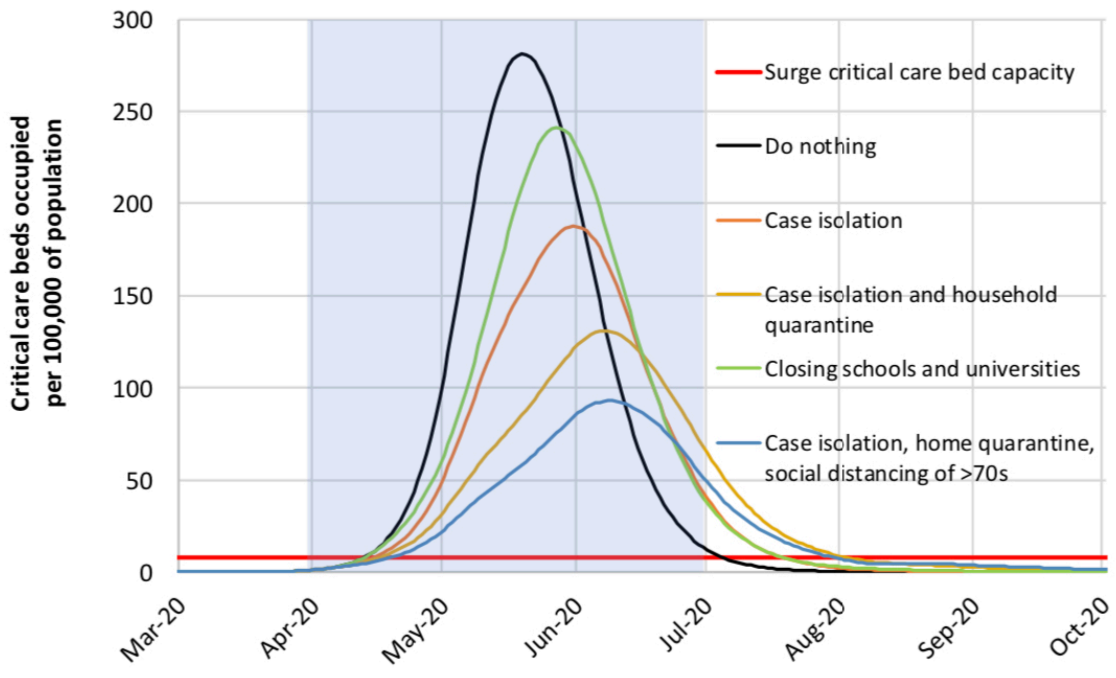


Figure 2: Mitigation strategy scenarios for GB showing critical care (ICU) bed requirements. The black line shows the unmitigated epidemic. The green line shows a mitigation strategy incorporating closure of schools and universities; orange line shows case isolation; yellow line shows case isolation and household quarantine; and the blue line shows case isolation, home quarantine and social distancing of those aged over 70. The blue shading shows the 3-month period in which these interventions are assumed to remain in place.

Results - ‘flattening the curve’

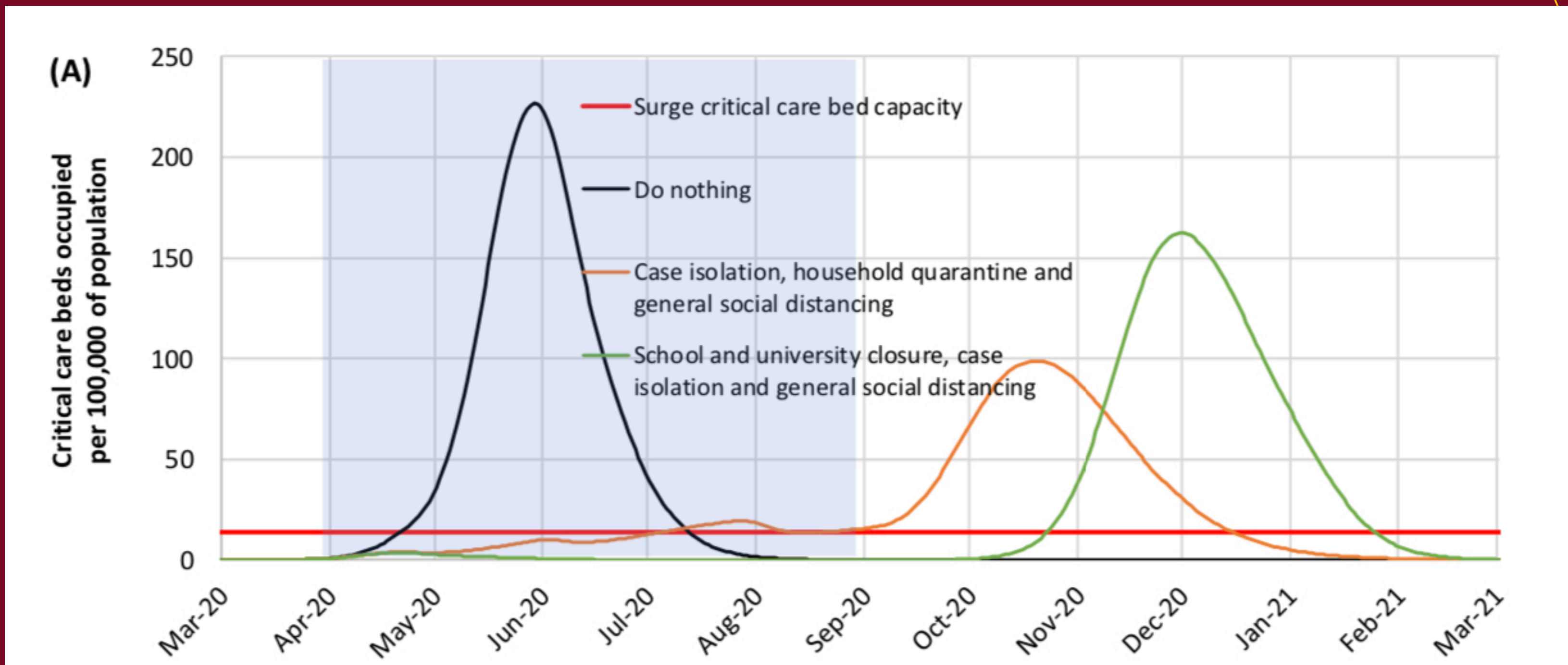


Figure A1: Suppression strategy scenarios for US showing ICU bed requirements. The black line shows the unmitigated epidemic. Green shows a suppression strategy incorporating closure of schools and universities, case isolation and population-wide social distancing beginning in late March 2020. The orange line shows a containment strategy incorporating case isolation, household quarantine and population-wide social distancing. The red line is the estimated surge ICU bed capacity in US. The blue shading shows the 5-month period in which these interventions are assumed to remain in place.

Once interventions are relaxed (in Figure A1, from September onwards), infections begin to rise, resulting in a predicted peak epidemic later in the year. The more successful a strategy is at temporary suppression, the larger the later epidemic is predicted to be in the absence of vaccination.

Adaptive triggering of NCIs

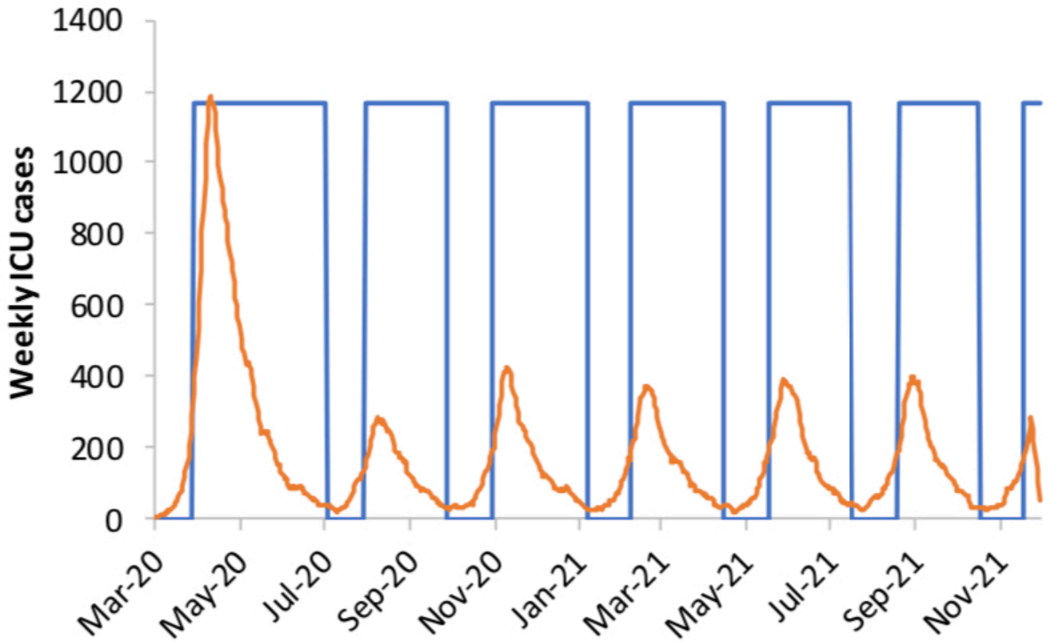


Figure 4: Illustration of adaptive triggering of suppression strategies in GB, for R_0=2.2, a policy of all four interventions considered, an "on" trigger of 100 ICU cases in a week and an "off" trigger of 50 ICU cases. The policy is in force approximate 2/3 of the time. Only social distancing and school/university closure are triggered; other policies remain in force throughout. Weekly ICU incidence is shown in orange, policy triggering in blue.

Total deaths

R_0	On Trigger	Total deaths: Do nothing	CI_HQ_SD	PC_CI_SD	PC_CI_HQ_SD
2	60	410,000	47,000	6,400	5,600
	100	410,000	47,000	9,900	8,300
	200	410,000	46,000	17,000	14,000
	300	410,000	45,000	24,000	21,000
	400	410,000	44,000	30,000	26,000
2.2	60	460,000	62,000	9,700	6,900
	100	460,000	61,000	13,000	10,000
	200	460,000	64,000	23,000	17,000
	300	460,000	65,000	32,000	26,000
	400	460,000	68,000	39,000	31,000
2.4	60	510,000	85,000	12,000	8,700
	100	510,000	87,000	19,000	13,000
	200	510,000	90,000	30,000	24,000
	300	510,000	94,000	43,000	34,000
	400	510,000	98,000	53,000	39,000
2.6	60	550,000	110,000	20,000	12,000
	100	550,000	110,000	26,000	16,000
	200	550,000	120,000	39,000	30,000
	300	550,000	120,000	56,000	40,000
	400	550,000	120,000	71,000	48,000

Table 4. Suppression strategies for GB. Impact of three different policy option (case isolation + home quarantine + social distancing, school/university closure + case isolation + social distancing, and all four interventions) on the total number of deaths seen in a 2-year period.

Social distancing and school/university closure are triggered at a national level when weekly numbers of new COVID-19 cases diagnosed in ICUs exceed the thresholds listed under "On trigger" and are suspended when weekly ICU cases drop to 25% of that trigger value.

Other policies are assumed to start in late March and remain in place.

Results are qualitatively similar for the US.

Discussion

We find that that optimal mitigation policies (combining home isolation of suspect cases, home quarantine of those living in the same household as suspect cases, and social distancing of the elderly and others at most risk of severe disease) might reduce peak healthcare demand by 2/3 and deaths by half. However, the resulting mitigated epidemic would still likely result in 100,000s of deaths [in the UK] and health systems […] being overwhelmed many times over. **For countries able to achieve it, this leaves suppression as the preferred policy option.** "

"Given that mitigation is unlikely to be a viable option without overwhelming healthcare systems, suppression is likely necessary in countries able to implement the intensive controls required. Our projections show that to be able to reduce R to close to 1 or below, a combination of case isolation, social distancing of the entire population and either household quarantine or school and university closure are required ."

"To avoid a rebound in transmission, these policies will need to be maintained until large stocks of vaccine are available to immunise the population – which could be 18 months or more."

"We estimate that for a national GB policy, social distancing would need to be in force for at least 2/3 of the time (for R_0=2.4) until a vaccine was available.

Discussion

"Long-term suppression may not be a feasible policy option in many countries. Our results show that the alternative relatively short-term (3-month) mitigation policy option might reduce deaths seen in the epidemic by up to half, and peak healthcare demand by two-thirds."

"School closure is predicted to be insufficient to mitigate (never mind suppress) an epidemic in isolation; this contrasts with the situation in seasonal influenza epidemics, where children are the key drivers of transmission due to adults having higher immunity levels."

"Overall, we find that the relative effectiveness of different policies is insensitive to the choice of local trigger (absolute numbers of cases compared to per-capita incidence), R_0 (in the range 2.0-2.6), and varying IFR in the 0.25%-1.0% range."

"For mitigation, the majority of the effect of such a strategy can be achieved by targeting interventions in a three-month window around the peak of the epidemic. For suppression, early action is important, and **interventions need to be in place well before healthcare capacity is overwhelmed**."

"Perhaps our most significant conclusion is that mitigation is unlikely to be feasible without emergency surge capacity limits of the UK and US healthcare systems being exceeded many times over."

Discussion

"We therefore conclude that epidemic suppression is the only viable strategy at the current time. The social and economic effects of the measures which are needed to achieve this policy goal will be profound."

"We emphasise that is not at all certain that suppression will succeed long term; no public health intervention with such disruptive effects on society has been previously attempted for such a long duration of time. How populations and societies will respond remains unclear."

"We show that intermittent social distancing – triggered by trends in disease surveillance – may allow interventions to be relaxed temporarily in relative short time windows, but measures will need to be reintroduced if or when case numbers rebound."

"We do not consider the ethical or economic implications of either strategy here, except to note that there is no easy policy decision to be made." (e.g. public health and well-being is known to suffer during recessions.)

Hope?

From “Science”:

A medical officer prepares to take samples from a visitor at a drive-through testing center at Yeungnam University Medical Center. REUTERS/KIM KYUNG-HOON

Coronavirus cases have dropped sharply in South Korea. What’s the secret to its success?

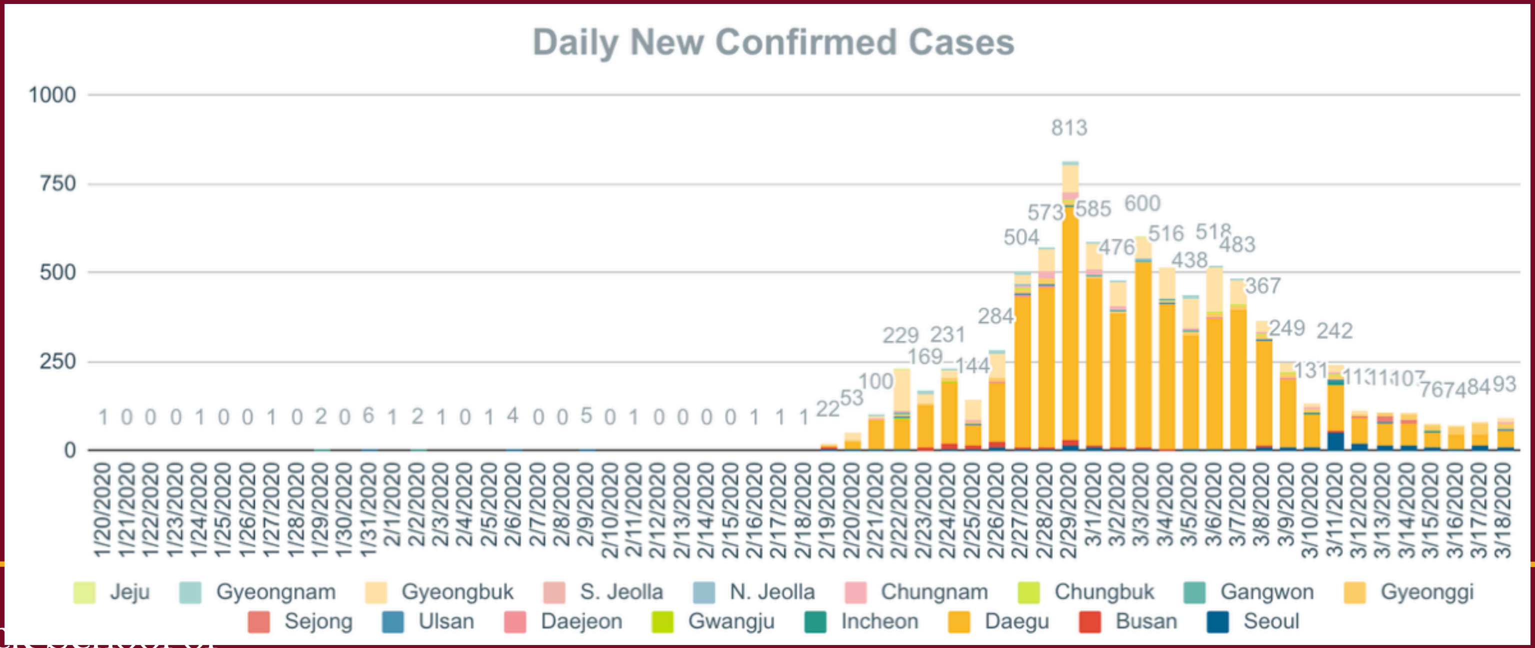
By **Dennis Normile** | Mar. 17, 2020 , 8:00 AM

South Korea has emerged as a sign of hope and a model to emulate. The country of 50 million appears to have greatly slowed its epidemic; it reported only 74 new cases today, down from 909 at its peak on 29 February

Hope?

Behind its success so far has been the most expansive and well-organized testing program in the world, combined with extensive efforts to isolate infected people and trace and quarantine their contacts. South Korea has tested more than 270,000 people,…

Strategy: detect early and isolate!



Keck School of Medicine of USC

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