First look at actual outcomes of coronavirus disease (COVID-19) versus scenarios presented in Imperial College COVID-19 Response Team document of 16th March 2020 "Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand (the Analysis[i]).

Attempt to extract data on deaths where COVID-19 was directly leading to death from ONS data on deaths "relating to" COVID-19

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Abstract

Some initial data is available for deaths associated with COVID-19 for the period to 10th April 2020, although at an early stage it is possible to compare this data against the various scenarios included by Imperial College ("IC") in the document above. In carrying out this exercise, it is necessary to adjust the data produced by the Office of National Statistics ("ONS") due to the fact that published data refer to deaths where COVID-19 is mentioned on the death certificate. This definition will then cover cases where COVID-19 is the cause of death (Part I) and cases where COVID-19 is not the cause of death (Part II). The calculation below estimates the deaths caused by COVID-19 and compare those to the deaths projected by IC.

The paper is designed for a wider audience than specialised epidemiologists, accordingly some of the commonly used terms and abbreviations are defined for the benefit of the generalist.

The paper is organised as follows;

1. Key assumptions behind IC unmitigated epidemic
2. The mitigation and suppression impacts
3. Actual data on COVID-19 deaths derived from ONS deaths "relating to" COVID-19
4. Flaws in the scope of the study
5. Conclusions

Definitions - approximate

Infection rate - point of time (PCR)	Test for coronavirus at a point in time will show % of people infected both symptomatic and asymptomatic bit will not include people with resolved infections.
Infection rate including resolved infections (antibodies)	% infected now or at any time in the past, identified by serological testing for SARS-CoV-2 antibodies
Symptomatic	With symptoms – these are cases.
Asymptomatic	Without symptoms – these are a subset of people infected who are not cases.
Cases	Infected, testing positive for the virus (PCR) and symptomatic.
CFR – Case Fatality Ratio	Deaths/cases
IFR – Infection Fatality Ratio	Deaths/number infected. Care needs to be taken whether the denominator is the cumulative total of individuals infected to that point (including resolved infections) or individuals who are infected at a particular point in time.

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1. Key assumptions behind Imperial College paper's unmitigated epidemic

The initial condition for the IC paper is the unmitigated epidemic, which essentially is the "do nothing" scenario and where the virus runs through the population with no mitigating actions being taken. IC quantifies the death level of the unmitigated epidemic at 510,000.

This outcome rests on three key assumptions;

- The assumption that 81% of the UK population will be infected by the virus.
- That there will be an infection fatality ratio (IFR) of 0.9%.
- The infections double every 5 days until a peak is reached and decline thereafter.

These conditions combined imply a very large number of people having need of critical care beds, the peak bed demand is around 270 per 100,000 of population. The text of the IC paper includes an infection fatality ratio of 0.9 giving total deaths at around 500,000 (UK population x 81% x 0.945% implied rather than 0.9% in text). For reference the IC paper includes a critical care beds capacity of 8 per 100,000 of population, implying that in a "do nothing" scenario, approximately 31 National Health Systems would be required to treat this pandemic[ii].

The various policy responses are then designed to reduce the peak demand for critical care beds to well below 8 beds per 100,000. From such a significant unmitigated pandemic scenario, it goes without saying that the very drastic actions are required to achieve a reduction in peak bed demand from 270 to less than 8 per 100,000 of population.

The author identified the assumptions underpinning the "do nothing" scenario. At the time that the IC paper was presented there were several data sets available. For the purposes of illustration the author considers the impact that the virus had on the Diamond Princess passengers as a complete data set. The statistics from that outbreak as presented by Eurosurveillances.org[iii], were as follows;

Age Group	**IFR (95% CI)**	**CFR (95% CI)**
All ages combined	1.30%	2.60%
CI	(0.38-3.6)	(0.89-6.7)
20th Feb 2020		
Cases on board	619 (17%)	
Asymptomatic	318	
Symptomatic	301	

eurosurveillance.org

Applying these outcomes to the UK population of 66.6 million, would imply total deaths of around 150,000, 3.5 x less that in the IC unmitigated pandemic scenario. This is important as it indicates a baseline against which the impact of various policy choices should be measured.

Looking at the IC assumption that 81% of the UK population would be infected, there is no source or reference for that assumption.

It would be interesting to establish, the evidence supporting the assumption that 81% would be infected and to clarify whether the infection level of 81% could be multiplied by an IFR of 0.9. The background of the IFR is also unclear, the underlying data is referenced to another IC paper by Verity et al[iv].

The Verity et al. paper starts with the observed figure of 2.29% deaths/cases (Diamond Princess was 2.6%) and a number of adjustments are used to arrive at an IFR of 0.657% for all ages.

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The exact nature of those adjustments is not entirely clear. There is then limited explanation as to how the transformation of 0.657% in the Wuhan context translates into 0.9% for the UK (adjusted for non-uniform attack rate). This is a very major adjustment when applied to a number equal to 81% of the population.

In actual fact 0.9% differs from the figure of 0.945% required to generate a figure of 510,000 deaths in an unmitigated epidemic. Furthermore multiplying the IC paper's IFR by age group by the UK population by age group at 2018 indicates an all ages WAV infection fatality ratio of 1.23% rather than 0.9%. This assumption is of central importance to the 510,000 deaths figure and is very difficult to trace to underlying evidence.

By way of illustration, assuming that a 17% infection rate for the Diamond Princess based on a point in time sample (PCR) was consistent with an overall rate of infection of 81% when including all resolved infections, this would imply an infection fatality rate of 0.273% (1.3% x 17%/81%). Recent studies from Santa Clara have suggested a lower level of IFR of between 0.2% and 0.12% based on a very limited set of samples[v]. Below is an illustration of the interplay between data from Diamond Princess and assumptions on the percentage of the population infected at any point in time, including resolved infections (the serological attack rate);

Implied population	% infected	IFR at point in time (as printed)	% infected at end of epidemic (infection attack rate)	Implied IFR applicable at to all infections including resolved cases	Deaths*
3,614	17%	1.30%	70%	0.32%	7
3,614	17%	1.30%	80%	0.28%	7
3,614	17%	1.30%	90%	0.25%	7
3,614	17%	1.30%	100%	0.22%	7

This is actual outcome, the ratios above generate an outcome of 7.99

In fact one of the authors of the IC paper mentioned that the infection rate on the Diamond Princess would have been unity, which implies an IFR at the end of a pandemic (including all resolved infections) of 0.22% versus the 0.9% used by IC..

The process of infecting the population is squeezed into a short window, with exponential growth equivalent to doubling every 5 days. The remaining assumptions on infectiousness, implies that the entire infection process is over within a 2.5 month timeframe. Towards the end of March, there was data suggesting that the rate of increase in coronavirus cases begins to decelerate and diverges from an exponential growth function[vi].

It is impossible to obtain perfect data as an unmitigated pandemic is a theoretical construct, both individuals and governments would react to the virus and produce an outcome less severe than the unmitigated epidemic. In any event looking at the WHO situation reports there does not appear to be a country that maintained exponential growth in deaths or cases beyond the very early stages.

The mitigating actions versus actual outcomes

Leaving aside the point that the unmitigated pandemic scenario is a theoretical construct, the model shows various policy initiatives, as set out below;

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Label	Policy
CI	Case isolation in the home
HQ	Voluntary home quarantine
SDO	Social distancing of those over 70 years of age
SD	Social distancing of entire population
PC	Closure of schools and universities

The model represents various impacts of using policies individually and in combination in order to reduce demand on critical care beds and deaths from the unmitigated pandemic figure of 510,000. This again highlights the importance of the figure derived from the unmitigated pandemic case, such a high figure together with the condition that "we do not consider the ethical or economic implications" of policy inevitably leads to a very strict imposition of restrictions (PC_CI_HQ_SD).

Clear mathematical impacts are represented for various policy choices, but no explanation is provided as to how those impacts were estimated. Many of the policies are non-controversial and formed part of the NHS flu pandemic response. However SD and PC did not seem to be part of that package. They have been introduced and assumed to provide a very substantial impact on reducing demand for critical care beds (without considering implications).

The SPI-M Modelling Summary[vii], states that; "little direct evidence is available on the effects of cancelling large public events". There is controversy over the assumption that social distancing of the entire population will achieve a significant reduction in ICU demand/deaths and providing some explanation would have been useful.

Under the most aggressive regime, total deaths are expected to be at 34,000, this presumably implies that lock down will have to continue in an on-off regime until a vaccine and/or drugs are developed, otherwise the main impact of suppression would be to delay rather than prevent deaths.

Without a clearly supported unmitigated epidemic position, there is no way of telling what the marginal benefit is. No account is taken of the associated costs, including the immediate effects of increasing death rates due to the reconfiguration of the NHS, especially the reduction of 128,000 A&E admissions in March 2020 compared with the prior year and the attendant increase in the NHS waiting list.

Reconciling the model projections to actual data

In theory there is ample actual data related to COVID-19 for the UK released both by the Office of National Statistics ("ONS"), Department of Health and Social Care ("DHSC") and reported to the World Health Organisation. Much has been made of the unusually high figure for the UK of approximately 12% deaths to cases versus circa 2% for Germany, South Korea and 2.6% for the Diamond Princess (WHO situation reports).

Many theories have been put forward about testing delays and so forth, however it is plausible that the real answer lies in the definition of deaths "relating to" the coronavirus (COVID-19). The cryptic title reflects the unusual nature of the statistic.

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Looking at the ONS definitions, a COVID related death is one where COVID is mentioned anywhere on the death certificate. In actual fact the death certificate is split into two section, Part I includes diseases directly contributing to death and Part II diseases that do not contribute directly to death.

Adding those together creates a large number, but that number is essentially meaningless as it is a combination of deaths from COVID-19 and deaths contemporaneous with but not due to COVID-19.

Given that ONS is currently not releasing figures on deaths from COVID-19 (Part I), it is necessary to estimate it. It is possible to estimate given that ONS provides the age breakdown of individuals with COVID-19 mentioned on their death certificate by age group. Treating this group (COVID mentioned on the death certificate) as a sample, it is possible to apply the infection fatality ratio from the IC paper in order to estimate the number of deaths that are caused by COVID-19. That gives the following data;

Week number	11	12	13	14	15				
Week ended	13-Mar-20	20-Mar-20	27-Mar-20	03-Apr-20	10-Apr-20				
Deaths involving COVID-19, all ages[1]	5	103	539	3,475		IC infection fatality ratio	IC scaled up to Diamond Princess 1.3%	Expect from COVID from sample	Expect from COVID from sample
Persons [4]									
Deaths by age group					WAV UK	1.23%	1.30%		
<1	0	0	0	0		0.002000%	0.002%	0.00	0.00
1-4	0	0	0	0		0.002000%	0.002%	0.00	0.00
5-9	0	0	0	0		0.002000%	0.002%	0.00	0.00
10-14	0	0	0	0		0.006000%	0.006%	0.00	0.00
15-19	0	0	0	3		0.006000%	0.006%	0.00	0.00
20-24	0	0	0	3		0.030000%	0.030%	0.00	0.00
25-29	0	0	1	5		0.030000%	0.030%	0.00	0.00
30-34	0	0	4	9		0.080000%	0.080%	0.00	0.01
35-39	0	0	3	12		0.080000%	0.080%	0.00	0.01
40-44	0	1	0	11		0.150000%	0.150%	0.00	0.02
45-49	0	0	8	42		0.150000%	0.150%	0.01	0.06
50-54	0	2	9	64		0.600000%	0.600%	0.05	0.38
55-59	0	2	16	137		0.600000%	0.600%	0.10	0.82
60-64	1	2	30	169		2.200000%	2.200%	0.66	3.72
65-69	0	11	42	224		2.200000%	2.200%	0.92	4.93
70-74	1	9	57	402		5.100000%	5.100%	2.91	20.50
75-79	2	11	84	549		5.100000%	5.100%	4.28	28.00
80-84	1	20	97	682		9.300000%	9.300%	9.02	63.43
85-89	0	24	102	617		9.300000%	9.300%	9.49	57.38
90+	0	21	86	546		9.300000%	9.300%	8.00	50.78
					Implied FROM COVID			35.44	230.04
					as % total with COVID			6.6%	6.6%

The infection fatality ratio is drawn from the IC paper, the paper refers to an IFR of 0.9, however multiplying the IFR by age group by UK population statistics gives and all ages IFR of 1.23%. In order to keep assumptions consistent with Diamond Princess outcomes, I have scaled up the IFR of 1.23% to 1.3%. The IC age distribution is taken from Verity et al with adjustments. There could be questions of comorbidity, however the above appears a possible way to estimate deaths from COVID-19 using data on COVID-19 being mentioned on death certificates. The table below presents a possible split of deaths where COVID is mentioned in death certificates to deaths which are caused by COVID 19 (Coronavirus).

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Converting with COVID to from COVID					
week ending		27th March	3rd April 2020		w-o-w
Total deaths all ages		11,141	16,387		5,246
Average over previous 5 years		10,130	10,305		175
Respiratory disease		1,534	2,016		482
COVID mentioned		539	3,475		2,936
Died from COVID		35	230		195
COVID mentioned but not cause		504	3,245		2,741
Total deaths not caused by COVID		11,106	16,157		5,051
% incremental deaths not attributal to COVID					96%

This is supported by a quote from an adviser to the Italian Minister of Health that; "only 12 per cent of death certificates have shown direct causality from coronavirus"viii. Dr. Bhakdi makes the same point; "How then, is a distinction to be made between genuine corona-related deaths and accidental virus presence at the time of death? "[ix]

As far as I am aware there is no reason not to apply the distribution to people with COVID-19, this is what the distribution means for a given sample with the disease (infected not cases). The key issue is that even for those that have it, a large % will not have any symptoms – so to classify them as COVID related death is strange and means that you don't have accurate data to track.

In the event that this analysis is correct then the vast majority of the increase in deaths both over their five-year average and on a week-on-week basis are due to causes other than COVID[x].

In terms of the DHSC figures, there is the same issue there that this relates to people who died, who also tested for the coronavirus. The dataset only relates to hospitals and does not differentiate between deaths due to COVID-19 and death contemporaneous with the coronavirus. In order to reduce the ratio of deaths (as defined by DHSC)/cases to the Diamond Princess level of 2.6% it would be necessary to divide DHSC figures by five.

Moving on to the model

From a common sense perspective the 510,000 unmitigated epidemic fatalities appears high. Compare that number against unmitigated epidemic estimates based on the Diamond Princess which generates a figure of around 160,000;

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Unmitigated pandemic

	Case	Population	% of population infected	% of infected which are symptomatic (cases)	Infection Fatality ration (UFR) on cumulative infections	Case Fatality Ratio (CFR)	Implied deaths
		millions	%	%	%	%	Number
1	IC paper unmitigated epidemic	66.65	80%		0.96%	0.96%	510,000
2	80% but with Bhattacharya IFR (high end)	66.65	80%		0.20%		106,640
3	COVID - Diamond Princess	66.65	17%	49%		2.6%	143,172
4	COVID - Diamond Princess MMWR	66.65	19%	53%		2.4%	161,270
	13						

number from separate SPI-M-O statement 2 March 2020

1 IC number infered to achieve 510,000 (published number 0.9 IFR)

2 COVIFD-19 antibody seroprevalence

3 Morbidity and Mortality Weekly Report 26th March 2020, symptomatic shown as 53% for simplicity instead of 48.6% derived from paper.

4 and infection rate of 19.2% with a total passengers and crew figure of 3,177

There are two studies on the Diamond Princess outcomes, one posted on Eurosurveillance.org and a second study published in Morbidity and Mortality Weekly report[xi] of March 26th 2020. The two data sets are similar, MMMWR shows percentage infection of 19.2% on a population of 3,711 and 53.5% symptomatic and an implied CFR of 2.36%. In this paper I generally used the assumption of 17% infected x 50% symptomatic with a CFR of 2.6% for illustrative purposes.

The IC model includes three key assumptions that drive everything else;

1. % of population being infected = 81%;
2. 0.9% infection fatality ration;
3. The geometric progression for infections, doubling every 5 days, which creates a very sharp curve upwards.

Looking at all the various country developments it appears that there is a geometric exponential progression for an initial period, but tends to slow thereafter (other than the ones reducing to zero, which is a targeting strategy). This pattern is repeated from many countries, irrespective of what mitigation or suppression strategies have been chosen.

The IC model does not provide a deaths per day number under the suppression scenario, but it appears that this number would peak approximately 800 deaths per day (Graph A, 20 x scale down from peak by 34/510 x 66 million/100,000).

For illustration the chart below plots the ONS data on deaths where COVID-19 mentioned on the death certificate, exponential growth with a doubling every five days (deaths will lag infections by around 17.8 days, Verity et al.) and estimate where deaths from COVID-19 run at 6.6% of deaths where COVID-19 mentioned.

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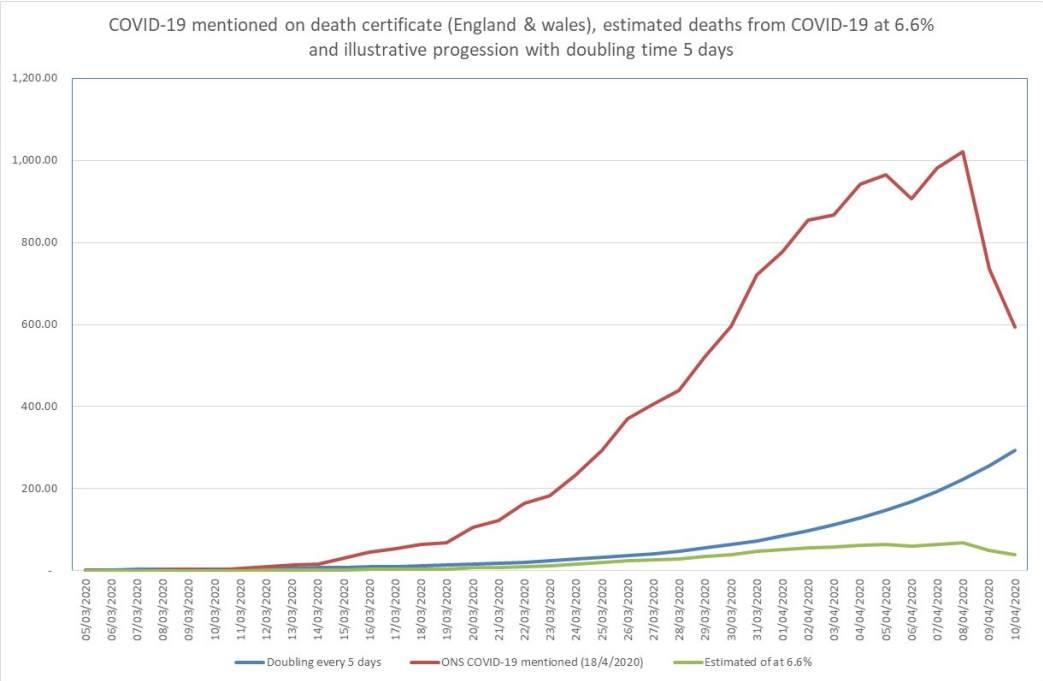
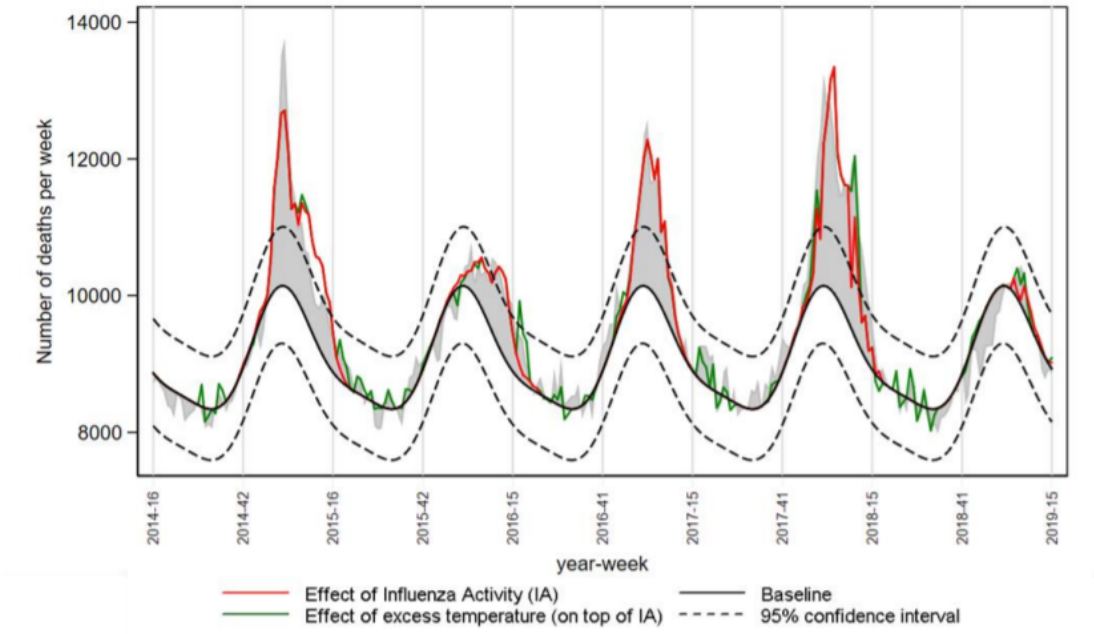


It is clear that the ONS data does not fit with predicted data. The divergence in deaths from COVID-19 estimated at 6.6% of cases where COVID-19 is mentioned versus an exponential growth curve begins after around 25 days.

What NHS capacity is available?

Figure 37. Weekly number of all-age deaths and attribution to influenza (red line) and extreme temperature (green line), England, 2014 to 2019 (up to week 15)



The chart above shows the deviations from baseline deaths caused by influenza [xii]. My understanding is that influenza is based on the WHO code system J00-99 which actually covers pneumonia and related infections. The weekly death data separates out this line item, which is

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labelled as "All respiratory diseases (ICD-10 J00-J99) ICD-10 v 2013 (IRIS)". A recent high occurred for this item during the week ending 12-Jan-2018 where this was equal to 3,075 (daily 439).

The below illustration shows possible ICU capacity requirements for a Diamond Princess predicted death rate over a 1 and 2 year period. The table is for illustrative purposes only:

	1 year	2 year
ICU needs		
Population	66.6	66.6
Infection rate	17%	17%
Symptomatic	50%	50%
CFR	2.60%	2.60%
Total deaths	147,186	147,186
Years to resolve	1	2
Daily plateau	403	202
% at hospital	50%	50%
% outside hospital	50%	50%
Days in ICU	6	6
ICU places needed - negative outcome	1,210	605
ICU places need - positive outcome (50-50)	1,210	605
Total ICU required	2,419	1,210
NHS England capacity (pre surge)	4,122	4,122
NHS scale up to UK (pre surge)	4,946	4,946
% Covid related	48.9%	24.5%
Respiratory deaths daily - Jan 2018 incident	439	439

NHS capacity has (so far) been sufficient to deal with the current wave of COVID-19. The result is consistent with the observation that there is unused intensive care unit (ICU) capacity at several London hospitals.

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There is an open question to what extent the introduction of delays to many operations will have contributed directly to the significant increase in deaths of around 5,000 seen for the w/e 3rd April 2020.

The Health Service Journal identified that 40.9% of acute beds were unoccupied[xiii].

Conclusions and further research

It appears that the model may have significantly overestimated deaths under an unmitigated pandemic scenario. This arises from an infection rate of 81% multiplied by an IFR of 0.9% (actually 0.945%). The history of 0.9% is opaque starting from a death's to cases number of 2.29% in the Verity et al. paper, which is adjusted to an IFR (posterior mode) of 0.657% which is then further adjusted to the IC paper value of 0.9% (0.945% is required to generate a deaths total of 510,000.)

Recent estimates of IFR based on cumulative infections plus resolutions (0.2%) also generate a significantly lower number of deaths in an unmitigated pandemic. This is consistent with data from the Diamond Princess, which generates an IFR of 0.22% assuming full infection.

There are questions as to what extent these assumptions create a RWC scenario. It appears that no countries are showing any pattern resembling the IC unmitigated pandemic scenario with 80% of the population infected within a 2-3 month period, even those with minimal mitigation in pace.

The statistics produced by the UK are somewhat confusing and it is very unusual to link a disease to a death (relating to) without having causality, especially as the data (Part I) of the death certificates is available. It would be useful to have full disclosure of all deaths from COVID-19 to establish this position. It is possible that Germany, Japan and South Korea (for example) are disclosing deaths from COVID-19 rather than related COVID -19 deaths and ending up with deaths/cases of around 2%.

The costs of the lock down policy are reflected in the increase in weekly death figures above their long-term averages, it is not unreasonable to assume that the reconfiguration of the NHS will have contributed to this increase.

Entering into such a significant policy whilst not considering the "ethical or economic implications" as part of the IC paper is unusual, likely any sensible balancing of the pros and cons would show that the policy is not delivering net benefits.

This paper provides an alternative explanation to lower than expected ICU demand and that is the original unmitigated pandemic death estimate was overstated by a factor of 3.5 which lead to a disproportionate policy response. In addition the policy includes assumptions on the efficacy of social distancing without providing evidence to support those assumptions. There are several renowned epidemiologists who have raised questions about the current policies[xivxv].

This paper attempts to shed light over some of the key assumptions. The author believes that it would be useful to provide clarity into those assumptions given their enormous significance. It would also be interesting to understand what the original unmitigated epidemic deaths figure was under a RWC scenario. Presumably, estimates from early March 2020 would have been lower than 510,000 and therefore the original NHS pandemic response guidance was appropriate.

It would be useful to have a peer review and release of the calculation methodology given the importance of the IC paper.

Further, a balanced policy should be identified without the limiting condition that only suppression of ICU demand is considered irrespective of consequences.

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Conflict of Interest

None declared

License, supplementary material and copyright

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Any supplementary material referenced in the article can be found in the online version.

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References

Extracts from ONS definitions and new instructions to Doctors

Table 1: Definitions of COVID-19 deaths between different sources

	DHSC COVID-19 (as published on GOV.UK)	ONS COVID-19 deaths registered	ONS COVID-19 death occurrence (actual date of death)	NHS England
Coverage	UK (however we only include England and Wales breakdowns for comparable coverage with ONS data)	Registrations in England and Wales	Registrations in England and Wales	England
		In discussions with devolved nations to create UK estimates in the near future	In discussions with devolved nations to create UK estimates in the near future	
Inclusion	Deaths in hospitals	Any place of death, including Nursing homes	Any place of death, including Nursing homes	Deaths in hospitals
	Deaths where patient has been tested for COVID-19	Deaths where COVID-19 has been mentioned on the death certificate	Deaths where COVID-19 has been mentioned on the death certificate	Deaths where patient has been tested for COVID-19

[i] https://www.imperial.ac.uk/media/imperial-college/medicine/sph/ide/gida-fellowships/Imperial-College-COVID19-NPI-modelling-16-03-2020.pdf
[ii] https://www.england.nhs.uk/statistics/statistical-work-areas/critical-care-capacity/
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[xiv] https://www.youtube.com/watch?v=bfN2JWifLCY
[xv] https://www.globalresearch.ca/open-letter-professor-sucharit-bhakdi-german-chancellor-dr-angela-merkel/5708004

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