The impact of aggressively managing peak incidence

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11th March 2020

Background

The herd-immunity threshold is breached when the epidemic peaks. At this point there are insufficient susceptibles in the population to sustain chains of transmission. However, in a typical epidemic there are roughly as many cases after the peak (after the herd immunity threshold is crossed) as there are before. That is, epidemics “overshoot” causing roughly twice as many cases that are needed to lead to herd immunity. The overshoot is caused by the very large number of infectious individuals in the population at the peak. Therefore, reducing the prevalence of infectious individuals at the peak will reduce the overshoot.

This short note looks at the impact of aggressively managing the peak, so as to reduce demand on the health system and reduce the size of the epidemic (minimise any overshoot).

Methods

We use the LSHTM age-structured stochastic transmission dynamic model. We chose to illustrate the concepts by picking a single county. Buckinghamshire was chosen as a typical medium-sized county (population 808,000). We model periods of school closure through planned holiday periods (Easter, half-term, summer). Three strategies were modelled:

1) An unmitigated epidemic, in which no additional control policies are implemented.
2) Cocooning of the elderly (65+) and self-isolation. Cocooning is assumed to result in a reduction in “Other” and “Work” contacts (as measured by POLYMOD) to 25% of their normal values. Self-isolation reduces the transmission of clinical cases by 35%. We assume that these strategies are implemented immediately and are in place for 7 months.
3) An aggressive, short-term (3 week) “lockdown” that is triggered when ICU services are being stretched. During a lock-down all contacts occurring outside the household are reduced by 90%. In the example shown here, the trigger is 10 new cases of COVID-19 per week. This strategy is repeated if the threshold is breached again. That is, multiple lockdowns might be triggered.

Sensitivity analyses for the “lockdown strategy” is performed in which different triggers are implemented (5, 10 and 15 cases per week in ICU) and a variable shut down strategy (“Hold”) in which the “lockdown” is held in place until the incidence in is reduced until it is below the threshold again. In the sensitivity analyses, a slightly different background social-distance policy is assumed (“mitigation”) of cocooning of the elderly and social distancing which reduces “work” and “other” contacts for individuals under 65 by 50%.

Results

Figure 1 shows that periodic aggressive measures added onto a background of social distance measures can mitigate the epidemic, preventing ICU services from being overstretched. This occurs at the expense of a longer epidemic, lasting perhaps a year. The overall, impact on the number of cases is dramatic, reducing this appreciably (Figure 2). This is because the prevalence of infectious individuals is never allowed to get very high, so the epidemic does not overshoot.

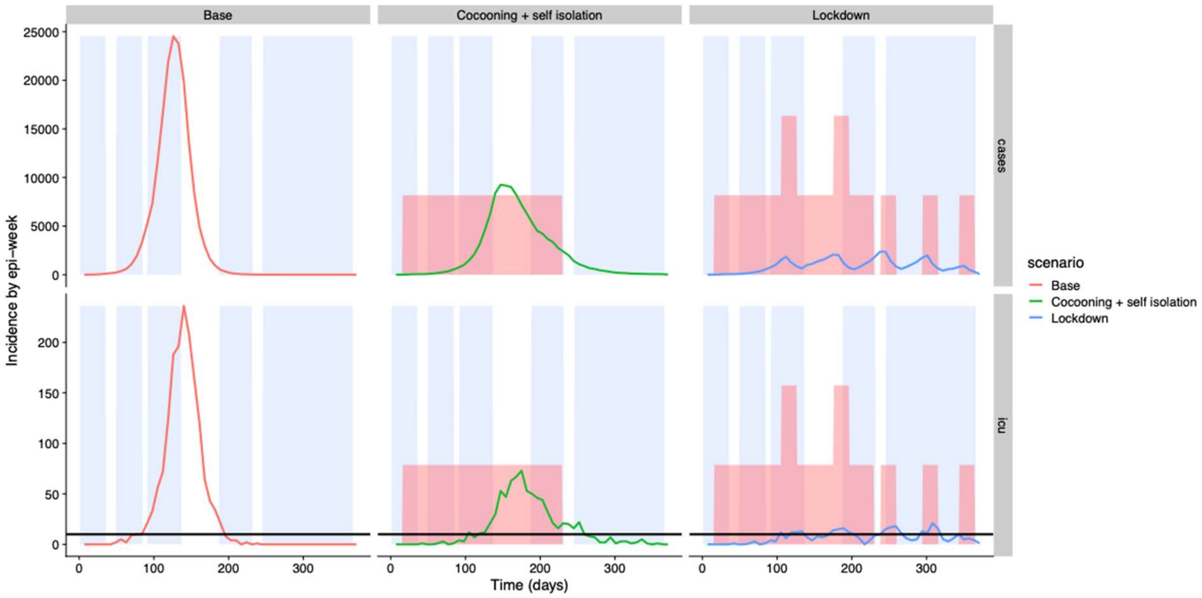


Figure 1: An example model run. The left hand column gives the weekly number of new cases (top) and new ICU beds under the uncontrolled epidemic. The middle column gives the impact of the cocooning and self-isolation. The period when this is implanted is given by the red box. The right-hand panel gives the impact of adding a lockdown when the threshold incidence of new cases (10 per week, given by black horizontal line) is breached. Each period of lockdown is given by a red rectangle. In each figure periods of school holidays are given as white vertical lines.

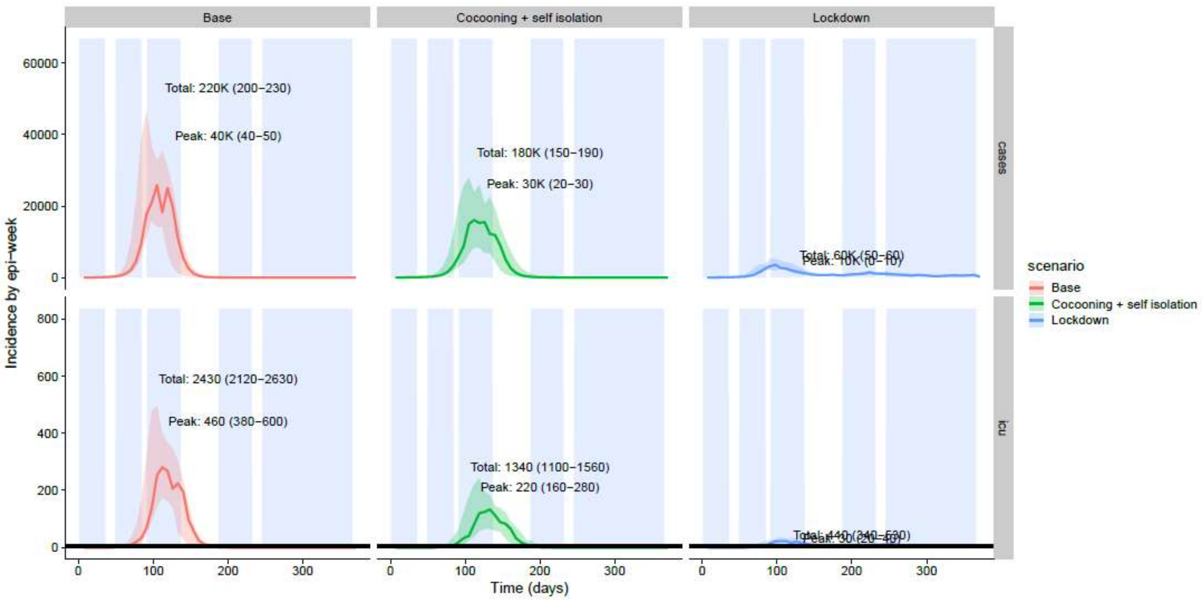


Figure 2: The median epidemic curve (solid lines) and associated CIs are given for the 3 strategies. The total numbers of cases and peak height (top row) and total number of ICU admissions demanded and peak weekly demand (bottom row) is given as text with CIs.

Sensitivity Analyses

The table shows the potential impact of the different strategies on the peak and overall incidence of cases and new ICU beds required. It also shows the number of different lockdowns implemented and the number of days spent in lockdown. As expected the lockdowns reduce the incidence and the variation in the incidence more than the package of mitigation strategies. The lower the trigger, the more effective they are. The "hold" strategies are more effective, but at the cost of considerable period spent in lockdown. The effect on overall number of cases and ICU cases is illustrated in Figure 3. The effect of parametric uncertainty and stochasticity is explored further in Figure 4.

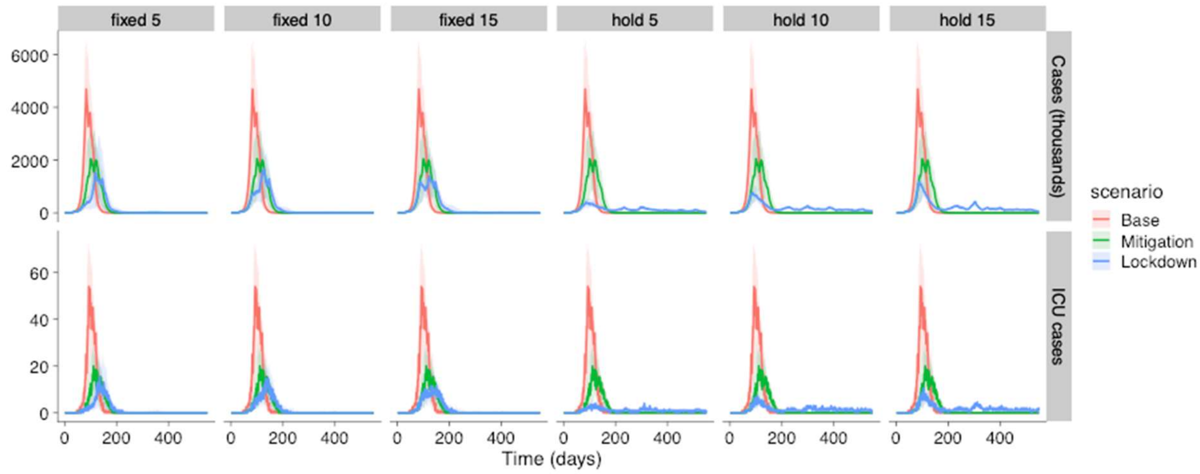
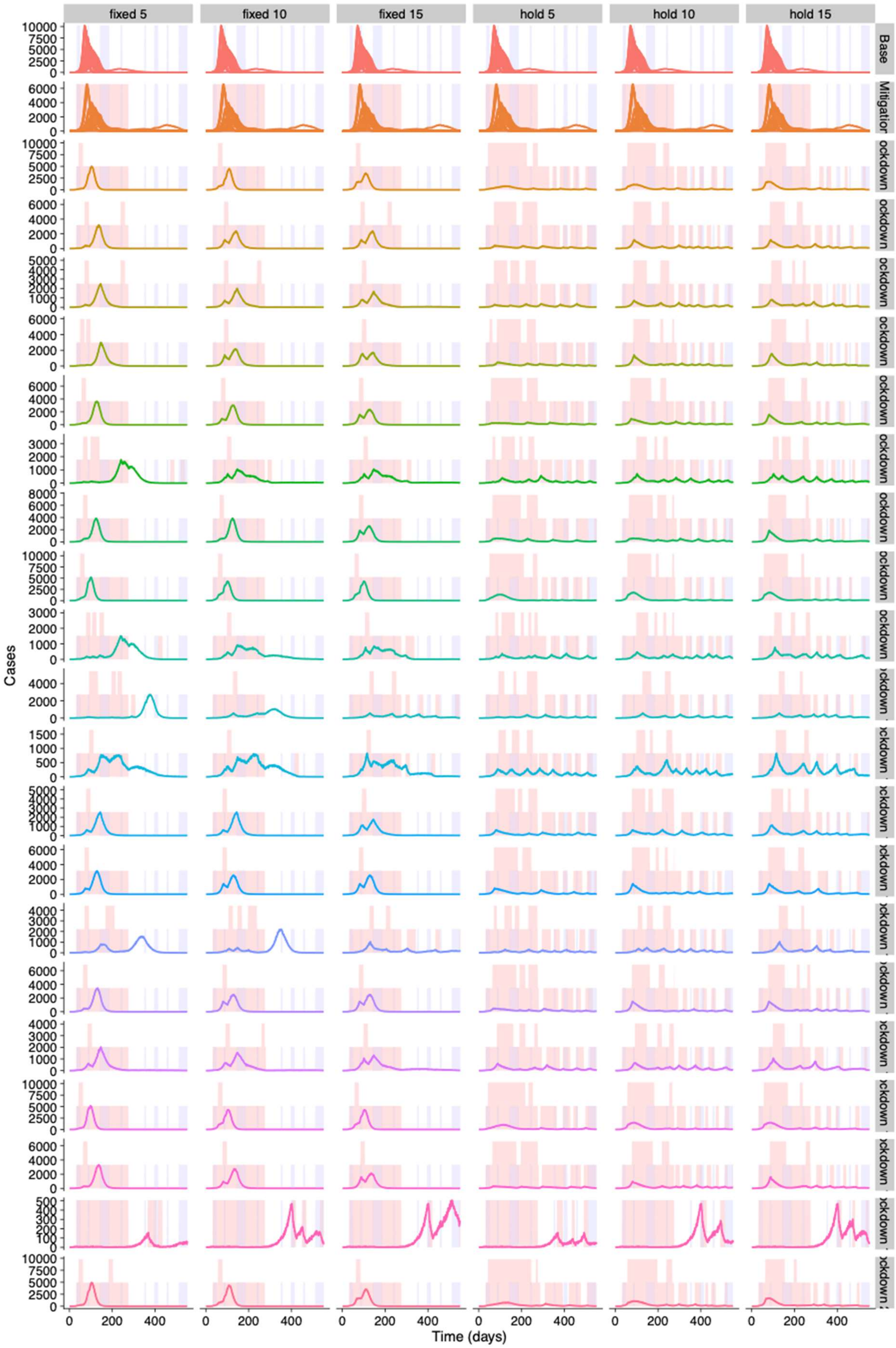


Figure 3: The effect of different triggers of numbers of weekly cases in ICU for a lockdown (5, 10 and 15 cases) and the impact of fixed 3 week period vs variable "hold" periods of lockdown on cases and cases requiring ICU care.

Table

	Scenario	fixed 5	fixed 10	fixed 15	hold 5	hold 10	hold 15
Peak week incidence: cases	Base	41K (33K-49K)	41K (33K-49K)	41K (33K-49K)	41K (33K-49K)	41K (33K-49K)	41K (33K-49K)
	Mitigation	22K (16K-25K)	22K (16K-25K)	22K (16K-25K)	22K (16K-25K)	22K (16K-25K)	22K (16K-25K)
	Lockdown	20K (13K-25K)	16K (9300-22000)	13K (6.7K-17K)	3.1K (2.4K-4.3K)	5.4K (4K-8.1K)	8.5K (5.4K-10K)
Peak week incidence: ICU	Base	460 (330-540)	460 (330-540)	460 (330-540)	460 (330-540)	460 (330-540)	460 (330-540)
	Mitigation	180 (120-220)	180 (120-220)	180 (120-220)	180 (120-220)	180 (120-220)	180 (120-220)
	Lockdown	180 (120-220)	140 (84-190)	120 (57-160)	29 (24-41)	44 (32-70)	60 (40-88)
Total: cases	Base	210K (200K-220K)	210K (200K-220K)	210K (200K-220K)	210K (200K-220K)	210K (200K-220K)	210K (200K-220K)
	Mitigation	160K (130K-170K)	160K (130K-170K)	160K (130K-170K)	160K (130K-170K)	160K (130K-170K)	160K (130K-170K)
	Lockdown	160K (140K-170K)	150K (140K-170K)	140K (120K-160K)	78K (70K-100K)	110K (92K-120K)	130K (110K-140K)
Total: ICU	Base	2400 (2100-2600)	2400 (2100-2600)	2400 (2100-2600)	2400 (2100-2600)	2400 (2100-2600)	2400 (2100-2600)
	Mitigation	1300 (1000-1500)	1300 (1000-1500)	1300 (1000-1500)	1300 (1000-1500)	1300 (1000-1500)	1300 (1000-1500)
	Lockdown	1400 (1200-1600)	1300 (1100-1600)	1200 (1000-1400)	710 (580-930)	980 (760-1200)	1200 (950-1300)
Lockdown days	Base	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
	Mitigation	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
	Lockdown	21 (21-47)	21 (21-42)	21 (21-42)	340 (290-380)	250 (220-260)	170 (160-190)
Lockdown number	Base	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
	Mitigation	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
	Lockdown	1 (1-2)	1 (1-2)	1 (1-2)	7 (5.8-8)	7.5 (7-8)	6 (5.8-6.2)



fixed 5
fixed 10
fixed 15
hold 5
hold 10
hold 15
Base
Mitigation
Cases
Time (days)

Figure 4: Top two rows show the results of 20 stochastic simulations for the uncontrolled epidemic (top row) and mitigated epidemic (second row). The other rows show 20, individual simulations. Each row has the same random number seed and parameter values, and shows a comparison of the impact of the different strategies holding all other things equal. Comparing rows shows the variability that could be expected from parameter uncertainty and stochasticity.

Discussion

The current strategy for the “Delay” and “Mitigation” phases are to delay the epidemic to ease winter pressures and slow the epidemic, so that the peak height and overall size of the epidemic is reduced. However, currently modelled strategies are still predicted to overwhelm NHS services, and result in very large numbers of deaths. A more aggressive management of the peak can reduce demand appreciably and achieve herd immunity without allowing the epidemic to overshoot. However, the most successful strategies are very disruptive to daily lives and therefore the economy, and mean that the epidemic is likely to continue for some considerable time (perhaps a year or more).