Comparison of quarantine and testing strategies to prevent onwards infection from infected travellers returning to the UK from abroad

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Introduction

We consider the number of SARS CoV2 infections potentially resulting from a returning traveller under different quarantine and testing return policy options:

1. 14 day quarantine of the returning traveller.
2. 5 day quarantine of the returning traveller plus PCR test after 5 days and isolation if positive, release if negative.
3. No quarantine of the returning traveller but lateral flow assay (LFA) testing every day for 3, 5 and 7 days. Isolation if positive.

We consider individual travellers returning into their households, and therefore include the effects of within-household contacts during quarantine, during which time household members are not quarantining.

For all scenarios we assume symptoms in any individual prompts PCR testing as per current TTI policy, with isolation on symptoms and contact tracing on positive test results. We assume 100% adherence to quarantine, PCR and LFA testing for comparability in light of little information about adherence to LFA testing. This is not a realistic assumption in practice.

Summary of findings

- We find potentially higher counts of infections resulting from returning travellers for all LFA testing durations as compared to the two quarantine options. Differences within quarantine policies and across LFA testing durations were relatively small.
- We find higher variation in the numbers of resulting infections from LFA testing strategies as compared to the quarantine and quarantine plus PCR test options, though differences in the median number of infections converge across the options over time.
- Our findings are likely sensitive to the distribution of infectious ages at arrival and the timing of when cases are likely to test positive via LFA testing.
- Further analyses would be required to fully interpret the dynamics potentially involved.

Caveats

- We consider a single traveller returning into households matching the distribution of UK households overall. It is possible that travellers might travel in household groups or pairs, which would mean a higher proportion or all household members would be subject to the returning traveller quarantine/testing policy. It is also possible that the demographic profile of current travellers might not be representative of the UK population in general, and therefore that the household size distribution is different.
- We use an LFA testing positivity curve that has been scaled by a relative effectiveness factor found among self-trained but not self-administered members of the public in evaluation [3]. The shape of the curve might not be accurate to LFA detection of positives.
- We assume that infected returning travellers will not travel if they are already symptomatic.
- In practice, the proportion of travellers adhering to quarantine versus LFA testing might change their relative effectiveness in preventing infections.

Methods

We use a household structured branching process model of infection and testing, tracing and isolation/quarantine [1] to investigate the number of infections that could occur from travellers returning to households in the UK for each of the policy options. In our simulations, 'returning travellers' are the starting infections of the branching process. They are assigned an infectious age at arrival, drawing uniformly from 0 days to symptom onset time (if asymptomatic, we draw their infectious age from the same distribution and model the probability of their testing positive as the same as those symptomatic over the time course of their infection). We assume that symptomatic individuals will not be travelling.

We use a household secondary attack rate of 25%. We consider 30% of cases are asymptomatic, with the same relative infectiousness as symptomatic cases in these simulations (though there is considerable uncertainty about these estimates). Travellers return solo into households drawn from a distribution of household sizes representative of the UK. Non-quarantining or isolating individuals make outside household contacts scaled to 60% of what is reported in Polymod to reflect physical distancing. We do not model repeat contacts. The model does not reflect any population immunity.

When nodes develop symptoms for any return policy option they have a delay before booking a PCR test and then a testing delay before receiving their results. They and their household contacts isolate on symptoms and tracing is conducted on positive test results.

Model parameters are given in Table 1.

Test Sensitivity

We assume that the LFA test sensitivity curve is the same shape as the PCR test sensitivity curve [2], Fig 1. When self administered by self-trained members of the public, LFA tests correctly identified 57.5% (95% CI:52.3-62.6%) of cases that were identified by PCR tests [3]. We rescale the curve so that this relationship holds true at all time points. We assume that the test sensitivity curve is the same for asymptomatic infections.

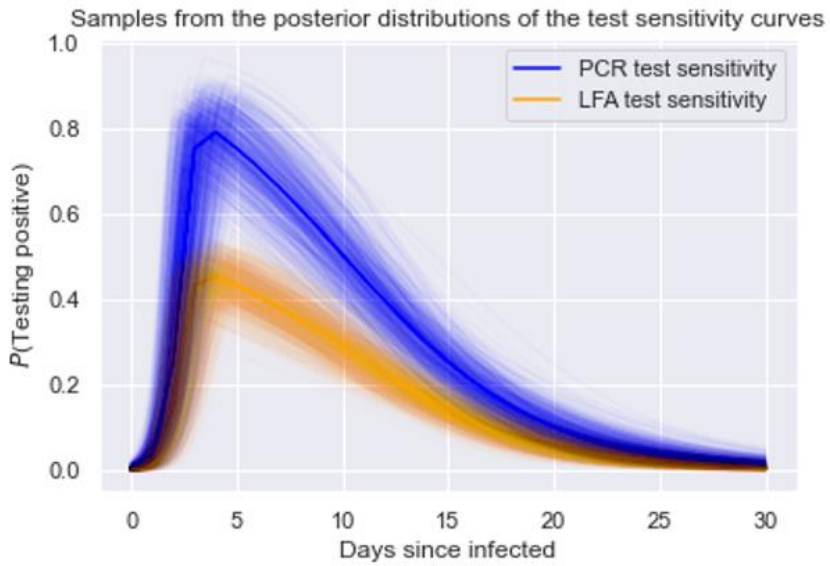


Figure 1: 1000 samples from the posterior distribution of the test sensitivity curve for PCR and LFA

Simulations

We consider 1000 returning travellers (starting infections for the branching process) for each simulation, and run 1000 simulations for each return policy option (including for each LFA testing duration, 5000 in total). We examine the distribution of the number of infections resulting from the infected returning travellers over a period of 25 days for each policy option.

Findings

Figure 2: Numbers of infections over time for each return policy option.

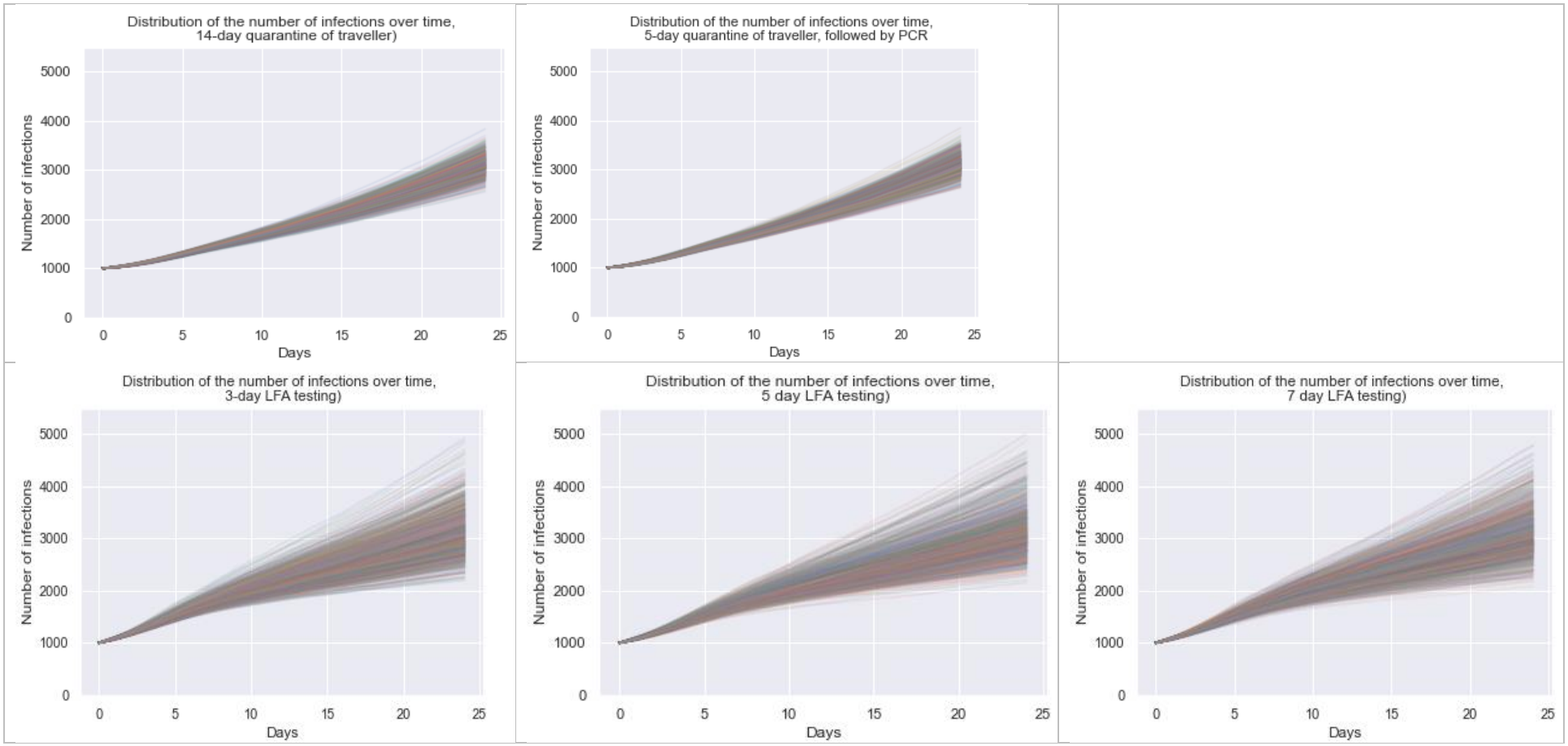
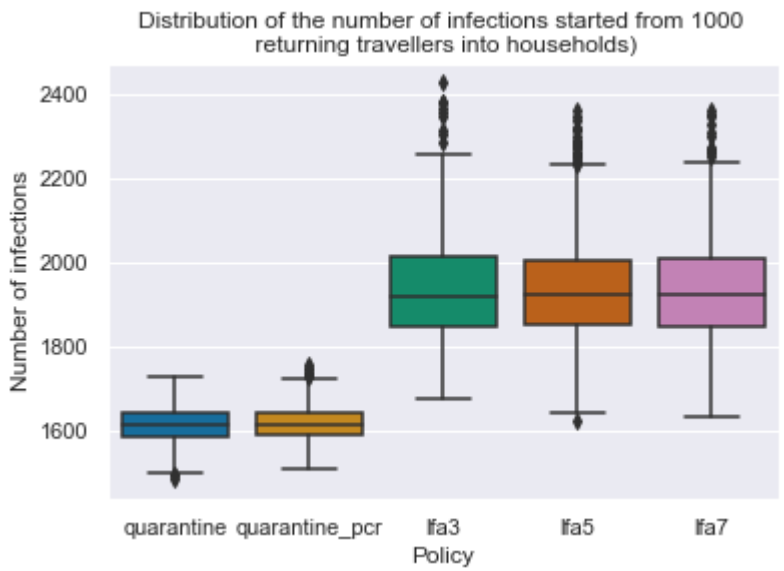
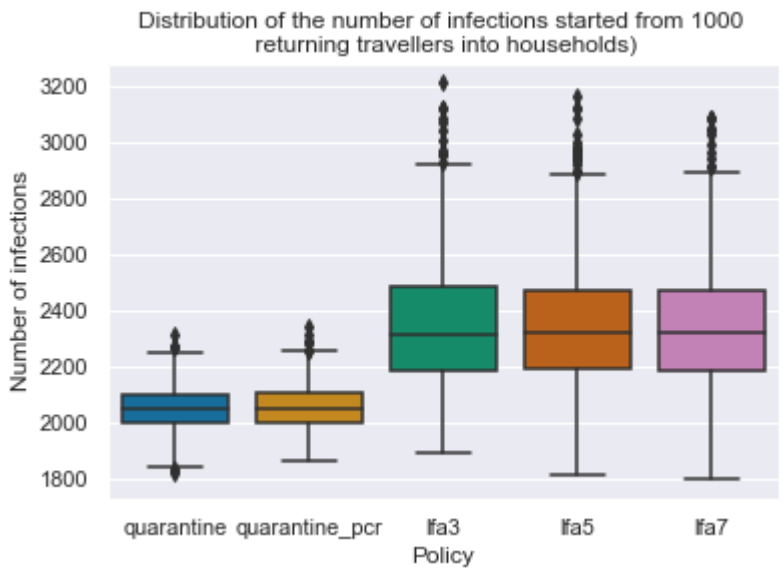


Figure 3: Median, IQR and Range of Number of infected individuals resulting from 1000 starting infections according to each return policy

After 10 days

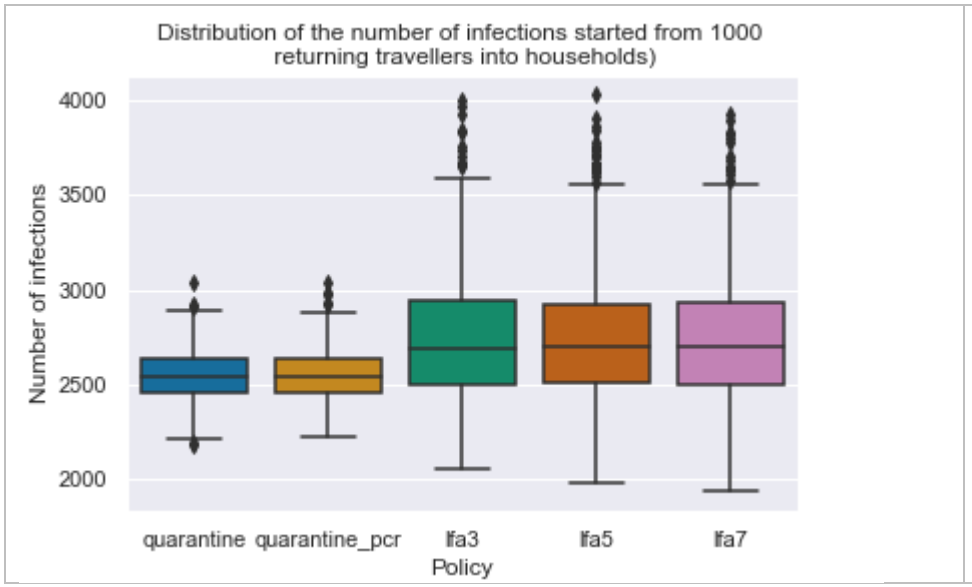


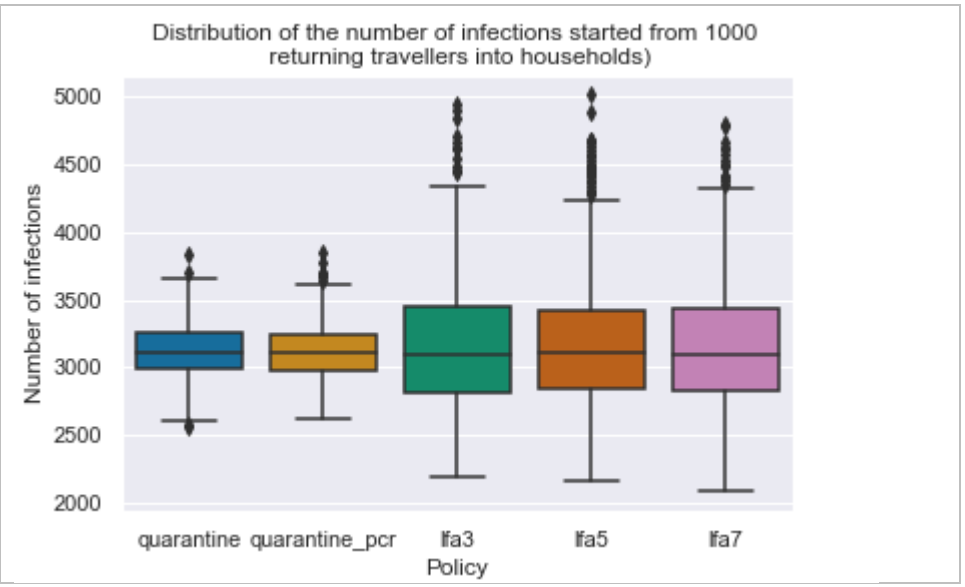
After 15 days



After 20 days

After 25 days


Distribution of the number of infections started from 1000 returning travellers into households)
Number of infections
4000
3500
3000
2500
2000
quarantine
quarantine_pcr
lfa3
lfa5
lfa7
Policy


Distribution of the number of infections started from 1000 returning travellers into households)
Number of infections
5000
4500
4000
3500
3000
2500
2000
quarantine
quarantine_pcr
lfa3
lfa5
lfa7
Policy

Interpretation

With the given set of assumptions, the outcomes of epidemics potentially seeded by infected returning travellers are more variable for the LFA testing options as compared to the quarantine options. As returning travellers do not need to quarantine if they are being LFA tested, this leads to a greater number of infectious contacts being made early on in the epidemic when we compare to a quarantine policy. The effects however interact with the contact tracing model, as the LFA testing possibly leads to earlier detection of the case (ie without all the delays associated with PCR testing and selection of symptomatic individuals who will report their infection). The combination of more infectious contacts being made earlier in the epidemics, alongside more efficient initiation of contact tracing leads to a great deal more stochasticity in the epidemics under the LFA policies. Further investigation would be required to unpick these effects, as well as to investigate scenarios regarding uptake and adherence to each policy, assumptions as to LFA testing sensitivity, and the distribution of infectious ages upon return. Furthermore, the overall effects of the policy would also depend on the travel and household circumstances of returning travellers (whether they travelled with all or most other household members also subject to the return policy, which we do not investigate) and from a population reflecting different household size distributions to the UK average.

Table 1 Parameter values

Parameter	**Values**
Growth Rate (pre-interventions or contact reductions)	0.22 per day (doubling time around 3 days) [6]
Incubation period	Gamma (shape=3.019, scale=1.6 days) [7]
Generation time	Weibull (mean=5, var=1.9^2 days) [8]
Household Size Distribution	(1: 0.29, 2: 0.35, 3: 0.15, 4: 0.14, 5: 0.05, 6: 0.02). Representative of UK as a whole, ONS 2018.
Household secondary attack rate	25% [9,10]
Overdispersion of secondary cases distribution	0.32

Proportion asymptomatic	0.3 [5]
Relative infectivity of asymptomatics	As symptomatic: 1 [5]
Number of social contacts per day	Polymod (within and outside household proportions, by household size) [4]
Reduction in global contacts per day due to physical distancing	60%
Onset to isolation and PCR test booking among untraced symptomatic individuals	Gamma (mean = 2.62, sd = 2.38) [6, data from Singapore]
PCR testing delay (test to result and tracing)	Specimen to report delay, Exponential distribution, mean 1.5 days
Contact tracing delay	Exponential distribution mean 1.5 days
Probability of successfully tracing a contact	0.7
Probability that an untraced symptomatic infected individual reports their symptoms and seeks a test	0.5

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