Technical Document 1:
Estimates concerning COVID-19 infections of patient-facing healthcare workers and resident-facing social care workers in England between 26th April and 7th June, and related estimates.

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Abstract

We use a variety of data sources, including the ONS COVID-19 Infection Survey pilot and the first results of the Vivaldi study of care homes, to estimate the percentage of all (post-incubation) COVID-19 infections in England that were among **patient-facing healthcare workers and resident-facing social care workers**, during the period from 26th April to 7th June. (These are the dates of the relevant release of the ONS Infection Survey pilot.) Using conservative (but plausible) estimates on the numbers of individuals in England in various roles and categories, we estimate that approximately **10%** of all COVID-19 infections in England were infections of patient-facing healthcare workers or resident-facing social care workers, during the above period (95% CI: 4% to 16%). We estimate that approximately **11%** of all COVID-19 infections in England were infections of **hospital inpatients clinically diagnosed with COVID-19**, during the same period (95% CI: 8% to 15%). We also estimate that at least 1% of all COVID-19 infections in England during the period 26th April to 7th June were definitely/probably contracted in hospitals by hospital inpatients, though we caution that this is a very conservative estimate and that the true percentage here could well be significantly higher. Finally, we estimate that approximately **6%** of all COVID-19 infections in England were infections of **care home residents**, during the above period (95% CI: 4% to 8%).

We emphasise that more data is needed to estimate these percentages more accurately, going forward. We draw attention to the fact that our estimates relate only to a fairly late phase of the COVID-19 outbreak in the UK (after 26th April), as we do not have sufficiently reliable data relating to the earlier phase (before 26th April).

1 Introduction, methodology and terminology

Our main objectives in this document are to estimate the percentages of all (post-incubation) COVID-19 infections in England that were (i) among **patient-facing healthcare workers and resident-facing social care workers**, (ii) among **hospital inpatients clinically diagnosed with COVID-19**, and (iii) among **care home residents**, during the period from 26th April to 7th June.

We find (under conservative, but plausible assumptions) estimates of 10% (95% CI: 4% to 16%) for (i), of 11% (95% CI: 8% to 15%) for (ii), and of 6% (95% CI: 4% to 8%) for (iii); a combined percentage of 27% from all these groups. These percentages give an indication of the relative size of that part of the epidemic which was among healthcare workers, social care workers, hospital inpatients and care home residents (as components of the overall epidemic), during May. We note that this is before taking into account the transmission of COVID-19 infections from healthcare workers and social care workers to their contacts in the general community.

In addition, we use some recent retrospective studies of hospital inpatients ([4, 14, 16]) to estimate that at least 1% of all COVID-19 infections in England during the period 26th April to 7th June were

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definitely/probably contracted in hospitals by hospital inpatients (using the officially recognised definitions of 'definitely' and 'probably', in this context). We caution, however, that this is a very conservative estimate and that the true percentage could well be significantly higher.

We remark that in Version 1 of this document (which was circulated privately, from Monday 29th June), we were unable to obtain an exact estimate for the percentage of COVID-19 infections that were infections of care home residents, as the first results of the Vivaldi study [2] of care home residents were only published on Friday 3rd July. In Version 1, we estimated that this percentage was between 2% and 16%, using estimates of the number of COVID-linked deaths among care home residents, and an estimate of the Infection Fatality Rate among care home residents in England. Our current estimate (of 6%) is slightly less than mid-way between our previous lower and upper estimates. Our more accurate estimate for care home residents has also led to a small change in our estimate for patient-facing healthcare workers and resident-facing social care workers; from 9% (in Version 1) to 10% (in this version). It has also led to a small change in our estimate for hospital inpatients clinically diagnosed with COVID-19; from 10% (in Version 1) to 11% (in this version).

We remark also that, unfortunately, we are not able to say at present how our estimate of 10%, for the proportion of infections among patient-facing healthcare workers and resident-facing social care workers, breaks down between patient-facing healthcare workers (on the one hand) and resident-facing social care workers (on the other). The target population of social care workers in the Vivaldi study [2] only consists of those social care workers directly employed by a care home providing care for dementia patients and those over 65; from it, we are able to estimate that at least 2.2% of all COVID-19 infections in England were among resident-facing social care workers directly employed by a care home providing care for dementia patients and those over 65, but the percentage for all resident-facing social care workers in England is probably significantly higher.

For brevity, in what follows we refer to the percentage in (i) as P_W, to the percentage in (ii) as P_D, and to the percentage in (iii) as P_R, the 'W' standing for healthcare/social care **w**orker, the 'D' standing for **d**iagnosed inpatient, and the 'R' standing for care home **r**esident.

To obtain our estimates, we rely crucially on the data from the ONS COVID-19 Infection Survey pilot, regarding the proportions of people (of certain roles or age-groups) ever testing positive for COVID-19 during the period 26th April to 7th June. These proportions are supplied (by the ONS) as point-estimates with 95% confidence intervals. Since the ONS Infection Survey provides no information on COVID-19 infections in institutional settings (such as hospitals, care homes and prisons), it was necessary to estimate these separately, using other sources. To obtain our estimates, it was also necessary to estimate the numbers of people fitting various specifications (e.g., the number of patient-facing healthcare workers in England during the period in question). We can give upper and lower bounds on each of these quantities with a very high degree of certainty, but in some cases we have no justification *a priori* for assuming any particular probability distribution on the intervals between these lower and upper bounds. We therefore give different point-estimates (with 95% confidence intervals) under different sets of plausible assumptions — which we term 'Plausible Scenarios A, B, C'. Plausible Scenario A was designed to give the lowest (i.e., the most conservative) estimate for P_W, though we emphasize that it is still plausible and roughly consistent with our current knowledge. We also emphasize that, roughly speaking, all of our final estimates for P_W are in the same ball park, drawing attention to the importance of developing more effective strategies for suppressing nosocomial incidence and transmission, going forward. This is particularly important as hospitals re-open for visitors and resume greater numbers of elective procedures, more sectors of the economy reopen (increasing the risk of community transmission), and the winter influenza season approaches. As is widely recognised, the winter 'flu season, in addition to the greater strain it will impose on the healthcare system, will lead to an increased prevalence in COVID-like symptoms, which in turn is very likely to reduce the effectiveness of the national Test-Trace-Isolate programme, and to increase the difficulty of correct COVID-19 diagnosis.

We do not attempt, in this document, to estimate accurately the extent of transmission of COVID-19 infection from healthcare workers and social care workers to their contacts in the general community population (such as household-members, friends and fellow-commuters). However, we observe that this transmission is likely to be significant (particularly to household-members), in view of our (conservative) estimate that 10% of all COVID-19 infections were among patient-facing healthcare workers and resident-facing healthcare workers (during the period from 26th April to 7th June). Assuming an average number of 0.9 secondary infections caused by each infected patient-facing healthcare worker and resident-facing social care worker during lockdown (a fairly conservative estimate for this group of people, but one which is in line with the upper estimates of R_0 under lockdown, used by SAGE), at least a further 9% of all infections are likely to have been due to direct transmissions from patient-facing healthcare workers and resident-facing social care workers to their contacts (including both household and non-household contacts). One must bear in mind that many of the close contacts of healthcare workers are themselves healthcare workers (e.g. partners, and some housemates and friends), so there could be some overlap between the 10% and the 9%, but equally, many contacts of healthcare workers are *not* themselves healthcare workers — for example, their elderly relatives and their children, fellow-commuters, and many of their friends.

In what follows, 'testing' always refers to PCR testing for COVID-19 — that is, virus detection by polymerase chain reaction — and never, e.g., to antibody testing for COVID-19. We consider only infections that are post-incubation, since only these infections are directly measured by the ONS Infection Survey pilot. However, as the period we consider is a relatively long one (43 days) compared to the length of the incubation period (which has a median of approximately 5 days, see [17]), including infections that are in the incubation period would not significantly change our final estimates.

We remark that perhaps the largest source of uncertainty in our estimates is that we do not know whether, in the ONS COVID-19 Infection Survey Pilot, members of the general population of working age were much more likely to self-swab incorrectly, than patient-facing healthcare workers and resident-facing social care workers. (The estimates above assume there was a significant difference.)

The remainder of this document is structured as follows. In Section 2, we give an outline of how we estimate the various quantities we need, and the sources used. In Sections 3 and 4, we outline our assumptions, and present our estimates. In Section 5, we outline how our estimate for P_W is very close to an estimate obtained from the Medical Research Council Biostatistics Unit's 'COVID-19 Nowcasting and Forecasting' project (which has independently modelled COVID-19 infection incidence in England); this increases our confidence in our methods and our estimates above.

2 Detailed discussion of methodology and sources

2.1 COVID-19 infections among patient-facing healthcare workers and resident-facing social care workers, 26th April – 7th June

The 25th June release [1] from the ONS Coronavirus Infection Survey pilot states that of those in England residing in the community (i.e., outside institutional settings) who self-reported working in patient-facing healthcare or resident-facing social care roles, **1.92%** ever tested positive for COVID-19 in the period 26th April to 7th June (95% confidence interval: 1.14% to 3.02%). This includes NHS professionals, such as nurses and doctors, as well as social care workers, such as nursing home or home care workers.

We proceed to estimate the corresponding numbers of infections. According to the September 2019 report of Skills for Care, 'The state of the adult social care sector and workforce in England' [12], in 2018, there were approximately 1.49 million social care workers in England (headcount), of whom approximately 76%, or 1.13 million (headcount), are resident-facing, i.e. involve directly providing care. We use this estimate for our period (of 26th April 2020 to 7th June 2020).

From the NHS Workforce Statistics [8], it is apparent that during January 2020, there were at least 905,489 NHS staff in England working in patient-facing roles (headcount), excluding in General Practice. We use this as an estimate for the period 26th April – 7th June.

For General Practice staff, NHS Digital reports that, as of 31st March 2020, England had 44,905 GPs, 24,077 nurses working in General Practice, and 20,681 other staff providing direct patient care in General Practice (headcounts). We add these to the figure of 905,489 above to obtain a total of at least 995,155 NHS staff in patient-facing roles.

In addition, during January 2020, there were 165,373 staff working in Scientific, Therapeutic and Technical roles, from whose job descriptions we were unable to determine whether or not they worked in patient-facing roles. There are also agency staff who are not directly employed by an NHS Trust or by a CCG; such agency staff are not included in NHS England's workforce statistics. We were unable to find a recent estimate for the total number of such agency staff, but we were able to find an estimate of 159,000 agency staff, employed directly or indirectly by the NHS, over the whole of 2018. This figure includes bank staff directly employed by an NHS Trust or by a CCG, who will also be included in the figure of 995,155 we calculated above. Moreover, the figure of 159,000 was over the whole of 2018, and many agency staff will work for the NHS for only part of the year; and NHS Trusts have been directed since 2018 to reduce their reliance on agency staff; these are further reasons why the figure of 159,000 is probably an overestimate for our period. On the other hand, we are aware that many NHS Trusts and CCGs have temporarily increased the number of agency staff they employ indirectly, to cope with the pressures of the COVID-19 outbreak. Nevertheless, we will use 159,000 as an upper bound for the number of agency staff *not* employed directly by an NHS Trust or by a CCG, for our period (of 26th April to 7th June). To obtain an upper bound for the number of patient-facing healthcare workers in England, we add it (together with the 165,373 Scientific, Therapeutic and Technical staff with indeterminate job descriptions) to the above figure of 995,155, obtaining an upper bound of $995,155 + 165,373 + 159,000 = 1,319,528$.

The 1.92% estimate from the ONS Infection Survey pilot, together with our (slightly conservative) estimate of 995,155 NHS staff in patient-facing roles, suggests that in England, there were a total of approximately $(995,155 + 1130000) \times 0.0192 \approx$ **40,800** individuals working in patient-facing healthcare roles or resident-facing social care roles (95% CI: 24,000 to 64,000), ever testing positive between 26th April and 7th June.

2.2 COVID-19 infections among people of working-age in England outside institutional settings (e.g. hospitals, care homes and prisons), and not in patient-facing healthcare roles or resident-facing social care roles, 26th April – 7th June

The 12th June release [1] from the ONS Coronavirus Infection Survey pilot states that among those in England of working age (16 to 64 years old), resident outside institutional settings (e.g. hospitals, care homes and prisons) and not employed in patient-facing healthcare or resident-facing social care roles, the percentage who ever tested positive for COVID-19 between 26th April and 7th June was **0.34%** (95% confidence interval: 0.26% to 0.44%). The working-age population of England is 36.3 million, of whom approximately 34.2 million are not in patient-facing healthcare roles or resident-facing social care roles, so the 0.34% figure for this group represents approximately $34,200,000 \times 0.0034 =$ **116,000** working-age individuals in England, ever testing positive between 26th April and 7th June (95% CI: 89,000 to 150,000).

2.3 COVID-19 infections among people in England not of working age, outside institutional settings, 26th April – 7th June

To estimate this from the previous figures, we assume the same attack-rate, of 0.34%, across all age-groups (among those who are not patient-facing healthcare workers or resident-facing social care workers). It might be thought that this could be a slight overestimate, as during the period of 26th April – 7th June, most of those not of working age and not in institutional settings will have been at home under lockdown, and therefore less likely to become infected than the average person of working age. This would not in fact matter for our purposes, as we are aiming for conservative estimates for P_W and P_D. But in fact, the ONS Infection Survey pilot found no significant difference between attack-rates among those not of working age, versus among those of working age who were not patient-facing healthcare workers or resident-facing social care workers. Indeed, it found the following point-estimates and 95% confidence intervals for the percentages of people in the following age-groups, ever testing positive during the period 26th April – 7th June.

Age-group	Point estimate	95% CI
2-11	0.38%	0.16% to 0.75%
12-19	0.30%	0.11% to 0.66%
50-69	0.33%	0.21% to 0.47%
70 and over	0.34%	0.18% to 0.59%

It is clear that these estimates do not differ significantly from the estimate (of 0.34%, 95% CI: 0.26% to 0.44%) for the general population of working age who are not patient-facing healthcare workers or resident-facing social care workers.

The total population of England is 56.0 million, of whom 36.3 million are of working age and 19.7 million are not. Assuming an attack rate independent of age, therefore, we estimate that there were $19,700,000 \times 0.0034 =$ **67,000** infections in this category of people, between the period of 26th April – 7th June (95% CI: 51,000 to 87,000).

2.4 COVID-19 infections among hospital inpatients and hospital staff in England, 26th April – 7th June

On 26th April, NHS England reported [3] that there were 11,101 patients in hospital in England, diagnosed with COVID-19. During the entire period of 26th April to 7th June, a total of 32,574 patients were admitted to hospitals in England for COVID-19 [3]. In addition to these two groups of patients, between 23rd April and 2nd June, Public Health England [10] reports that 6,837 patients admitted to hospital for other reasons, were diagnosed with COVID-19 while in hospital (this is termed 'hospital onset', as opposed to 'community onset' for patients admitted to hospital with suspected COVID-19). Public Health England also reports 15,345 'unlinked' positive COVID-19 PCR-tests during this period. Many of these 'unlinked' tests will have been on NHS staff, but some were almost certainly on patients in cases where those recording the test result did not know whether the case was 'hospital onset' or 'community onset'. All we can say with certainty is that between $6,837$ and $6,837 + 15,345 = 22,182$ patients admitted to hospital for other reasons, were diagnosed with COVID-19 while in hospital, during the period 23rd April to 2nd June. We assume the same upper estimate for our period (26th April to 7th June), which differs by only three days each side. This is likely to lead to only a small overestimate, given that, in the week commencing 23rd April, 1,989 patients were diagnosed with 'hospital onset' COVID-19 and 4931 unlinked COVID-19 positive PCR tests were recorded (i.e., averages of 284 per day and 704 per day, respectively, each day that week), whereas in the week commencing 28th May, 419 patients were diagnosed with 'hospital onset' COVID-19 and 729 'unlinked' positive COVID-19 PCR tests were recorded (i.e., averages of 60 per day and 104 per day, respectively, each day that week). To summarise, we estimate that the number of clinically diagnosed COVID-19 patients who were inpatients in a hospital in England at some time between 26th April and 7th June, was between $11,101 + 32,574 + 6,837 = 50,512$ and $11,101 + 32,574 + 6,837 + 15,345 = 65,857$.

2.5 Asymptomatic and pauci-symptomatic COVID-19 positive hospital inpatients, 26th April – 7th June

We ignore asymptomatic/pauci-symptomatic hospital inpatients who were admitted to hospital for other reasons than confirmed/suspected COVID-19, were not included in the ONS survey, and were COVID-19 positive while in the hospital in question but were not known or suspected to be so, on the basis that the number of such is likely to be small. Indeed, such individuals are likely to have been true asymptomatics (otherwise they are likely to have been diagnosed in hospital, at some stage). True asymptomatics have been estimated to represent around 18% (95% CrI: 15.5%-20.2%) of all COVID-19 infections [20]. There were (on average, each day) 111,324 hospital beds occupied overnight during March 2020 [9]. Assuming the same level of occupancy for the period 26th April – 7th June (likely an overestimate for non-covid patients), ignoring the fact that many of the occupants would have been confirmed COVID-19 cases, and assuming an attack-rate the same as in the general community (0.34%, as per the ONS Survey), but assuming no turnover, one obtains an upper estimate of $111,324 \times 0.0034 \approx 380$ infections in the above-mentioned group, of whom $380 \times 0.18 \approx 70$ may have been truly asymptomatic. This number can be neglected in the context of the much larger numbers elsewhere.

2.6 COVID-19 infections among care home residents in England, 26th April – 7th June

To estimate the number of COVID-19 infections among care home residents in England between 26th April and 7th June, we use the first results of the Vivaldi study [2], published by the ONS on 3rd July. The target population of the survey was all residents of the 9,081 care homes in England that provide care for dementia patients and for people of aged 65 and over. This population is estimated at 293,301 residents (95% CI: 293,168 to 293,434). The survey estimates that, of this target population of 293,301 care home residents, 10.7% (95% CI: 10.1% to 11.3%) would have tested PCR-positive for COVID-19, over the entire period from 26th April to 19th June. This equates to approximately 31,400 COVID-19 infections. However, the period of 26th April to 19th June is 12 days longer than the period (from 26th April to 7th June) to which our other estimates relate, though the two periods have the same starting-point, of 26th April. We must therefore estimate the number of care home residents who would have tested PCR-positive between 8th June and 19th June, but not before 8th June. The care home residents in this category would have experienced illness onset between 8th June and 19th June. If we assume that the time of illness onset (among those who tested positive at any time over the entire period 26th April to 19th June) is uniformly distributed between those two dates, the number of such would be $\frac{12}{55} \times 31,400 = 6,850$. In reality, this time was almost certainly not uniformly distributed, since it is almost certain that there were more infections towards the beginning of the period, than towards the end (see Section 6), so 6,850 is almost certainly an overestimate. However, since we are aiming for a conservative estimate of P_R, we will use $31,400 - 6,850 = 24,600$ as a lower bound on the number of care home residents in England who would have tested PCR-positive for COVID-19 between 26th April and 7th June. We use 31,400 as an upper bound.

2.7 COVID-19 infections among prisoners in England, 26th April – 7th June

To obtain conservative estimates for P_W and P_D, our priority is to obtain an upper estimate on the number of cases among prisoners. Modelling by Public Health England and HMPPS [21] predicted that, under the mitigation measures that were imminently to be adopted in prisons (regime changes, cohorting and shielding), there would be a total of 2,800 infections among prisoners in England. This is based on a reasonable worst-case scenario (without mitigation measures), followed by an estimate of the impact of the mitigation measures. We assume (to obtain conservative estimates for P_W and P_D) that 2,800 infections occurred before 7th June, and that the only ones occurring before 26th April were those confirmed by PCR testing prior to 24th April (227 confirmed cases, [21]). This yields an upper estimate of $2,800 - 227 = 2,573$ cases, for our period.

2.8 Assumptions on other COVID-19 infections in institutional settings

We ignore COVID-19 infections in all institutional settings other than hospitals, care homes and prisons, on the basis that the number of such infections is likely to be small.

2.9 Sensitivity/specificity of PCR testing

We assume that all PCR tests used to produce the above data have high specificity (see e.g. [11]), so we ignore the issue of false-positives (though, as we will outline in Section 3, assuming lower specificity would only increase our estimates for P_W and P_D). However, it is quite possible that sensitivity (the rate of false negatives) differs significantly depending on who is taking the swabs, so we cannot ignore this issue. There are two sources of insensitivity: the sensitivity of the actual PCR test of the sample, and the possibility that swabs are not correctly taken (leading to negative samples from covid-positive individuals).

Under 'Methods and Further Information', the latest ONS Infection Survey pilot release [1] states:

'We report the number of people testing positive for the coronavirus (COVID-19), which is different from the prevalence rate. To calculate the prevalence rate, we need an accurate understanding of the number of false-negative and false-positive swab results. Currently, we do not have these numbers because tests are still being developed as scientists study the virus. However, by using Bayesian analysis, it is possible to estimate what prevalence could be. Based on similar studies, we think the sensitivity of the test that the pilot study uses is plausibly between 85% and 95% (with around 95% probability) and the specificity of the test above 95%. Sensitivity measures how often the test correctly identifies those who have the virus, so a test with high sensitivity will not have many false-negative results. Specificity measures how often the test correctly identifies those who do not have the virus, so a test with high specificity will not have many false-positive results. In addition to test accuracy, we also need to consider additional false-negative results caused by individuals incorrectly self-swabbing. We do not know how often this occurs. To understand the potential effect, we have estimated what the prevalence rate would be if the test sensitivity was much lower. Based on evidence within the academic literature we estimate this at 60% (or between 45% and 75% with 95% probability).'

An earlier release (5th June) helps to clarify what is meant in the last sentence.

'Based on similar studies and information in the academic literature, we think the sensitivity of the test may be between 85% and 95% (with around 95% probability) and the specificity of the test above 95%. Sensitivity measures how often the test correctly identifies those who have the virus, so a test with high sensitivity will not have many false-negative results. Specificity measures how often the test correctly identifies those who do not have the virus, so a test with high specificity will not have many false-positive results. If these figures are correct, our overall estimate for COVID-19 prevalence in the community-based population would be 0.13% (credible interval: 0.05% to 0.22%), similar to our positivity rate of 0.10%.

In addition to test accuracy, we also need to consider the possibility of additional false-negative results caused by individuals incorrectly self-swabbing. We do not know how often this occurs, but to understand the potential impact we have estimated what the prevalence rate would be if the test sensitivity was much lower. Based on evidence within the academic literature, this has been estimated to be 60% (or between 45% and 75% with 95% probability) and when factored in, the overall estimate for COVID-19 prevalence in the community-based population would be 0.19% (credible interval: 0.07% to 0.35%).'

In the light of the above, in Plausible Scenario A (described in full below, in the next section), we assume that for working-age adults in the ONS Infection Survey pilot, who were *not* in patient-facing healthcare or resident-facing social care roles, the overall sensitivity was 60% (95% CI: 45% to 75%). Plausible Scenario A yields the 'conservative' estimate for P_W that we quote above (in the Abstract, and in Section 1).

As above quotation from the ONS Infection Survey pilot release highlights, it is not yet known how often individuals self-swabbed incorrectly, in the survey. It is, however, plausible that patient-facing healthcare workers and resident-facing social care workers in the ONS survey are somewhat more likely to self-swab correctly, than other working-age individuals in the ONS survey. In Plausible Scenario A, we therefore assume a higher test sensitivity for patient-facing healthcare workers and resident-facing social care workers, in the ONS survey, than for others of working age. Viz., we assume the sensitivity for the former is 90% (95% CI: 85% to 95%). Based on our reading of the ONS Infection Survey release, we believe that the 60% estimate for the sensitivity was a 'reasonable worst case scenario' estimate. Plausible Scenario A may well be somewhat pessimistic in postulating such a large difference between the sensitivity for patient-facing healthcare workers and resident-facing social care workers, and the sensitivity for others of working age; we believe Plausible Scenario C may be closer to the truth (see below). In Plausible Scenario C, we assume a smaller gap between the overall sensitivity for patient-facing healthcare workers and resident-facing social care workers, and the overall sensitivity for others of working age. Viz., we assume the sensitivity for the former is 70% (95% CI: 60% to 80%), and that the sensitivity for the latter is 60% (95% CI: 45% to 75%). Of all our assumptions, those about the sensitivity of the tests in the ONS Infection Survey pilot are those that have the greatest effect on our estimates. However, the effect of these sensitivity assumptions is still limited. Indeed, if we instead assume that the sensitivity of the tests in the ONS Infection Survey pilot are 90% (95% CI: 85% to 95%) for *all* those of working-age (the sensitivity assumption giving the maximum possible estimate for P_W), our point-estimate for P_W only goes up from 10% to 13%. (This is what we have called Plausible Scenario B, below.)

3 Estimates

Plausible Scenario A

This plausible scenario was chosen to give a conservative (but plausible) estimate for the percentage (P_W) of all infections among patient-facing healthcare workers and resident-facing social care workers.

Plausible Scenario A, Assumptions:

1. Self-swabbing + PCR testing of healthcare workers and social care workers (in the ONS Infection Survey pilot) had an overall sensitivity of 90% (95% CI: 85% to 95%), and specificity of 100%.
2. Self-swabbing + PCR testing of those of working-age who were *not* healthcare workers or social care workers (in the ONS Infection Survey pilot) had overall sensitivity of 60% (95% CI: 45% to 75%), and specificity of 100%.
3. Attack-rates in the general community population (among those who are not patient-facing healthcare workers or resident-facing social care workers) did not differ significantly between those of working age, versus those not of working age. (See Section 2.3 for a justification of this assumption.)
4. There were 1.13 million social care workers in England, in resident-facing roles, from 26th April to 7th June.
5. There were 995,155 healthcare workers in England, in patient-facing roles, from 26th April to 7th June.
6. During the period 26th April to 19th June, there were 293,301 residents of care homes in England that provide care for dementia patients and for people of aged 65 and over (95% CI: 293,168 to 293,434). Of these, 10.7% (95% CI: 10.1 % to 11.3%) would have tested PCR-positive for COVID-19 between 26th April to 19th June; this equates to 31,400 individuals. All of the latter would in fact have tested positive within the slightly narrower period between 26th April and 9th June. The tests used here had an overall sensitivity of 90% (95% CI: 85% to 95%).
7. There were 2,573 (post-incubation) COVID-19 infections among prison inmates in England, during the period 26th April to 7th June.
8. We ignore COVID-19 infections in institutional settings in England other than in hospitals, care homes and prisons, during the period 26th April to 7th June, on the basis that the number of such is likely to be small.
9. We ignore asymptomatic/pauci-symptomatic hospital inpatients who contracted COVID-19 in the community, were admitted to hospital for other reasons, were not included in the ONS survey, and were COVID-19 positive while in the hospital in question but were not known or suspected to be so, on the basis that the number of such is likely to be small (see Section 2.5).

We remark that assuming a specificity lower than 100% for PCR testing in the ONS Infection Survey, would actually increase our estimates for P_W (and our estimate for P_D in the next section).

Estimates: These assumptions yield a point-estimate of

$$\begin{aligned} P_W &= \frac{(1130000 + 995155) \times 0.0192 \times \frac{100}{90} \times 100\%}{(1130000 + 995155) \times 0.0192 \times \frac{100}{90} + (116000 + 67000) \times \frac{100}{60} + 65,857 + 2,573 + 31,400 \times \frac{100}{90}} \\ &= \frac{45,300 \times 100\%}{454,000} \\ &= 10.0\% \end{aligned}$$

(95% CI: 4% to 16%).

We draw attention to the fact that the denominator of the above expression (454,000) represents a (conservative, but plausible) upper estimate for **the total number of (post-incubation) COVID-19 infections in England, during the period from 26th April to 7th June**. This number includes both infections in the general community population, and in the institutional settings we consider above — namely, hospitals, care homes and prisons. For brevity, we refer to this number as N, from now on. To be precise, we would obtain a slightly higher estimate for N by assuming a lower sensitivity than 90% for self-swabbing + PCR testing by patient-facing healthcare workers and resident-facing social care workers; we give such an estimate in Section 4.2, below. However, assuming a lower sensitivity would actually increase our estimate for P_W overall, which is not what we want in Plausible Scenario A.

Technical note concerning possible overcounting. It is possible that there may be some overcounting in the above estimate (of 454,000) for the total number of COVID-19 infections in England during our period, due to some individuals being counted in more than one category. This would lead to an estimate for the total number of infections that is slightly too high, and therefore to a slight underestimate for P_W. Since we are aiming for a conservative (lower) estimate for P_W, this does not matter very much for our purposes. We proceed to outline why, in any case, the amount of overcounting is likely to be small compared to the total number of infections involved. The possible overcounting is of hospital patients who were clinically diagnosed with COVID-19 and who also happened to be prison inmates or care home residents, or were included in the ONS Infection Survey. Such patients can be counted at most twice, leading to an overcount of at most 65,857 in the very worst-case scenario; this is still only approximately a seventh of the size of the denominator (454,000), so that (in the worst case scenario) our estimate for P_W above should have been 11.7% rather than 10.0%.

It could also be argued that some of 11,101 inpatients in hospitals on 26th April, who had been clinically diagnosed with COVID-19, could by that point have cleared the infection, while still needing to recover in hospital. We do not actually believe that this represents an overcount, for our broad purposes. Although patients who were recovering in hospital after clearing the infection would no longer have been infectious, they still would have imposed demands on the healthcare system. In any case, the median length of stay in hospital is estimated by Docherty et al [14] to be eight days, and 75% of patients in their (large, stratified) survey were discharged after at most 15 days; this compares with a mean duration from onset until recovery which is estimated at 24.7 days [23]. So the proportion of hospital inpatients fitting the above description (out of all 11,101 inpatients in hospitals on 26th April who had been clinically diagnosed with COVID-19) was probably fairly small.

Plausible Scenario B

In this scenario, we make all the same assumptions as in Plausible Scenario A *except* that we change assumption 2, and instead assume that all the PCR testing concerned has the same sensitivity, of 90% (95% CI: 85% to 95%). This slightly increases our estimate for P_W, relative to Plausible Scenario A.

Estimate: These assumptions yield a point-estimate of

$$P_W = \frac{(1130000 + 995155) \times 0.0192 \times \frac{100}{90} \times 100\%}{(1130000 + 995155) \times 0.0192 \times \frac{100}{90} + (116000 + 67000) \times \frac{100}{90} + 65,857 + 2,573 + 31,400 \times \frac{100}{90}} = 12.9\%$$

(95% CI: 5% to 20%).

Plausible Scenario C

In this scenario, we make all the same assumptions as in Plausible Scenario A *except* that we change assumption 1, and instead assume that self-swabbing + PCR testing of healthcare workers and social care workers (in the ONS Infection Survey pilot) had an overall sensitivity of 70% (95% CI: 60% to 90%), and a specificity of 100%. This slightly increases our estimate for P_W, relative to Plausible Scenario A. Based on personal communications from those involved in the testing programme for NHS staff, we believe Plausible Scenario C is actually more plausible than Plausible Scenario A.

Estimate: These assumptions yield a point-estimate of

$$P_W = \frac{(1130000 + 995155) \times 0.0192 \times \frac{100}{70} \times 100\%}{(1130000 + 995155) \times 0.0192 \times \frac{100}{70} + (116000 + 67000) \times \frac{100}{60} + 65,857 + 2,573 + 31,400 \times \frac{100}{90}} = 12.5\%$$

(95% CI: 5% to 20%).

Scenario D

In this scenario, we adjust our assumptions so as to give an upper estimate on P_W. (This can be seen as a 'sensitivity analysis' of our assumptions above, which we believe are closer to the truth than the assumptions below.) Specifically, we assume here:

1. Self-swabbing + PCR testing of healthcare workers and social care workers (in the ONS Infection Survey pilot) has overall sensitivity of 60% (95% CI: 45% to 75%), and specificity of 100%.

2. Self-swabbing + PCR testing of those of working-age who were *not* healthcare workers or social care workers (in the ONS Infection Survey pilot) had overall sensitivity of 60% (95% CI: 45% to 75%), and specificity of 100%.

3. Attack-rates in the general community population (among those who are not patient-facing healthcare workers or resident-facing social care workers) did not differ significantly between those of working age, versus those not of working age. (See Section 2.3 for a justification of this assumption.)

4. There were 1.13 million social care workers in England, in resident-facing roles, from 26th April to 7th June.

5. There were 1,319,528 healthcare workers in England, in patient-facing roles, from 26th April to 7th June.

6. There were 50,512 hospital inpatients diagnosed with COVID-19, from 26th April to 7th June, and none were care home residents or participated in the ONS Infection Survey. (We note that, even if some had participated in the survey, or been care home residents, our estimate for P_W below would only increase very slightly.)

7. During the period 26th April to 19th June, there were 293,301 residents of care homes in England that provide care for dementia patients and for people of aged 65 and over (95% CI: 293,168 to 293,434). Of these, 10.7% (95% CI: 10.1 % to 11.3%) would have tested PCR-positive for COVID-19 between 26th April to 19th June; this equates to 31,400 individuals. Of these, $\frac{43}{55} \times 31,400 = 24,600$ would have tested positive for COVID-19 between 26th April and 7th June, i.e. in the first 43 days of the 55-day period from 26th April to 19th June. The tests used here had an overall sensitivity of 90% (95% CI: 85% to 95%).

8. There were no (post-incubation) COVID-19 infections among prison inmates in England, during the period 26th April to 7th June.

9. We ignore COVID-19 infections in institutional settings in England other than in hospitals, care homes and prisons, during the period 26th April to 7th June, on the basis that the number of such is likely to be small.

10. We ignore asymptomatic/pauci-symptomatic hospital inpatients who contracted COVID-19 in the community, were admitted to hospital for other reasons, were not included in the ONS survey, and were COVID-19 positive while in the hospital in question but were not known or suspected to be so, on the basis that the number of such is likely to be small (see Section 2.5).

Estimate:

$$P_W = \frac{(1130000 + 1,319,528) \times 0.0192 \times \frac{100}{60} \times 100\%}{(1130000 + 1,319,528) \times 0.0192 \times \frac{100}{60} + (116000 + 67000) \times \frac{100}{60} + 50,512 + 0 + 24,600 \times \frac{100}{90}} = 17.0\%$$

(95% CI: 8% to 28%).

4 Further estimates

4.1 Infection rates of patient-facing healthcare workers and resident-facing social care workers, versus the general working age population

We draw attention to the fact that the ONS Infection Survey pilot data quoted above, suggests that those in patient-facing healthcare roles or resident-facing social care roles were approximately $\frac{1.92}{0.34} \approx 6$ times more likely to test positive for COVID-19 in the survey than the average among the working-age population (95% CI: between 3 and 10 times more likely); a large multiple. Even making the Scenario A assumptions about the sensitivities of the tests in each case (90% for those in patient-facing healthcare or resident-facing social care roles, and 60% for others of working age, leading to a more conservative estimate of this multiple), would suggest that infection-rates among those in patient-facing healthcare roles or resident-facing social care roles were approximately 4 times higher than the average among the working-age population.

4.2 Total number of (post-incubation) COVID-19 infections in England from 26th April to 7th June

We recall that, under Plausible Scenario A, we found an estimate for the total number N of (post-incubation) COVID-19 infections in England between 26th April and 7th June, of

$$N = (1130000 + 995155) \times 0.0192 \times \frac{100}{90} + (116000 + 67000) \times \frac{100}{60} + 65,857 + 2,573 + 31,400 \times \frac{100}{90} = 454,000.$$

(95% CI: 347,000 to 596,000). As discussed in the technical note on page 9, there may be overcounting in this estimate, but certainly by no more than one seventh of the size of the estimate. A more conservative upper estimate (i.e., a higher estimate) would be obtained by assuming a 70% (95% CI: 60% to 80%) overall sensitivity of swabbing + PCR testing for patient-facing healthcare workers and resident-facing social care workers, rather than 90%; the 70% figure is precisely the Plausible Scenario C assumption. It yields an estimate of

$$N = (1130000 + 995155) \times 0.0192 \times \frac{100}{70} + (116000 + 67000) \times \frac{100}{60} + 65,857 + 2,573 + 31,400 \times \frac{100}{90} = 467,000.$$

4.3 Percentage of (post-incubation) COVID-19 infections in England from 26th April to 7th June that were among hospital inpatients

We proceed to give a (conservative, but plausible) estimate for the percentage of all (post-incubation) infections in England from 26th April to 7th June, that were among hospital inpatients clinically diagnosed with COVID-19. (Recall that we refer to this percentage as P_D, for brevity.) Under the same assumptions as in Plausible Scenario A above, but assuming the lower estimate (of 50,152) for the relevant number of hospital inpatients, rather than the upper one (of 65,857), and assuming an overall sensitivity of 70% (95%

CI: 60% to 80%) for the testing of patient-facing healthcare workers and resident-facing social care workers (in order to obtain a conservative, but plausible, estimate for P_D), we obtain an estimate of

$$P_D = \frac{50152 \times 100\%}{(1130000 + 995155) \times 0.0192 \times \frac{100}{70} + (116000 + 67000) \times \frac{100}{60} + 50152 + 2,573 + 31,400 \times \frac{100}{90}} = 11.1\%$$

(95% CI: 8% to 15%).

4.4 Percentage of (post-incubation) COVID-19 infections in England from 26th April to 7th June that were definitely or probably contracted in hospitals by hospital inpatients

The retrospective study of Rickman et al found [16] that a significant proportion all PCR-confirmed cases COVID-19 in a major London teaching hospital between 2nd March and 12th April, met the criterion either for definitely or for probably hospital-acquired infections. Indeed, of 435 cases of PCR-positive COVID-19 inpatients in this six-week period, 47 (11%) met the criterion for definite hospital acquisition, with a further 19 (4%) meeting the criterion for probable (but not definite) hospital-acquisition. (The criterion for definite hospital acquisition is symptom-onset 14 days or more after hospital admission. The criterion for probable hospital acquisition is symptom-onset 7 days or more after admission, *or* documented symptom-onset 5/6 days after admission combined with documented preceding contact with a confirmed COVID-19 case in the hospital.) The much larger (stratified, UK-wide) study of Docherty et al ([14]; see also [4]), concerning 34,130 patients admitted to UK hospitals and clinically diagnosed with COVID-19, found the percentage with symptom-onset 14 days or more after hospital admission (i.e., the criterion for definite hospital acquisition) peaking at approximately 11.7% (during the week beginning 27th April), before going down somewhat, to approximately 5.1% (during the seven-day period beginning 7th May, the last week for which data was available). Moreover, the percentage with symptom onset 7 days or more after hospital admission (and therefore meeting the criterion for either probable or definite hospital acquisition) peaked at approximately 16.5% (during the week beginning 27th April), before going down somewhat, to approximately 10.5% (during the seven-day period beginning 7th May).

This, combined with our estimate for P_D, suggests that at least 1% of all COVID-19 infections in England during the period 26th April to 7th June were definitely or probably contracted in hospitals by hospital inpatients, but we caution that the true percentage could well be higher. Indeed, the study of Docherty et al did not examine the patient-level data sufficiently finely to determine all cases of probable hospital acquisition. Moreover, IPC differs greatly between hospitals, so the study of Rickman et al may not be representative. Reports suggest [10] that London teaching hospitals now have relatively good IPC practises, whereas some other hospitals, such as Weston General Hospital in Weston Super-Mare, and Western General Hospital in Edinburgh, have recently experienced outbreaks (see the main report).

We observe that, since hospital inpatients are likely to be much more vulnerable to severe illness and death than the average member of the population (if exposed to COVID-19), the damage done by these infections would have been disproportionately high.

4.5 Percentage of (post-incubation) COVID-19 infections in England from 26th April to 7th June that were among care home residents

We now to give a (conservative, but plausible) estimate for the percentage of all (post-incubation) infections in England from 26th April to 7th June, that were among care home residents in England. (Recall that we refer to this percentage as P_R, for brevity.) Under the same assumptions as in Plausible Scenario A above, but assuming the lower estimate (of 24,600) for the number of care-home residents testing PCR-positive between 26th April and 7th June, rather than the upper one (of 31,400) — see Section 2.6 — and assuming an overall sensitivity of 70% (95% CI: 60% to 80%) for the testing of patient-facing healthcare workers and resident-facing social care workers in the ONS Infection Survey pilot (in order to obtain a conservative, but plausible, estimate for P_R), we obtain an estimate of

$$P_R = \frac{24,600 \times \frac{100}{90} \times 100\%}{(1130000 + 995155) \times 0.0192 \times \frac{100}{70} + (116000 + 67000) \times \frac{100}{60} + 65857 + 2,573 + 24,600 \times \frac{100}{90}} = 5.9\%$$

(95% CI: 4% to 8%).

We draw attention to the fact that, while 5.9% of all infections may not seem a very large proportion, these infections have clearly caused a disproportionately high number of deaths. Indeed, the ONS reports a total of 18,562 deaths among care home residents, with COVID-19 mentioned anywhere on the death certificate, occurring in England between 2nd March and 12th June, and being registered by 20th June [7]. Hence, the suppression of COVID-19 transmission in care homes (and to care home residents in other settings) is clearly of paramount importance.

5 A comparison with estimates from the MRC BSU 'COVID-19 Nowcasting and Forecasting' project

The Medical Research Council Biostatistics Unit (Cambridge) has independently produced estimates [6] of the total number of new daily infections in England, for each day in our period (and indeed, for each day since the start of the COVID-19 outbreak in England). Using these estimates (and using the ONS Infection Survey only to estimate the number of patient-facing healthcare workers and resident-facing social care workers testing positive), together with data on the distributions of the incubation period and of the duration from illness onset until outcome, we obtain an estimate for the percentage of PCR-positive individuals in England at the beginning of the period of the ONS Infection Survey (i.e., on 27th April), who were patient-facing healthcare workers or resident-facing social care workers. In what follows, we refer to this percentage as Q_W, for brevity. It turns out that our estimate for Q_W (based on the Nowcasting estimates), is very close to the estimates for P_W presented above (under Plausible Scenarios A, B or C). This increases our confidence that these three estimates for P_W are all in the right ball-park.

We note that Q_W is defined slightly differently to P_W, but we believe that the true values of P_W and Q_W are likely to be close to one another, on the basis that over the period from 26th April to 7th June, the number of infected individuals was almost certainly decreasing — both among patient-facing healthcare workers and resident-facing social care workers, and in the general community population in England. In the Appendix, we justify this claim. We remark that we have used the Nowcasting estimates to estimate Q_W (rather than attempting to use them to estimate P_W directly), for several reasons. Firstly, because the ONS data relating to PCR-positivity rates of patient-facing healthcare workers and resident-facing healthcare workers (and others of working age) between 26th April and 7th June, does not appear to be weighted according to when (or how often) samples were taken, so comparing the two (as we have essentially done in our estimates for P_W, above, as well as accounting for smaller contributions from institutional settings) is safer than comparing them with a different quantity calculated from the Nowcasting estimates. Secondly, the Nowcasting estimates are likely to be more reliable as one goes further back in time, as more reliable data regarding contact matrices and precise times and causes of death become available.

The MRC Nowcasting project estimates the daily incidence of new infections in England (regardless of setting, i.e. in both the general community and institutional settings such as hospitals and care homes), on each day since 17th February. (Here, and henceforth, we use the term 'new infection' to refer to the transmission event, i.e. to the start of the incubation period for the newly infected individual.) To obtain from these Nowcasting estimates an estimate of the number of PCR-positive individuals in England on 27th April, we assume the PCR-positivity probabilities (depending on time since exposure) from Lauer et al [18] (see [19] for updated data). Under these assumptions, we estimate (using the Nowcasting estimates) that there were 340,000 PCR-positive individuals in England on 27th April. We remark that, since we do not know the statistical dependencies between the different variables for which confidence intervals are given in the Nowcasting estimates, we cannot give meaningful confidence intervals for this estimate of 340,000, but since our purpose is only to show rough consistency with our estimates for P_W above, we do not view this as a serious issue.

To estimate the number of patient-facing healthcare workers and resident-facing social care workers in England who were PCR-positive on 27th April, we use the estimate from the ONS Infection Survey pilot that, at any given time during the two-week period from 27th April to 10th May, 0.26% of the community population in England would have tested PCR-positive (95% CI: 0.17% to 0.40%). As above, we assume the same attack-rates across all age-groups, among those who are not patient-facing healthcare workers or resident-facing social care workers. (See Section 2.3 for further justification of this assumption.) We recall that the ONS Infection Survey pilot also found that, for the overall period 26th April – 7th June, 1.92% of those in patient-facing healthcare roles or resident-facing social care roles tested positive, compared to 0.34% of those in other roles. To obtain a conservative estimate for Q_W, we assume the same attack-rates among those not of working age as among those of working age. We also assume the same ratio of $\frac{1.92}{0.34}$ for PCR positivities (in patient-facing healthcare workers or resident-facing social care workers, versus others of working age) on 27th April, as over the entire period from 26th April to 7th June. This yields an estimate that, on 27th April, $0.26\% \times \frac{1.92}{0.34} = 1.47\%$ of patient-facing healthcare workers and resident-facing social care workers in England would have tested PCR-positive. Finally, we combine this with our (slightly conservative, but plausible) estimate of the numbers of patient-facing healthcare workers and resident-facing social care workers in England (in Section 2.1), to obtain an estimate that

$$(1130000 + 995155) \times 0.0147 = 31,000$$

patient-facing healthcare workers and resident-facing social care workers in England would have tested PCR-positive on 27th April, had all been tested in the ONS Infection Survey pilot. This, combined with our estimate of 340,000 above, yields an estimate for Q_W of

$$Q_W = \frac{31,000 \times 100\%}{340,000} = 9.1\%,$$

which is remarkably close to our estimates for P_W above.

6 Appendix

Our purpose in this Appendix is to justify the claims made in Section 2.6 and Section 5 that, during the period from 26th April to 7th June, COVID-19 infection prevalence was almost certainly decreasing — both among patient-facing healthcare workers and resident-facing social care workers, in the general community population in England, and among care home residents.

We note first that the ONS Infection Survey pilot data suggests that prevalence of COVID-19 infections in the general community population in England (i.e., those outside institutional settings) was decreasing throughout the period 27th April – 7th June, as can be seen from Table 1 below, taken from the latest ONS Infection Survey release.

Table 1: Estimated percentages (weighted) of the community population in England who were PCR-positive, on any given day during the relevant two-week periods.

Two-week period	Point estimate	95% CI
27th April to 10th May	0.26%	0.17% to 0.40%
11th May to 24th May	0.22%	0.10% to 0.44%
25th May to 7th June	0.05%	0.02% to 0.10%

In addition, all reputable modelling studies of which we are aware, predict that the prevalence of COVID-19 infections in England as a whole was decreasing during the period from 26th April to 7th June; these include (for example) the MRC BU Nowcasting study, and the Imperial College model of Flaxman et al [13]. Since it is very unlikely indeed that infection prevalence in the general community peaked later than infection prevalence in institutional settings, it would follow that the prevalence of COVID-19 infections in the general community population in England was also decreasing, during the period from 26th April to 7th June.

The evidence for a decrease among patient-facing healthcare workers is somewhat sparser, due to the lack of systematic nationwide longitudinal surveillance of healthcare workers over the period in question. However, there is good reason to believe that the shape of the infection incidence curve for patient-facing healthcare workers in England follows roughly the overall shape of the infection incidence curve for England as a whole — and, while there may be a short time-lag between the two curves, this time-lag is almost certain to be less than one month. Given that the peak in new infection incidence in England as a whole almost certainly occurred on (or very slightly before) 23rd March, this would strongly suggest that the peak in new infection incidence among patient-facing healthcare workers almost certainly occurred before 27th April, and probably well before 27th April. We proceed to justify these claims.

Most modelling studies suggest that the peak in new infection incidence for England occurred on or very slightly before 23rd March (on the evening of which day the lockdown was announced with immediate effect). The MRC BU Nowcasting study [6], for example, estimates that the peak in new infection incidence for England was on 23rd March itself. The model of Flaxman et al [13] estimates the same date for the peak.

If most infections of patient-facing healthcare workers take place in the general community (outside hospitals), then one would expect the peak in new infection incidence for patient-facing healthcare workers to coincide with the peak in new infection incidence in the surrounding community, so one would expect no time lag between these two peaks. If, on the other hand, most infections of patient-facing healthcare workers are due to (direct) transmissions from asymptomatic hospital patients who are covid-positive but not known to be so, then, given that the median serial interval of SARS-CoV-2 is estimated at 5.2 days (see [15]), one would expect there to be a time-lag (between the two peaks) of at most a week. If most infections of patient-facing healthcare workers are due to (direct) transmissions from diagnosed covid patients, one would expect the peak in new infection incidence among patient-facing healthcare workers to occur at roughly the same time as the peak in the number of hospital beds occupied by diagnosed covid patients; the latter peak was on 11th April. If there is a very significant amplification effect from transmission between healthcare workers, the delay between the peaks could be somewhat longer. In any case, however, we believe it is very highly likely that the peak in new infection incidence among patient-facing healthcare workers in England occurred before 23rd April, and therefore that the peak in PCR-positivity in this group occurred before 3rd May — and probably a long time before that date. The publicly available evidence, though somewhat sparse, supports the latter view. For example, the preliminary results of the longitudinal study [22] of Treibel et al (of 400 healthcare workers in Barts Health NHS Trust, who were asymptomatic at the start of the study) show rates of PCR-positivity decreasing steadily in the weeks following 23rd March, as shown in Table 2 below.

Table 2: Percentages of healthcare workers testing PCR-positive in the study [22] of Treibel et al.

Week	**% testing PCR-positive**	**95% CI**
23rd March – 29th March	7.1%	4.9% to 10.0%
30th March – 5th April	4.9%	3.0% to 8.1%
6th April – 12th April	1.5%	0.6% to 3.8%
13th April – 19th April	1.5%	0.6% to 3.8%
20th April – 26th April	1.1%	0.4% to 3.2%

This would suggest that the peak in PCR-positivity among frontline healthcare workers in Barts Health NHS Trust could well have occurred at some point during the week beginning 23rd March, or possibly at the start of the next week. Just before the lockdown, the outbreak in London was estimated by SAGE to be between one and two weeks ahead of the outbreak in most other parts of England; adjusting for this delay and extrapolating from the Barts Health study to the rest of England (which may however be questionable, in view of different IPC measures in different Trusts), would suggest that the peak in PCR-positivity among frontline healthcare workers outside London occurred no more than two weeks after 23rd March.

Regarding rates of PCR-positivity over time among care home residents, the ONS release [7] shows that daily deaths of care home residents in England, with COVID-19 mentioned anywhere on the death certificate, peaked on 13th April. It is reasonable to assume the same date for the peak in daily deaths of care home residents where the direct cause was COVID-19. We do not have very precise estimates on the probability distribution of the duration from illness onset until the end of PCR-positivity, or the probability distribution of the duration from illness onset until death, among care home residents specifically (or among those of comparable ages). However, in the general population, the maximum probability of PCR-positivity is estimated to occur typically three days after illness onset [18], with the median duration between illness onset and the end of PCR-positivity being approximately 11 days; this duration is unlikely to be very much longer in the elderly. On the other hand, in the (large, stratified) survey of Docherty et al [4], the median duration from hospital admission until death, for those over 80 who were admitted to hospital with confirmed/suspected COVID-19 and subsequently died in hospital, was just over eight days. It is therefore highly likely that the the peak in PCR-positivity among care home residents in England took place before the peak in the daily incidence of deaths, i.e. before 13th April, and certainly before 27th April.

Regarding rates of PCR-positivity over time among resident-facing social care workers, there is even less data available; we are not aware of any longitudinal studies of rates of PCR-positivity in resident-facing social care workers in England. There is reason to believe that they may follow a somewhat different pattern (or shape) over time than in the general population, as prior to 16th April, COVID-19 outbreaks in care homes may have been seeded by the discharge of patients from hospitals who were asymptomatic or pauci-symptomatic at the time of discharge; new guidelines [5] introduced on 16th April will have curtailed this. (The guidelines stipulated that 'With immediate effect, the NHS now has responsibility for testing patients being discharged from hospital to a care home, in advance of a timely discharge. Where a test result is still awaited, the patient will be discharged and pending the result, isolated in the same way as a COVID-positive patient will be. Hospitals funded by the NHS will need to make the necessary arrangements to implement this.' Many Trusts reportedly adopted this policy somewhat earlier in April, i.e. before 16th April, as testing capacity increased in early April.) Based on the argument in the previous paragraph, we can assume that the number of new daily transmissions of COVID-19 infections from care home residents to resident-facing social care workers peaked on or before 13th April. Even allowing for some amplification from transmission between social care workers, we believe the rate of PCR-positivity among resident-facing social care workers is highly likely to have peaked by 27th April, and probably well before that date.

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