Effect of Implementation of Aerosol Respiratory Protective Equipment, Vaccination and Natural

Infection on a Covid-19 Cohort Ward:

A Retrospective Observational Cohort Study

Dr Matthew Butler¹, Dr Teresa Inkster², Charlotte Foster RN³, Dr Tom Lawton⁴, Dr Eilir Hughes⁵, Dr Huw Waters⁶, Dr Christine Peters⁷

Affiliations & Contributions

1. Consultant Geriatrician, Addenbrookes Hospital, Cambridge University Hospitals NHS Foundation Trust, (Main author, study lead)

2. Consultant Microbiologist, NHS Greater Glasgow and Clyde (Text revisions and discussion)

3. Ward Manager, Addenbrookes Hospital, Cambridge University Hospitals NHS Foundation Trust (Data collection)

4. Critical Care Consultant, Bradford Institute for Health Research (Text revisions and statistical analysis)

5. General Practitioner, Ty Doctor, Ffordd Dewi Sant, Gwynedd (Final review of article)

6. (Text revisions)

7. Consultant Microbiologist, NHS Greater Glasgow and Clyde (Text revisions, discussion and microbiology lead for article)

Corresponding author; Dr Matthew Butler, Addenbrookes Hospital, Cambridge University Hospitals NHS Foundation Trust. Email ; matthew.butler2@nhs.net. Telephone; (01223) 596097

Abstract

Objectives: Transmission routes for SARS-CoV2, include fomites/ surfaces, ballistic droplets and aerosols/airborne. Current infection prevention and control guidance in the UK does not make strong recommendations against the airborne aerosol route perceiving the other routes to be more relevant.

Methods: We conducted a single centre retrospective observational study before and after implementation of enhanced respiratory protection with FFP3 respirators.

Results: There was a 59% reduction in staff absence due to Covid-19 infection from the ten weeks prior vs four weeks post implementation of FFP3 respirators (3.2 vs 1.3 staff off sick per week respectively). This corresponded with a 65% reduction in total days absent from work for the same periods (18 vs 6.25 sick days per week).

Conclusions: Although causation cannot be proven from this study, significant decreases in staff sickness from Covid-19 were observed following FFP3 implementation.

Keywords: Respiratory protective equipment, COVID-19, SARS-CoV2, FFP3, FRSM, personal protective equipment

Introduction

The impact and contribution of SARS-CoV2 transmission routes are hotly debated within the scientific community. The three major routes are 1) fomite and surface spread, 2) ballistic droplets and 3) airborne/inhalable droplets.^{1,2} Guidance issued by Public Health England and the Health and Safety Executive acknowledge the importance of ventilation in reducing transmission by the airborne route.^{3,4} However in terms of respiratory protective equipment, UK infection protection and control (IPC) guidance has focused on routes 1 and 2, accepting that there will be some reduction in airborne spread when using ballistic droplet precautions.⁵ There have been multiple cases of healthcare worker infections with infection rates higher than that of the general population.⁶ A large study conducted at the hospital in this study, utilising genomic sequencing, demonstrated that half of staff infections are likely to be occurring from patients (pre-print; not peer-reviewed).⁷ Multiple studies also highlight a dose-dependent relationship between exposure and likelihood of infection.^{6,8-11} This suggests that current respiratory protective equipment fails to prevent SARS-CoV2 infection in high-risk groups; namely those working on Covid-19 cohort wards, emergency departments and admission units. Emerging evidence has supported the notion that enhanced respiratory protective equipment (RPE) for health care workers, such as FFP2/N95 or FFP3 respirators, may prove beneficial, particularly in a hospital setting.^{12,13}

Methods

This was a single centre retrospective observational study. A total of 53 healthcare workers (nurses and healthcare assistants) were included in the study who worked more than 95% of their allocated shifts on a single Covid-19 red cohort ward within Addenbrookes Hospital, Cambridge University Hospitals NHS Foundation Trust (CUH), between 19th October 2020 and 5th February 2021. During this study period, staff had access to weekly asymptomatic PCR screening for SARS-CoV2 infection. Doctors and other allied health professionals were excluded from the study as their exposure was likely to have been mixed, given that

these staff groups move between other clinical areas. Ten weeks into the study period, enhanced RPE with FFP3 masks was implemented on 22nd December 2020. Fluid resistant surgical masks (FRSM) had previously been in use at the trust on Covid-19 cohort wards. Surgical scrubs & hair protection were also in use throughout the study period; remaining personal protective equipment (PPE) was in line with guidance⁵. For the last two weeks of the study period, a pilot study utilising ultraviolet (UV-C) air filtration began in a single four bedded bay, on the Covid-19 cohort ward (27 beds; 15% of total beds or 1.9% of all bed/days).

Staff sickness data, specific to Covid-19 and determined by PCR positivity from the employee scheduling software, was analysed. Furthermore, a voluntary survey completed by 14 staff members (seven nurses and seven healthcare assistants) was used to evaluate individual experiences of the implementation of enhanced RPE. The survey was also used to collect work schedule data and data on Covid-19 infections and vaccinations. Data for admissions to the hospital were obtained from Public Health England (PHE) online data dashboard (<https://coronavirus.data.gov.uk/>). Immunity was assumed to be 100% after 2 weeks of either vaccination or symptom onset from natural infection and assumed all staff retained immunity for the entirety of the study period.

Statistical analysis was performed in R 4.0.0 (R Core Team, 2020). Time series were constructed using the CausalImpact 1.2.6 library (Brodersen/Hauser, 2021), with a changepoint set one week after the implementation of enhanced RPE to account for the viral incubation period. Analyses were performed both unadjusted, and adjusted for staff immunity as estimated from survey data.

Results

Fourteen staff members (33%) completed the survey, of which twelve provided their work schedule (figure 1A). Four (33%) surveyed staff members (Figure 1A, boxes) and seventeen (32%) staff in total (Figure 1C)

94 became infected with SARS-CoV2, during the study period from the 5th December 2020, confirmed by a
95 positive PCR test. The peak of staff infections preceded the peak period for new Covid-19 patient
96 admissions - those most likely to be highly infectious - by seventeen days, which ran from the 22nd
97 December 2020 to the 30th January 2021 (Figure 1B), for both the hospital and individual Covid-19 cohort
98 ward. Prior to the introduction of FFP3 respirators, it is estimated that only one (8.3%) of the healthcare
99 workers had immunity, owing to previous infection within the last 6 months, based on those who
100 completed the survey. Post-FFP3 implementation, 59% (109 out of 186) of days were worked by staff who
101 remained susceptible to SARS-CoV2 infection. Following the introduction of FFP3 respirators, we observed
102 progressive increases in estimated staff immunity due to natural infection (41.7%) and vaccination (41.7%),
103 as well as decreasing staff sickness to zero sick days in the final two weeks of the study period (Figure 2).
104 There was a 59% reduction in staff absence due to Covid-19 infection from the 10 weeks prior vs 4 weeks
105 post implementation of FFP3 respirators (3.2 vs 1.3 staff of sick per week respectively). This corresponded
106 with a 65% reduction in total days absent from work for the same periods (18 vs 6.25 sick days per week).
107
108 On an unadjusted time-series analysis, the post-intervention period showed a decrease of 54% in staff off
109 sick with Covid-19 (95% confidence interval 16 to 96%, $p=0.004$, Figure 3)). On adjusting to take account of
110 estimated immunity we estimate a reduction of 37% (95% confidence interval 87% decrease to 11%
111 increase, $p=0.07$). In absolute terms this is a reduction in the number of staff off sick with Covid-19 each
112 week of 2.0 (1.6 adjusted) after the intervention (Figure 3).
113
114 Of the 14 staff who completed the survey, three (21%) stated they would like to go back to using FRSM. Of
115 these, two (66%) were not aware of the reason for the change to using FFP3 respirators (increased staff
116 sickness). Of the 11 staff who wished to continue using FFP3 respirators, only one (9%) was unaware of the
117 reason for switching to enhanced RPE. Seven staff members (50%) reported some problems post
118 introduction of FFP3; three (43%) had minor problems related to comfort and one (14%) reported
119 difficulties in obtaining the correct mask, to which they had been fit tested. Of concern, two staff (29%)

reported pressure sores and one (14%) reported difficulty breathing and chest pains. Of the three that reported significant problems, all wished to go back to using FRSM. By the end of the study period, 12 staff members (86%) had been vaccinated (Figure 1A).

Discussion

SARS-CoV2 transmission via fomite/surface spread and ballistic droplet routes have been the main focus of IPC within UK hospital settings. Here we describe the effects of both developing immunity through either natural infection or vaccination, and the implementation of enhanced respiratory protection against aerosol/airborne transmission with FFP3 respirators on staff infections and work absence, due to Covid-19. Whilst a causative link between FFP3 respirator implementation and sickness cannot be concluded, the elimination of staff infections in the final two weeks of the study period, coupled with large numbers of staff remaining susceptible to SARS-CoV2 infection, is reassuring. Even more so in light of some concerns that FFP3 respirators may act as fomites and paradoxically increase transmission.¹⁴ Our estimates are that in the post-intervention period there was a 37% reduction in staff off sick with Covid-19 even accounting for immunity. The effect of this multiplied across the entire NHS in avoiding staff sickness, long Covid, and even death would be enormous

Others have highlighted concerns regarding comfort and difficulties in communication that arise as a result of FFP3 use.^{15,16} In our study it is reassuring that the overwhelming majority of staff members (79%), following eight weeks of enhanced respiratory protection with FFP3, stated their preference to continue their use. This study also highlights the importance of clear explanations being provided to staff prior to implementing changes to PPE guidance locally. Of the three staff members who wished to return to using FRSM, 66% were not aware that increasing staff sickness rates were responsible for the switch to FFP3 in their area. Interestingly, these staff members were also more likely to complain of sores or other symptoms following FFP3 implementation. This may suggest that the reporting of symptoms was made

more likely, if staff had not been made aware of why PPE guidance was changed; i.e. a shift in reporting of discomfort from mild to major by staff members. Importantly, all respondents to our survey were female, which has been reported to be a risk factor for poorly fitting PPE. Whilst renewed focus has been placed on optimising ventilation, it is important to note that it does not mitigate against short-range aerosol transmission, where the concentrations of aerosols is at its greatest. Therefore, the last line of defence - namely RPE - also needs to be optimal.

Whilst causation cannot be inferred from observational studies, there are significant ethical issues posed by conducting a randomised controlled trial (FFP2/3 vs FRSM), for a pathogen widely accepted to transmit through aerosols. Other factors that we did not observe however, may have led to the reduction in staff infections. Immunity in this study was estimated via a survey i.e., staff members aware they had developed Covid-19 or had been vaccinated. This could have missed cases of asymptomatic Covid-19, however all staff at CUH had access to serology testing post the first wave, in addition to weekly PCR swab screening. Other factors might include additional airborne mitigations, in particular the trial of air filtration for the last two weeks of the study period, however it only accounted for 2% of total days exposed. Trust policy also changed on the 7th January 2021 with a focus on improving natural ventilation via a trust-wide email, however staff report very little change on the Covid-19 cohort ward studied owing to the very low external temperatures experienced in January and February 2021.

The time series analysis is clouded by the fact that immunity mediated both by vaccines and infection would decrease the number of staff available to become infected, and lead to a spurious effect when analysed. We have attempted to control for this by providing an analysis adjusting for estimated immunity to provide an estimate of the change that would have been seen if immunity had not been a factor.

FFP3 implementation was followed by declines in staff absences and sick days due to proven Covid-19. This was likely due to a combination of enhanced protection from inhalable droplets/aerosols offered from

172 FFP3 respirators, as well as increasing prevalence of staff immunity following natural infection and, to a
173 lesser extent, vaccination as this occurred later. FFP3 use was associated with increases in discomfort in a
174 minority of staff with some developing pressure sores, highlighting the importance of appropriate mask
175 fitting and barrier skin protection. Appropriate education is required prior to implementing FFP3 to
176 improve tolerability. FFP3 should be considered for health and social care workers treating suspected or
177 confirmed Covid-19 patients, especially healthcare workers at heightened risk from Covid-19 infection i.e.
178 those taking immunosuppressive medications. Enhanced RPE would ideally form part of layered airborne
179 mitigations such as increased use of social distancing and improvements to existing ventilation systems
180 including the use of portable air filtration.

181
182 Conflicts of interest; Nil declared

183
184 Source of Funding; Nil received

185
186 Ethical approval: NA

187
188 Informed consent: Obtained for all staff agreeing to the survey

189
190 Registry and the Registration No. of the study/Trial: NA

191
192 Animal Studies: NA

References

- 1) World Health Organization: Modes of transmission of virus causing COVID-19: implications for IPC precaution recommendations. WHO, Geneva July 2020, <https://www.who.int/news-room/commentaries/detail/modes-of-transmission-of-virus-causing-covid-19-implications-for-ipc-precaution-recommendations>
- 2) World Health Organization: Transmission of SARS-CoV-2: implications for infection prevention precautions. WHO, Geneva 2020, <https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precautions>
- 3) Public Health England. Ventilation of indoor spaces to stop the spread of Coronavirus (COVID-19) [Ventilation of indoor spaces to stop the spread of coronavirus \(COVID-19\) - GOV.UK \(www.gov.uk\)](https://www.gov.uk/government/news/ventilation-of-indoor-spaces-to-stop-the-spread-of-coronavirus-covid-19)
- 4) Health and Safety Executive. [Ventilation and air conditioning during the coronavirus \(COVID-19\) pandemic \(hse.gov.uk\)](https://www.hse.gov.uk/coronavirus/ventilation/)
- 5) COVID-19: Guidance for the remobilisation of services within health and care settings Infection prevention and control recommendations, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910885/COVID-19_Infection_prevention_and_control_guidance_FINAL_PDF_20082020.pdf
- 6) Shields A, Faustini SE, Perez-Toledo M, Jossi S, Aldera E, Allen JD, Al-Taei S *et al.* SARS-CoV-2 seroprevalence and asymptomatic viral carriage in healthcare workers: a cross-sectional study. *Thorax* 2020; **75**:1089-1094. <http://dx.doi.org/10.1136/thoraxjnl-2020-215414>

- 219 7) Illingworth C, Hamilton W, Warne B, Routledge M, Popay A, Jackson C, Fieldman T, *et al.* Superspreaders
220 drive the largest outbreaks of hospital onset COVID-19 infection. 2021;Feb
221 <https://doi.org/10.31219/osf.io/wmkn3>
222
- 223 8) Rivett L, Sridhar S, Sparkes D, Routledge M, Jones NK, Forrest S, Young J *et al.* "Screening of healthcare
224 workers for SARS-CoV-2 highlights the role of asymptomatic carriage in COVID-19 transmission." *eLife* vol.
225 9 e58728. 11 May. 2020, <https://dx.doi.org/10.7554/eLife.58728>
226
- 227 9) Jespersen S, Mikkelsen S, Greve T, Kaspersen KA, Tolstrup M, Boldsen JK, Redder JD *et al.* Severe Acute
228 Respiratory Syndrome Coronavirus 2 Seroprevalence Survey Among 17 971 Healthcare and Administrative
229 Personnel at Hospitals, Prehospital Services, and Specialist Practitioners in the Central Denmark
230 Region, *Clinical Infectious Diseases*, ciaa1471, <https://doi.org/10.1093/cid/ciaa1471>
231
- 232 10) CDC COVID-19 Response Team. Characteristics of Health Care Personnel with COVID-19 - United States,
233 February 12-April 9, 2020. *MMWR Morb Mortal Wkly Rep.* 2020;**69**(15):477-481. Published 2020 Apr 17.
234 doi:10.15585/mmwr.mm6915e6
235
- 236 11) Eyre DW, Lumley SF, O'Donnell D, Campbell M, Sims E, Lawson E, Warren F, *et al.* Differential
237 occupational risks to healthcare workers from SARS-CoV-2 observed during a prospective observational
238 study, *eLife* 2020;**9**:e60675 <https://doi.org/10.7554/eLife.60675>
239
- 240 12) MacIntyre CR, and Chughtai AA. "A rapid systematic review of the efficacy of face masks and
241 respirators against coronaviruses and other respiratory transmissible viruses for the community,
242 healthcare workers and sick patients." *International Journal of Nursing Studies* vol. **108** (2020): 103629.
243 doi:10.1016/j.ijnurstu.2020.103629
244

13) Klompas M, Baker M, Griesbach D, Tucker R, Gallagher G, Lang A, Fink T, Cumming M, Smole S, Madoff L, Rhee C, Transmission of SARS-CoV-2 from asymptomatic and presymptomatic individuals in healthcare settings despite medical masks and eye protection, *Clinical Infectious Diseases*, 2021;, ciab218, <https://doi.org/10.1093/cid/ciab218>

14) M. Garcia-Haro, C. Bischofberger Valdés, J. Vicente-Guijarro, C. Díaz-Agero Pérez, M. Fabregate-Fuente, P. Moreno-Nunez, J.M. Aranaz-Andrés. Decontamination of filtering facepiece respirators using a low-temperature-steam–2%-formaldehyde sterilization process during a pandemic: a safe alternative for re-use. *Journal of Hospital Infection*. 2021;**108**:113-119

15) Rammohan R, Varadarajan V, Mohaanty K. 2020 [Unmasking problems due to disposable FFP3 masks: Snapshot survey on FFP3 masks usage by frontline healthcare professionals during COVID-19 pandemic \(boa.ac.uk\)](https://boa.ac.uk)

16) Swaminathan R, Mukundadura BP, Prasad S. Impact of enhanced personal protective equipment on the physical and mental well-being of healthcare workers during COVID-19, *Postgraduate Medical Journal* Published Online First: 03 December 2020. doi: 10.1136/postgradmedj-2020-139150

264 **Figure 1) A.** Days worked by staff on Covid-19 cohort ward (exposure); light grey = susceptible to SARS-
265 CoV2, dark grey = immunity to infection from SARS-CoV2 (>14 days post symptom onset or vaccination), x
266 = symptom onset, black = SARS-CoV2 PCR positive, black boxes = 14 days isolation post Covid-19 symptom
267 onset, V = Pfizer/BioNTech SARS-CoV2 (BNT162b2) first dose vaccination. **B.** SARS-CoV2 / Covid-19 hospital
268 admissions to the hospital (top), Covid-19 cohort ward (middle) and percentage of new admissions of total
269 admitted onto Covid-19 cohort ward (bottom). **C.** Staff sickness by number of staff absent (top) and
270 number of days absent due to SARS-CoV2 / Covid-19 (bottom). White to black scale utilizing 50th
271 percentile as the midpoint (grey), black arrow indicates implementation of FFP3 respirators at the hospital.

272
273 **Figure 2)** Sick days due to SARS-CoV2 / Covid-19 (dark grey bars) and immunity as percentage of all staff
274 (dashed grey line) as estimated from staff survey; >14 days post symptom onset with PCR proven infection
275 with SARS-CoV2 and vaccination; by week. Black arrow indicates implementation of FFP3 respirators at the
276 hospital, grey rectangle/arrow = potential incubation period for SARS-CoV2 infection acquired prior to FFP3
277 implementation, V = start of vaccinations on 11th January.

278
279 **Figure 3)** Time series analysis of staff off sick with COVID-19. Vertical line denotes the candidate
280 changepoint a week after the FFP3 implementation (to account for incubation)

281

Figure 1

Figure 2

287

288

289

290 *Figure 3*