


Management of a large outbreak of COVID-19 at a British Army training centre: lessons for the future

Matthew Routledge ^{1,2} J Lyon,³ C Vincent,⁴ A Gordon Clarke,⁵ K Shawcross,⁶ C Turpin,⁷ H Cormack,⁸ S C Robson,^{9,10,11} A Beckett,¹⁰ S Glaysher,¹² K Cook,⁹ C Fearn,⁹ S Goudarzi,⁹ E J Hutley,¹ D Ross¹³

¹Defence Pathology, Royal Centre for Defence Medicine, Birmingham, UK

²Medical Officer, 254 Medical Regiment, Cambridge, UK

³Senior Medical Officer, Royal Military Academy Sandhurst, Camberley, UK

⁴Medical Planner, HQ Army Recruiting and Initial Training Command, Pewsey, UK

⁵XO, HQ Army Recruiting and Initial Training Command, Pewsey, UK

⁶Environmental Health, Medical Branch, Head Quarters Regional Command, Aldershot, UK

⁷ACOS, Royal Military Academy Sandhurst, Camberley, UK

⁸Chief of Staff, HQ Army Recruiting and Initial Training Command, Pewsey, UK

⁹School of Pharmacy & Biomedical Science, University of Portsmouth, Portsmouth, UK

¹⁰Centre for Enzyme Innovation, University of Portsmouth, Portsmouth, UK

¹¹School of Biological Sciences, University of Portsmouth, Portsmouth, UK

¹²Research & Innovation, Queen Alexandra Hospital, Portsmouth Hospitals University NHS Trust, Portsmouth, UK

¹³Parkes Professor, Army Medical Services, Camberley, UK

Correspondence to

Matthew Routledge, 254 Medical Regiment, Cambridge CB1 8HQ, UK; matthew.routledge@doctors.org.uk

Received 11 August 2021

Accepted 7 October 2021



© Author(s) (or their employer(s)) 2021. No commercial re-use. See rights and permissions. Published by BMJ.

To cite: Routledge M, Lyon J, Vincent C, et al. *BMJ Mil Health* Epub ahead of print: [please include Day Month Year]. doi:10.1136/bmjilitary-2021-001976

ABSTRACT

Introduction The COVID-19 pandemic has posed major challenges for infection control within training centres, both civilian and military. Here we present a narrative review of an outbreak that occurred at the Royal Military Academy Sandhurst (RMAS) in January–March 2021, in the context of the circulating, highly transmissible SARS-CoV-2 variant B.1.1.7.

Methods Testing for SARS-CoV-2 was performed using a combination of reverse transcriptase PCR and Lateral Flow Devices (LFDs). Testing and isolation procedures were conducted in line with a pre-established symptom stratification system. Genomic sequencing was performed on 10 sample isolates.

Results By the end of the outbreak, 185 cases (153 Officer Cadets, 32 permanent staff) had contracted confirmed COVID-19. This represented 15% of the total RMAS population. This resulted in 0 deaths and 0 hospitalisations, but due to necessary isolation procedures did represent an estimated 12 959 person-days of lost training. 9 of 10 (90%) of sequenced isolates had a reportable lineage. All of those reported were found to be the Alpha lineage B.1.1.7.

Conclusions We discuss the key lessons learnt from the after-action review by the Incident Management Team. These include the importance of multidisciplinary working, the utility of sync matrices to monitor outbreaks in real time, issues around Officer Cadets reporting symptoms, timing of high-risk training activities, infrastructure and use of LFDs. COVID-19 represents a vital learning opportunity to minimise the impact of potential future pandemics, which may produce considerably higher morbidity and mortality in military populations.

INTRODUCTION

The COVID-19 pandemic has posed major challenges for those managing institutional outbreaks, both within the civilian and military context.¹ In the UK, cases began to emerge in January 2020, peaking in mid-April, then declining to low levels in the summer months.² In September 2020, cases began to rise again in a second wave of cases/deaths that surpassed the first. Cases peaked in the first week of January 2021 before declining. This second wave saw the emergence of a new highly transmissible variant (the Alpha lineage B.1.1.7) first identified in South East England in September 2020.³ The outbreak described here occurred during this second UK wave.

Infection control in military training centres poses similar challenges to other large institutions

Key messages

- ▶ Multidisciplinary working with a broad range of stakeholders is key to successful outbreak management.
- ▶ Using a shared, live sync matrix to track cases is invaluable.
- ▶ There will inevitably be situations where the needs of infection control and training conflict.
- ▶ Taking account of transmission dynamics of SARS-CoV-2 when planning training activity can help reduce its spread.
- ▶ Physical infrastructure is crucial when controlling outbreaks. Training centres in future should be designed with this in mind.

with captive populations (eg, care homes, prisons). However, they differ in that, like other educational centres (eg, schools, universities), a balance needs to be struck between optimising infection control and facilitating education/training. An inability to train military personnel has substantial downstream effects on defence and national security. We present this outbreak, and the lessons drawn from it for the interest of the wider infection control community. They are particularly relevant to those responsible for training centres that cannot rely on virtual learning alone.

METHODS

Setting

Royal Military Academy Sandhurst (RMAS) is responsible for initial officer training within the British Army. It is based on a ~44-acre site in the town of Sandhurst, Berkshire in South East England. It hosts residential commissioning courses with an annual intake of ~1000 Officer Cadets. Predominantly, Officer Cadets are UK citizens, but there is also a cohort of international cadets. At the time of the outbreak, RMAS was hosting 111 international cadets, representing 44 countries. The mean age of the cadets was 26 years (range 19–31) with a 16:1 M:F ratio. It also hosts a cadre of instructing staff who are resident on-site (mean age 32 years, range 20–66).

The largest cohort of Officer Cadets attend the 44-week regular commissioning course which is taught in three separate terms (designated Juniors, Intermediates and Seniors). At any one time there are cadets from all three terms on-site.

Officer Cadets are divided into Platoons comprising roughly 30 personnel. Three Platoons are organised into a Company. Junior Companies lived in Old College and the Intermediate/Senior Companies in New College and Victory College. Old College is a Greek Revival style building and New College is a large Edwardian building. Both have large sash windows and good ventilation. Victory College is a 1960s style building with small windows and relatively poor ventilation. The Academy established an isolation facility for positive cases. This was a purpose-built accommodation block with each room providing ensuite facilities, the only such area on the campus.

In general, Companies and Platoons live and train in isolation, being brought together only for large outdoor exercises.

Laboratory testing

Testing for SARS-CoV-2 was performed using either reverse transcriptase PCR or Lateral Flow Devices (LFDs). PCR testing was performed on combined nasal and throat swabs using the Hologic Panther Fusion platform, with sampling performed by trained medical staff. PCR was performed for all Officer Cadets/staff members presenting with symptoms. Innova LFDs were used for the initial day 0 and day 7 screening (described below) and during the enhanced case finding phase of the outbreak (ie, testing of asymptomatic individuals). They were self-performed under observation by trained RMAS staff in accordance with the manufacturer standard operating procedure. Towards the end of the outbreak, PCR was conducted in the Defence COVID-19 Laboratory using in-house E gene and Taqpath Thermofisher assay.

Whole genome sequencing

As the majority of tests were performed using the Panther Fusion PCR platform or LFDs, most samples were not available for genomic sequencing of SARS-CoV-2. Due to the restricted sequencing capacity nationally at the time of the outbreak, only sequencing for the first 10 positive cases was able to be undertaken.

Whole genome sequencing of samples was performed by the COVID-19 Genomics UK Consortium (COG-UK) at the University of Portsmouth sequencing site. Sequencing was performed using the ARTIC nCOV-2019 sequencing protocol V.3 (LoCost), using primers from Integrated DNA Technologies (Iowa, USA).^{4,5} Samples were sequenced on a GridION X5 system (Oxford Nanopore Technologies, UK) along with a synthetic positive control (Twist Biosciences, USA) and a nuclease-free water negative control. Analysis of the resulting data was performed using the ARTIC fieldbioinformatics toolkit V.1.2.1 (<https://github.com/artic-network/artic-ncov2019>). Lineage assignment for resulting consensus sequences was conducted using Pangolin (<https://github.com/cov-lineages/pangolin>) with PANGOLearn V.2021-04-21.⁶ Resulting consensus sequence fasta files and mapped read BAM files were deposited in the European Nucleotide Archive, and high-quality (>90% coverage) consensus genome files were deposited in the Global Influenza Surveillance and Response System Database.

Infection control precautions

Prior to the outbreak, training was performed in Platoon households to minimise interaction. Infrastructure limited the ability to house Platoons in separate compounds. In general, Platoons

Epidemic curve of RMAS outbreak

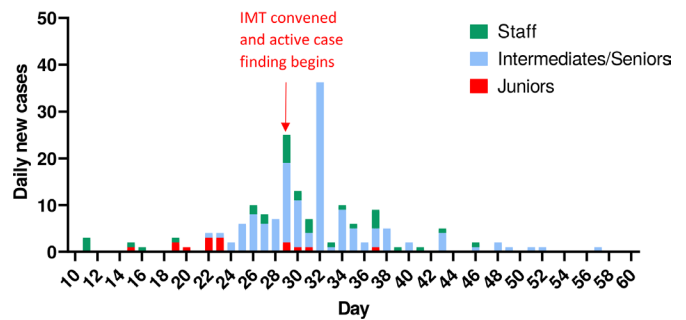


Figure 1 Epidemic curve showing daily number of new cases across the duration of the outbreak. Day of new case was defined as day of cases first positive test (either LFD or PCR). The majority of cases were in Intermediate/Senior Officer Cadets. Smaller, probably unrelated, outbreaks occurred in the Juniors and Staff groups. IMT, Incident Management Team; LFD, Lateral Flow Device; RMAS, Royal Military Academy Sandhurst.

shared communal ablutions, apart from the dedicated isolation facility, as described above. Face masks were worn indoors.

RESULTS

Narrative of the outbreak

The course of the outbreak is summarised in [Figure 1](#) and [Table 1](#). What follows is a narrative description of the outbreak, its investigation and management.

Officer Cadets returned from a 3-week holiday break to RMAS in January 2021. This coincided with the eventual peak of the second UK wave. They entered an initial 14-day period of controlled monitoring where 2m social distancing measures were rigorously enforced. LFD testing was performed on day 0 (arrival) and day 7. Officer Cadets were not permitted to leave the site apart for medical emergencies and exercises. Some had travelled abroad during the holidays prior to their return to RMAS, but were subject to national requirements for travel and quarantine.

Day 0 and 7 testing each returned a single positive case, with both isolated. On day 11, three symptomatic staff members were tested, found to be positive and isolated. Over the following days, three further symptomatic staff cases presented.

No other positive cases were identified. On day 14, controlled monitoring was lifted and, where necessary for training, Officer Cadets were permitted to break 2m social distancing within their Platoon households. Social distancing remained between the different Platoons.

On day 18, a symptomatic Officer Cadet in Juniors Platoon 1 presented and was tested. Platoon 1 began isolation on day 21, when a positive result for that Officer Cadet was received.

Table 1 Characteristics of positive cases

	Population	Total positive cases (% group)	PCR positive (% of positives)	LFD positive (% of positives)
Juniors	258	15 (6*)	12 (80)	3 (20)
Intermediates/Seniors	454	138 (30*)	58 (42)	80 (58)
Staff	483	32 (7*)	30 (94)	2 (6)
Total	1195	185 (15)	100 (54)	85 (46)

*Denotes statistical significance between individual groups and overall total, based on 95% CI of total percentage positive cases ($\pm 2.0\%$).
LFD, Lateral Flow Device.

The following day, two individuals from Platoon 2 presented with symptoms, were found to be positive and isolated along with the rest of the platoon. Over the following days, two additional symptomatic Officer Cadets from Platoon 1 and five from Platoon 2 were found to be positive.

Between days 15 and 19, Intermediates took part in a 5-day outdoor exercise. On days 20 and 21, a scheduled Academy Weekend took place, which involved all the Officer Cadets in both Intermediates and Seniors term. During this weekend, no training activity was scheduled and Officer Cadets were allowed to spend their time as they wished, within the confines of their accommodation. The following day (day 22), the first symptomatic positive case was identified in Seniors Platoon 6. On day 23, another large Group Activity for a subset of Officer Cadets in both Intermediates and Seniors took place and a second positive symptomatic case, this time in Intermediates, was identified. Over the following days, a large number of symptomatic Officer Cadets began coming forward for testing and case numbers rapidly rose (see Figure 1).

At this point, RMAS command staff isolated all Officer Cadets in their rooms and physical training was stopped. An Incident Management Team (IMT) was convened on day 29. The IMT included Headquarters staff from Army Recruiting and Initial Training Command, RMAS staff (both medical and non-medical), Defence Public Health and Defence Microbiology. Enhanced case finding by testing asymptomatic individuals at three daily intervals began. LFDs were used due to the large numbers involved. Platoons had to complete 14-day isolation and return three rounds of negative LFDs, before being released from isolation. This was on the basis that previous work has suggested that frequent LFD testing may outperform less frequent PCR testing with regard to identifying cases.⁷

On day 32, Juniors Platoon 1 (ie, the first platoon with a positive case) completed its isolation period. Three days later, another student in that Platoon presented with symptoms and was found to be positive, resulting in a second period of isolation. On investigation, it transpired that a student in Platoon 1 had had unauthorised contact with a visitor to campus and this likely represented reintroduction of the virus. Enhanced case finding identified two additional cases in Juniors Platoon 3 and one in Platoon 2. Overall, the IMT judged that the Juniors outbreak was separate from the much larger outbreak in Intermediates/Seniors. This is likely because they lived in an entirely separate building (Old College), did not have any contact with the other terms and did not participate in the Academy Weekend or Group Activity. Of note, all cases in Juniors were concentrated in a single Company, likely reflecting their shared accommodation.

By the end of the outbreak, there had been 138 confirmed cases in Intermediates/Seniors, representing 75% (138 of 185) of the outbreak case numbers. Of these, 58% (80 of 138) were identified by asymptomatic LFD testing and 42% (58 of 138) by symptomatic PCR testing. Given that the first symptomatic case presented a single day after the Academy Weekend, we have concluded that SARS-CoV-2 was circulating prior. It is likely that both the Academy Weekend and the Group Activity represented amplification events given how rapidly subsequent cases emerged.

Intermediates Company 3 (Platoons 7, 8 and 9) were outliers, continuing to return positive cases well beyond the others. This company was housed in Victory College, separate from the rest of the Officer Cadets. Members of the IMT conducted a site visit and it became evident that Platoons 7 and 8 shared ablutions and laundering facilities on the first floor of the building. The pattern of positive cases clustered around shared facilities, rather than along the length of the corridor (see Figure 2). Platoon 9 had fewer cases, which was likely explained by them being on the ground floor and having twice the facilities per person. It was also noted that some Platoons complied with restrictions more consistently than others, possibly explaining some of the variance in case numbers. The attitude of key personalities and subunit leadership within the Platoons was thought to be key.

Overall, 185 individuals tested positive for SARS-CoV-2 by either PCR or LFD, with 0 hospitalisations and 0 deaths. The low morbidity/mortality generated by this outbreak was likely a reflection of the relatively young and fit population. By calculating the number of days each platoon was in isolation and multiplying this by the number of members in each platoon, we estimate that 12959 person-days of lost training (ie, 35 person-years) were generated by this outbreak. While some of this was mitigated with knowledge/theory lessons being taught virtually while Platoons were in isolation, the lost training time and implications are stark.

SARS-CoV-2 genomics

Five of 10 (50%) samples sequenced showed nearly 100% genome coverage, with lower coverage samples indicative of lower viral load. Nine of 10 (90%) were identified as the Alpha variant B.1.1.7 with high probability. The 10th sample had <50% coverage, meaning that no lineage could be assigned. However, all mutations identified for this sample were also consistent with B.1.1.7.

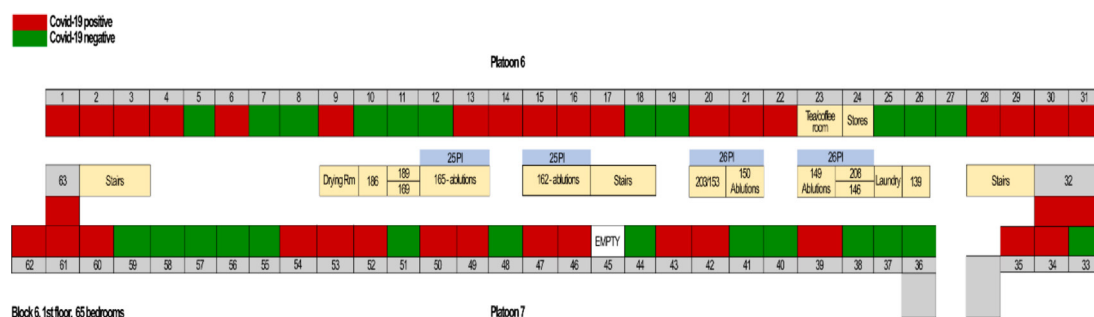


Figure 2 Schematic map of the first floor of Victory College showing distribution of positive cases in Intermediates, Platoons 6 and 7. Cases appeared to cluster around shared facilities rather than along the length of the corridor.

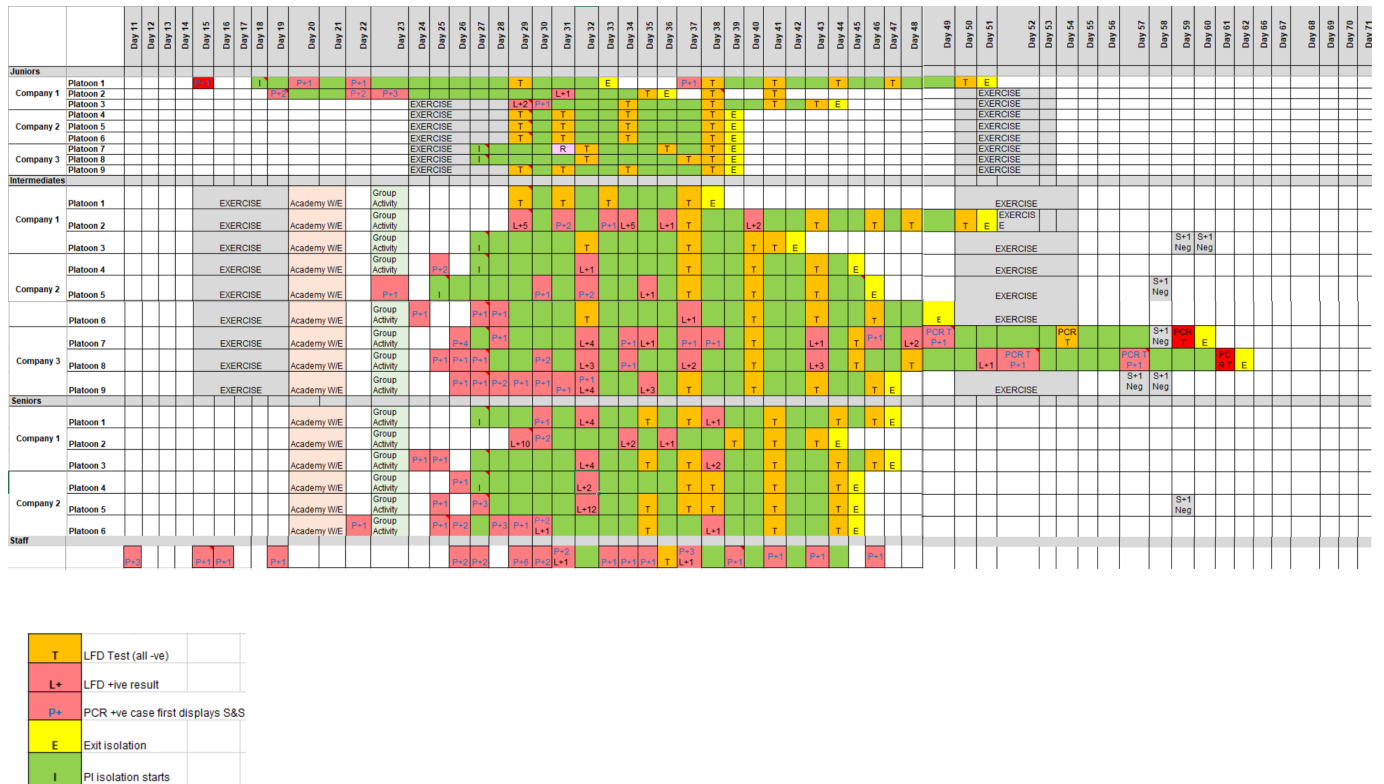


Figure 3 Redacted sync matrix used by IMT during the described outbreak. The sync matrix was used in real time to track the emergence of new cases in the various Platoons, Companies and Staff groups. Key events such as planned test dates and the beginning/end of isolation periods were plotted for each group. This gave the remotely convened IMT a clear understanding of problem areas and allowed the chain of command to plan and administer the programme of enhanced case finding. IMT, Incident Management Team; LFD, Lateral Flow Device.

CONCLUSIONS

Multidisciplinary working

The IMT contained a multidisciplinary team, including members from a broad range of backgrounds. There was support from behavioural psychologists who interviewed many of the staff and students following the outbreak, gaining invaluable insights. Multidisciplinary working and shared decision-making was key to the successful control of the outbreak and we encourage others to work similarly in future.

Monitoring the outbreak: use of sync matrices

During the outbreak, the chain of command developed a sync matrix to track progress. A simplified and redacted version is available as Figure 3. This was an invaluable tool, enabling the virtually convened IMT to quickly establish an understanding of case numbers across each Platoon and make decisions, particularly with regard to enhanced testing and isolation. Its format is familiar to a non-medical military audience, giving a single reference point for decision-making. It has now been adapted as a generic tool and used during the management of other outbreaks.

Issues with reporting of symptoms

Despite Officer Cadets being encouraged to report any symptoms, we have concerns from our investigation that this did not happen universally. That lost training time through isolation potentially delayed graduation, almost certainly was a factor. Among the Juniors and Staff groups, 80% and 94% of cases, respectively, were identified in symptomatic individuals, presenting for testing. This is in contrast to only 42% in Intermediates/Seniors. Given the low rates of true asymptomatic infection, this suggests

that Officer Cadets in these later phases of the course may have been downplaying symptoms and failing to report them.⁸ We also feel that the Public Health England symptom definition was insufficiently sensitive in our population.

This is a difficult issue to tackle. While it may be tempting to allow progress, despite lost training time, this may not always be appropriate if key assessments have been missed, etc. We would suggest institutions seek to reinforce a culture of openness and dissuade stigma.

Timing of high-risk events

During this outbreak, we identified two high-risk events (the Academy Weekend and Group Activity) where transmission was likely amplified, fuelling the rapid rise in cases. Based on the transmission dynamics, the timing of these two events was unfortunate. Given the average incubation period of COVID-19 is ~5–6 days, with peak infectiousness ~day 3–4,⁹ holding events where there is a risk of transmission around 3–4 days apart will dramatically increase the risk of a rapid rise in cases.

We would suggest that high-risk events should be scheduled at least 5–6 days apart. This is particularly important with highly transmissible variants such as the Alpha variant B.1.1.7 and Delta variant B.1.617.2. By lengthening the period between events, this risk should be minimised by allowing individuals time to develop symptoms and take action before attending a second high-risk event during peak infectivity. A similar approach should be taken in future with other infectious agents where pre-symptomatic transmission occurs.

Infrastructure

The physical environment is a key consideration to the infection control practitioner. RMA has many in-built advantages in controlling disease spread, when compared with other centres. First, Officer Cadets have individual rooms, so isolation is feasible when required. This is in contrast to other centres, where ~30 individuals can sleep and work in the same room. Additionally, it is a campus composed of several discrete buildings that can be selectively isolated, as opposed to a single large compound.

This outbreak proves that, even in this favourable environment, COVID-19 has the potential to spread rapidly. The case of Intermediates Platoons 7 and 8 illustrates that shared areas represent a risk when it comes to spreading infection. Additionally, these Platoons were housed in less well-ventilated accommodation (ie, Victory College), which may have played a role. When designing training centres in the future, the experience of COVID-19 should be kept in mind by considering smaller units of well-ventilated rooms with fewer large shared areas.

Lateral flow devices

LFDs were used to test asymptomatic individuals, identifying 46% (85 of 185) of the total case number. LFDs have been used in various settings for asymptomatic screening.¹⁰ Their performance varies between assays and manufacturers, but they offer a cheap and convenient alternative to gold standard PCR testing. In our cohort, eight individuals tested negative on LFD, only to then present with symptoms and test positive by PCR in the subsequent 48 hours, suggesting the LFD results were false negatives. We would encourage the use of LFDs in contexts such as this, that is, an outbreak setting with high incidence and limited PCR capacity. We caution against their use as a screening tool as they can offer false reassurance. For example, we would advise against their use to screen the crew of a ship prior to embarkation, due to the high risk of false negatives and the consequences of missed cases.

Closing remarks

COVID-19 poses a challenge for infection control in large institutions. Its transmission via airborne aerosols makes indoor areas with poor ventilation hazardous.¹¹ Its mild presentation in young, fit individuals makes it difficult for infectious individuals to realise that they pose a risk. The transmission dynamics of SARS-CoV-2 compound this, whereby individuals are at their most infectious 1–2 days prior to the development of symptoms.⁹

In young healthy populations, the risk of serious illness and death from COVID-19 is low, but lost training time can be substantial and has major implications for defence and national security. Low mortality among the young may well not be the case in future pandemics. It is sobering to note that the average age-specific mortality for H1N1 Spanish influenza was 28 years old, almost exactly the average age of our population.¹² It is key that lessons learnt from COVID-19 are retained and translated into action. From our investigation of this outbreak, we draw several lessons that will inform our practice in future and hope will be of use to others.

Contributors MR drafted, revised and submitted the manuscript. JL collected data, reviewed and revised the manuscript. CV collected data, reviewed and

revised the manuscript. AC collected data, reviewed and revised the manuscript. KS collected data, reviewed and revised the manuscript. CT collected data, reviewed and revised the manuscript. HC collected data, reviewed and revised the manuscript. SR collected/analysed data, reviewed and revised the manuscript. AB collected/analysed data. SG collected/analysed data. KC collected/analysed data. CF collected/analysed data. SG collected/analysed data. EJH collected data, reviewed and revised the manuscript (joint senior author). DR collected data, reviewed and revised the manuscript (joint senior author). MR will act as guarantor.

Funding Whole genome sequencing of SARS-CoV-2 samples was funded by the COG-UK Consortium, which is supported by funding from the Medical Research Council part of UK Research & Innovation, the National Institute of Health Research and Genome Research Limited, operating as the Wellcome Sanger Institute. SR is part funded from Research England's Expanding Excellence in England Fund.

Disclaimer The funders had no role in study design, data collection and analysis, decision to publish or preparation of the manuscript.

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval All data were acquired as part of the routine outbreak management. This report does not fulfil the definition of research, therefore does not require formal ethical approval. This work also forms part of the COG-UK surveillance study, which was granted ethical approval by the PHE Research Ethics and Governance Group (REGG) on 8 April 2020 (PHE R&D ref: NR0195).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplemental information.

This article is made freely available for use in accordance with BMJ's website terms and conditions for the duration of the covid-19 pandemic or until otherwise determined by BMJ. You may use, download and print the article for any lawful, non-commercial purpose (including text and data mining) provided that all copyright notices and trade marks are retained.

ORCID iD

Matthew Routledge <http://orcid.org/0000-0003-0423-6857>

REFERENCES

- Taylor H, Wall W, Ross D, *et al.* Cross sectional investigation of a COVID-19 outbreak at a London army barracks: neutralising antibodies and virus isolation. *Lancet Reg Health Eur* 2021;2:100015.
- Anderson RM, Hollingsworth TD, Baggeley RF, *et al.* COVID-19 spread in the UK: the end of the beginning? *Lancet* 2020;396:587–90.
- Grabowski F, Preibisch G, Giziński S. SARS-CoV-2 variant under investigation 202012/01 has more than twofold replicative advantage. *medRxiv* 2021.
- Yan Y, Wu K, Chen J, *et al.* Rapid acquisition of high-quality SARS-CoV-2 genome via Amplicon-Oxford nanopore sequencing. *Viral Sin* 2021. doi:10.1007/s12250-021-00378-8. [Epub ahead of print: 13 Apr 2021].
- Tyson JR, James P, Stoddart D, *et al.* Improvements to the ARTIC multiplex PCR method for SARS-CoV-2 genome sequencing using nanopore. *bioRxiv* 2020. doi:10.1101/2020.09.04.283077. [Epub ahead of print: 04 Sep 2020].
- Rambaut A, Holmes EC, O'Toole Áine, *et al.* A dynamic nomenclature proposal for SARS-CoV-2 lineages to assist genomic epidemiology. *Nat Microbiol* 2020;5:1403–7.
- Larremore DB, Wilder B, Lester E, *et al.* Test sensitivity is secondary to frequency and turnaround time for COVID-19 screening. *Sci Adv* 2021;7. doi:10.1126/sciadv.abd5393. [Epub ahead of print: 01 01 2021].
- Byambasuren O, Cardona M, Bell K, *et al.* Estimating the extent of asymptomatic COVID-19 and its potential for community transmission: systematic review and meta-analysis. *medRxiv* 2020. doi:10.1101/2020.05.10.20097543
- He X, Lau EHY, Wu P, *et al.* Temporal dynamics in viral shedding and transmissibility of COVID-19. *Nat Med* 2020;26:672–5. doi:10.1038/s41591-020-0869-5
- Mina MJ, Peto TE, Garcia-Fiñana M, *et al.* Clarifying the evidence on SARS-CoV-2 antigen rapid tests in public health responses to COVID-19. *Lancet* 2021;397:1425–7.
- Morawska L, Tang JW, Bahnfleth W, *et al.* How can airborne transmission of COVID-19 indoors be minimised? *Environ Int* 2020;142:105832.
- Gagnon A, Miller MS, Hallman SA, *et al.* Age-Specific mortality during the 1918 influenza pandemic: unravelling the mystery of high young adult mortality. *PLoS One* 2013;8:e69586.