Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company’s public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Original Research

Estimating COVID-19 recovery time in a cohort of Italian healthcare workers who underwent surveillance swab testing

R. Benoni, I. Campagna, S. Panunzi, M.S. Varalta, G. Salandini, G. De Mattia, G. Turrina, F. Moretti, G. Lo Cascio, G. Spiteri, S. Porruf, S. Tardivod, A. Polid, C. Bovo

a Postgraduate School of Hygiene and Preventive Medicine, University of Verona, Verona, Italy
b Department of Diagnostics and Public Health, Unit of Epidemiology and Medical Statistics, University of Verona, Verona, Italy
c Postgraduate School of Occupational Medicine, University of Verona, Verona, Italy
d Department of Diagnostics and Public Health, Section of Hygiene, University of Verona, Verona, Italy
e Department of Pathology, Microbiology and Virology Unit, University Hospital of Verona, Verona, Italy
f Department of Diagnostics and Public Health, Section of Occupational Medicine, University of Verona, Verona, Italy
g Clinical Unit of Occupational Medicine, University Hospital of Verona, Verona, Italy
h Medical Direction, University Hospital of Verona, Verona, Italy

ARTICLE INFO

Article history:
Received 7 December 2020
Received in revised form
26 April 2021
Accepted 12 May 2021
Available online 19 May 2021

Keywords:
COVID-19
Healthcare workers
Health surveillance
Recovery time
Swab test

ABSTRACT

Objectives: The COVID-19 pandemic is putting a huge strain on the provision and continuity of care. The length of sickness absence of the healthcare workers as a result of SARS-CoV-2 infection plays a pivotal role in hospital staff management. Therefore, the aim of this study was to explore the timing of COVID-19 recovery and viral clearance, and its predictive factors, in a large sample of healthcare workers.

Methods: The analysis was conducted on data collected during the hospital health surveillance programme for healthcare staff at the University Hospital of Verona; healthcare workers were tested for SARS-CoV-2 through RT-PCR with oronasopharyngeal swab samples. The health surveillance programme targeted healthcare workers who either had close contact with SARS-CoV-2-infected patients or were tested as part of the screening-based strategy implemented according to national and regional requirements. Recovery time was estimated from the first positive swab to two consecutive negative swabs, collected 24 h apart, using survival analysis for both right-censored and interval-censored data. Cox proportional hazard was used for multivariate analysis.

Results: During the health surveillance programme, 6455 healthcare workers were tested for SARS-CoV-2 and 248 (3.8%, 95% confidence interval [CI]: 3.4–4.3) reported positive results; among those who tested positive, 49% were asymptomatic, with a median age of 39.8 years, which is significantly younger than symptomatic healthcare workers (48.2 years, \( P < 0.001 \)). Screening tests as part of the health surveillance programme identified 31 (12.5%) of the positive cases. Median recovery time was 24 days (95% CI: 23–26) and 21.5 days (95% CI: 15.5–30.5) in right- and interval-censoring analysis, respectively, with no association with age, sex or presence of symptoms. Overall, 63% of participants required >20 days to test negative on two consecutive swabs. Hospitalised healthcare workers (4.8%) were older and had a significantly longer recovery time compared with non-hospitalised healthcare workers in both analyses (33.5 vs 24 days, \( P = 0.005 \)).

Conclusions: Recovery from COVID-19 and viral clearance may take a long time, especially in individuals who are hospitalised. To detect asymptomatic cases, screening programmes for healthcare workers is recommended.

© 2021 The Royal Society for Public Health. Published by Elsevier Ltd. All rights reserved.

* Corresponding author. Department of Diagnostics and Public Health, University of Verona, Strada Le Grazie, 8 – 37134 Verona, Italy. Tel.: +39 0458027659.
E-mail address: roberto.benoni90@gmail.com (R. Benoni).
Introduction

SARS-CoV-2 is a new single-stranded RNA coronavirus, first identified in Wuhan, China, in December 2019, and it is responsible for the onset of coronavirus disease 2019 (COVID-19) in humans. The most common clinical presentation of severe COVID-19 is acute respiratory distress syndrome, while many people report mild symptoms, such as fever, cough and coryza. Some cases of COVID-19 are fully asymptomatic; however, the exact percentage of asymptomatic cases remains uncertain.

Italy is among the countries that has been worst hit by the coronavirus pandemic, with 3,920,945 total cases and 118,357 deaths (data last updated 22 April 2021). Veneto, where the University Hospital of Verona is located, has the second most numerous cases among the Italian regions (405,031 total cases and 11,183 deaths).

The COVID-19 pandemic has proved to be a challenge for healthcare systems around the world and, although many ongoing studies are making a valuable contribution in understanding this new infection, many issues remain unresolved. Criteria to safely readmit SARS-CoV-2-infected individuals into the community are still debated. Healthcare workers (HCWs) are a particular subset of the general population that may acquire SARS-CoV-2 as an occupational infection. Special attention should be paid to plan their re-integration into the workplace, as they may transmit the infection to patients, other HCWs or visitors. One of the main problems with SARS-CoV-2-infected HCWs is finding the right balance between the necessity to isolate until viral clearance and returning to work to ensure the continuity of care for patients.

Up to October 2020, in Italy, a SARS-CoV-2 patient was considered to have recovered and to no longer be infectious following two negative tests, together with the complete resolution of the signs and symptoms of COVID-19. Whereas, a 14-day self-quarantine was recommended for untested individuals who had close contact with a SARS-CoV-2-infected case. However, it is still unclear what actual timespan is required for an individual to reach viral clearance and to no longer be considered infectious. The aim of this study was to explore the timing of COVID-19 recovery and viral clearance, and its predictive factors, in a large sample of HCWs.

Methods

A retrospective study was conducted using data from the health surveillance programme (HSP) of the University Hospital of Verona (UHV) located in the Veneto Region (Italy).

Health surveillance programme

The HSP was established at a national level to ascertain the SARS-CoV-2 virological status of all employees in healthcare settings, to protect the health of healthcare staff and their patients, and to ensure the continuity of care. Specific procedures aimed at implementing the HSP at the local level were developed by the Veneto region as described below.

Setting and population. The HSP was conducted at the UHV, which is one of the main hospitals in the Veneto region, with 1215 beds and 124 day-hospital beds. As a high-level facility, it serves an area of 922,000 inhabitants, as well as patients from other Italian regions. The programme was organised and conducted by a specially appointed taskforce, comprising of staff from the Hospital Medical Management, Occupational Medicine and Microbiology Units, as well as residents of the postgraduate Schools of Hygiene and Occupational Medicine. The HSP included all UHV employees, staff temporarily operating at UHV structures (e.g. contractors, PhD students, internship holders) and University of Verona staff operating at UHV facilities. Employees on parental or sick leave and staff not currently working at the UHV were excluded from the HSP. All HCWs involved in the HSP between 29 February 2020, the date of the first swab collected in the UHV, and 18 May 2020, were included in this retrospective analysis.

HSP pathways for symptomatic and asymptomatic cases. The HSP had two different pathways for symptomatic and asymptomatic HCWs who had close contact with a SARS-CoV-2-infected individual (see Supplementary file). Close contact was defined as either contact with a SARS-CoV-2-infected individual within two metres, for more than 15 minutes and without any personal protective equipment, or unprotected direct contact with the secretions of a SARS-CoV-2-infected individual. Asymptomatic close contacts were offered an oronasopharyngeal swab as soon as possible. Specific ambulatories were assigned to the HSP and the booking was managed by the staff of the task forces. HCWs who tested negative after close contact were exempt from quarantine, but they were monitored with swab repetition at days 7 and 14, starting from the date of close contact. For symptomatic (cough, rhino conjunctivitis, fever, ageusia, anosmia, sore throat) individuals who had come into close contact with a SARS-CoV-2 individual, a test was performed as quickly as possible in dedicated spaces of the emergency room to avoid contact with asymptomatic HCWs. If the test result was negative, they were required to stay home until resolution of symptoms and then to follow the HSP asymptomatic pathway.

If an individual had a positive test result to any of the swabs, home self-isolation was recommended for 14 days. At the end of this period, two swabs were performed, 24 hours apart. Only if both swabs were negative the HCW was considered ‘recovered’ and allowed to go back to work. In cases where one of the two swabs tested positive, both swab tests had to be repeated after 7 days.

Prior to swab sample collection, a short epidemiological questionnaire was completed for every HCW (both symptomatic and asymptomatic), to ascertain the actual date of close contact, the presence of any symptoms, the nature of the contact (whether in the workplace or outside), and HCW age, working ward and personal contact details. Trained medical personnel, assisted by a professional nurse, collected oronasopharyngeal (both nostrils) swabs, in accordance with national and international guidelines. Samples were tested for SARS-CoV-2 infection by a commercial real-time PCR method, Seegene AllplexTM2019-nCoV Assay (Seegene, Seoul, South Korea), which identifies the virus by a multiplex real-time PCR targeting three viral genes (E, RdRP and N gene). Samples were considered positive with a cycle threshold (Ct) value of ≤ 40 for at least one of the three target genes. Validation of the results was done with the National Reference Laboratory of National Health Institute. Limit of detection of the AllplexTM2019-nCoV Assay was 4.8 copies/mL

HSP screening. In addition to providing oronasopharyngeal swabs for individuals who were identified as having been in close contact with a SARS-CoV-2 patient, the HSP also provided testing to all HCWs, hence adopting a mass testing strategy. Repeated screening swabs were carried out with different timings based on ward risk, in accordance with the protocols of the Veneto region. Individuals working in high-risk wards were tested every 10 days, employees in the other clinical and surgical wards every 20 days, whereas the staff in the administrative sector were tested every 30 days. In the UHV, intensive care units, infectious and respiratory diseases wards and COVID units were considered as high-risk wards.

Ethics

In accordance with Decree-Law N.14 of 9 March 2020, personal data were collected to guarantee public health and to ensure the diagnosis and care of infected individuals in the context of the
COVID-19 emergency. All the data were collected exclusively for the purpose of the HSP; they were anonymised and presented in an aggregated format to ensure privacy of the participants. The research was performed following the ethical standards of the 1964 Declaration of Helsinki and was launched and approved by the Institutional Board of the Veneto Regional Health Authority.

Statistical analyses

A descriptive analysis was first conducted; frequency rates and percentages were used for categorical variables and medians for continuous variables. Cumulative incidence of COVID-19-positive HCWs was obtained through the Clopper Pearson method with an established 95% confidence interval (CI). Continuous variables were compared via the Mann-Whitney-U non-parametric test. Proportions for categorical variables were compared using the Chi-squared and Fisher’s exact test. The median time to viral clearance (i.e. two consecutive negative tests, 24 h apart) was examined by Kaplan-Meier estimates. The association between clinical and demographic characteristics was investigated via Cox proportional hazard regression. Survival analysis was applied when considering either right- or interval-censored data. With right-censoring analysis, the date of the second negative test was taken to be the exact recovery time. On the other hand, interval-censoring analysis considered the first positive swab as starting time point (t₀), the last positive swab before two consecutive negative swabs as left limit of the interval (t₁) and the second negative swab as right limit of the interval (t₂). A P-value <0.05 was considered significant. All analyses were performed using R software (version 3.5.2).

Results

Characterisation of COVID-19-positive HCWs

In the study period, 6455 HCWs underwent at least one oronasopharyngeal swab and 248 (3.8%; 95% CI: 3.4–4.3) tested positive for SARS-CoV-2 (Table 1). No significant differences emerged between the group of SARS-CoV-2-positive HCWs and non-infected HCWs with respect to age-, sex- or ward-related risk (Table 1). COVID-19-positive HCWs were identified either after referral to the HSP following close contact with a SARS-CoV-2–infected case (n = 217; 87.5%) or following the screening provided by the HSP (n = 31; 12.5%). Of the 248 COVID-19-positive HCWs, 127 (51%) experienced at least mild symptoms (e.g. cough, rhinoconjunctivitis, fever, ageusia, anosmia, sore throat). Symptomatic HCWs had a median age of 48.2 years and were significantly older than the asymptomatic HCWs (39.8 years, P < 0.001). Seven of the symptomatic subjects (5.5%) were identified through the screening provided by the HSP. For the 109 (85.8%) HCWs with a known date of symptom onset, the median time between this date and the first positive swab was 3 days (95% CI: 2–4). In 16 (14.7%) of the symptomatic HCWs, symptoms appeared after the first positive swab (with a median time-lag of 3.5 days).

During the study period, 95% (n = 236) of COVID-19-positive HCWs were back at work after two consecutive negative swab tests for SARS-CoV-2.

Recovery time estimation

The median time of recovery, starting from the first positive swab test result and taking the second negative swab as the last day of infection, was 24 days (95% CI: 23–26) (Fig. 1). At the end of the study, 156 (63%) HCWs needed more than 20 days to achieve two consecutive negative swabs. HCWs who were tested after having been in close contact with a SARS-CoV-2–infected case had a median recovery time of 25 days (95% CI: 23–28); however, the median recovery time was 21 days (95% CI: 16–24) for those who were tested as part of the HSP (Tables 2 and 3).

HCWs who required hospitalisation for SARS-CoV-2 infection showed statistically longer times for recovery than COVID-19-positive HCWs who were not hospitalised (33.5 days vs 24 days; P = 0.005) (Fig. 2).

The HSP scheduled tests at fixed time points. Data structure was therefore considered with an analysis for median recovery time in the presence of interval-censored data. Results obtained with interval-censoring method showed a slight difference in the estimate of median time to recovery compared with right-censoring analysis. For interval-censoring data analysis, the median recovery time estimate was 21.5 days (95% CI: 15.5–30.5) (Fig. 1); having been in close contact with a SARS-CoV-2–infected case and hospitalisation were still found to be associated with a longer recovery time (Tables 2 and 3).

Discussion

To date, only a few studies have investigated the virological status of HCWs, even though SARS-CoV-2 is known to be a nosocomial agent with important outbreaks occurring in hospitals and

Table 1

| Characteristic | Positive swab in HCWs | Symptoms in positive HCWs | Unknown (n = 3) | Hospitalisation of positive HCWs |
|----------------|-----------------------|--------------------------|----------------|----------------------------------|
|                | Yes (n = 248) | No (n = 6207) | p-Value | Yes (n = 127) | No (n = 118) | p-Value | Yes (n = 12) | No (n = 236) | p-Value |
| Sex [n (%)]    | Male | 80 (32%) | 1906 (31%) | | 46 (36%) | 33 (28%) | (33%) | 6 (50%) | 74 (31%) | 0.010 |
|                | Female | 168 (68%) | 4301 (69%) | 0.432 | 81 (64%) | 85 (72%) | 2 (67%) | 6 (50%) | 162 (69%) | 0.007 |
| Age in years  [Median (IQR)] | 45.1 (31.1–53.9) | 45.7 (32.3–54.1) | | 48.2 (33.8–54.9) | 39.8 (29.9–52.3) | 46.2 | 56.2 (45.3–60.9) | 44.7 (30.9–53.2) | 0.002 |
| Ward [n (%)]  | High-risk | 24 (10%) | 542 (9%) | | | | | | |
|                | Low-risk | 244 (90%) | 5665 (91%) | | | | | | |

IQR, interquartile range.

1 p-values were computed using Chi-squared test and Mann-Whitney-U non-parametric test.

2 p-values were computed using Fisher’s exact test and Mann-Whitney-U non-parametric test.

3 IQR not reported because of the low number of subjects.

4 Infectious disease and respiratory disease ward, intensive care unit, COVID unit.
in nursing homes.23,24 Because asymptomatic individuals are thought to be contagious,25 it is important to extend testing to all HCWs. Indeed, in the present study sample, almost half of the COVID-19-positive cases showed no symptoms at the time of testing. While no difference in age, sex or working ward was detected between negative and positive subjects, as shown in other studies,24 the symptomatic cases were significantly older. Older people are known to be more severely affected by SARS-CoV-2.28 A minority (14.7%) of the individuals who tested positive developed symptoms after the initial swab test. As infectiousness begins in the preclinical stage,29 the HSP strategy was effective in identifying cases at disease onset, thus reducing the potential spread of the infection. HCWs who showed symptoms were not permitted to return to work and were rapidly tested.

In the study sample, 95% of COVID-19-positive HCWs had recovered at the time of data collection. The median time from the first positive swab to the second consecutive negative test was 24 days, which is similar to findings reported by Carmo et al.,30 who found a median recovery time of 24 ± 9 days. Recovery times between 9.531 and 21 days9,32,33 have been reported in other studies.34,35 These differences may be due to different diagnostic strategies or to the timing of the first positive swab. Indeed, in our

![Kaplan-Meier curves for recovery probability analysis with right-censoring data analysis (left panel) and interval-censoring data analysis (right panel).](image)

**Table 2**

Kaplan–Meier estimation of recovery time considering right- and interval-censoring analysis.

| Stratification variables | Right-censoring analysis | Interval-censoring analysis |
|--------------------------|--------------------------|----------------------------|
|                          | n | Median recovery (days) | 95% CI | n | Median recovery (days) | 95% CI |
| Total                    | 236 | 24.0 | 23–26 | 236 | 21.5 | 15.5–30.5 |
| Sex                      |    |                  |        |    |                  |        |
| Male                     | 78 | 25.5 | 22–30 | 78 | 22.5 | 15.5–34.5 |
| Female                   | 158 | 24 | 23–26 | 158 | 20.5 | 15.5–30.5 |
| Age group (years)        |    |                  |        |    |                  |        |
| 25–29                    | 32 | 20 | 17–23 | 32 | 16.5 | 15.5–31.5 |
| 30–39                    | 61 | 25 | 23–31 | 61 | 23.5 | 15.5–39.5 |
| 40–49                    | 42 | 27 | 22–30 | 42 | 22.5 | 17.5–31.5 |
| 50–59                    | 81 | 23 | 20–26 | 81 | 20.5 | 15.5–30.5 |
| 60–66                    | 20 | 29.5 | 23–24 | 20 | 25.5 | 21.5–30.5 |
| Symptoms                 |    |                  |        |    |                  |        |
| Yes                      | 123 | 26 | 23–29 | 123 | 22.5 | 15.5–31.5 |
| No                       | 111 | 23 | 21–26 | 111 | 20.5 | 15.5–30.5 |
| Close contact            |    |                  |        |    |                  |        |
| Yes                      | 210 | 25 | 23–28 | 210 | 22.5 | 15.5–30.5 |
| No                       | 26 | 21 | 16–24 | 26 | 16.5 | 15.5–23.5 |
| Hospitalisation          |    |                  |        |    |                  |        |
| No                       | 224 | 24 | 22–26 | 224 | 21.5 | 15.5–30.5 |
| Yes                      | 12 | 33.5 | 27–56 | 12 | 29.5 | 26.5–NA* |

CI, confidence interval.

* A 95% upper confidence limit of NA (infinity) is common in survival analysis due to the fact that the data is skewed.
Table 3
Recovery hazard ratios (HRs) estimated in the multivariate Cox proportional hazard model considering right- and interval-censoring analysis.

| Characteristic    | Right-censoring analysis | Interval-censoring analysis |
|------------------|--------------------------|----------------------------|
|                  | HR 95% CI P-Value        | HR 95% CI  P-Value         |
| Sex              | 0.93 0.70–1.23 P = 0.614 | 0.90 0.67–1.21 P = 0.488  |
| Age              | 1.00 0.99–1.01 P = 0.762 | 1.00 0.99–1.01 P = 0.780  |
| Symptoms         | 0.91 0.69–1.19 P = 0.489 | 0.95 0.69–1.30 P = 0.766  |
| Close contact    | 0.44 0.28–0.69 P < 0.001 | 0.48 0.32–0.71 P < 0.001  |
| Hospitalisation  | 0.42 0.23–0.77 P = 0.005  | 0.46 0.22–0.96 P = 0.039   |

CI, confidence interval.

a Recovery probability is 54% significantly lower in subjects who had a close contact compared to those who did not and 58% significantly lower in hospitalised subjects compared to non-hospitalised ones.

b Recovery probability is 52% significantly lower in subjects who had a close contact compared to those who did not and 54% significantly lower in hospitalised subjects compared to non-hospitalised ones.

study, there is a significant difference between those who were tested in the shortest time possible (i.e. because of being in close contact with an infected individual) and those who tested positive at the regular HSP testing. Individuals who tested positive as part of the HSP showed a shorter median recovery time (21 days), which is consistent with the aforementioned studies. Moreover, when we conducted a censoring-interval survival analysis to take into account the surveillance timing structure, the recovery time resulted in a median recovery time of 21.5 days, in line with literature data.

Considering the two types of analysis (Fig. 1), recovery time estimated through a right-censored analysis describes the time needed to confirm (as per HSP criteria) the recovery of HCWs and thus to allow them back to work. This result plays a crucial role for the organisation and staff management. To adequately plan the workplace, might lead to repeated tests, thus becoming unnecessarily expensive. A longer time interval before testing to confirm time of viral clearance since it takes into account the interval between the last positive and the two negative swabs, when clearance is likely to have occurred.

In our study, the multivariate Cox proportional hazard model showed no significant differences in the time to recovery related to sex, which is consistent with the literature. Age was also not related to a longer recovery time in our sample; however, other studies, have found a significant association between older age and prolonged time to viral clearance.

COVID-19-positive HCWs who required hospitalisation had a significantly longer recovery time, when all other covariates in the model were fixed. This result, confirmed in the censoring-interval analysis, highlights how the severity of the disease is an independent risk factor for a longer time of recovery and viral clearance.

The main limitation of the present study is the retrospective study design. The analysis was based on data collected primarily for the HSP. Elderly people, who are most severely affected by COVID-19, are not represented in the HSP sample, which consisted of young and middle-aged HCWs. In addition, only a few HCWs in this investigation were hospitalised; thus, further studies are needed to confirm the associations suggested by the current results. These issues might limit the generalisability of the results, although the current findings have important implications for surveillance programmes and public health policies.

In Italy, the current guidelines, based on the WHO strategy, recommend testing after 10 days from the first positive swab in the case of asymptomatic individuals and testing after 10 days from the onset of symptoms (with at least 3 days without symptoms) in the case of symptomatic individuals. In accordance with the results of the present research, the time needed to achieve viral clearance is much longer and therefore such a close swab timing, while beneficial for a rapid re-integration into social life and into the workplace, might lead to repeated tests, thus becoming unnecessarily expensive. A longer time interval before testing to confirm
SARS-CoV-2 clearance in infected individuals might be advisable, especially in resource-limited countries.30

Conclusions
The viral clearance of SARS-CoV-2 and, consequently, the recovery assessment through a negative RT-PCR test takes a long time, especially in hospitalised individuals and in infected HCWs who had been in close contact with a SARS-CoV-2—infected case. This represents a serious burden for the health system and for personnel management. HCWs, hospital management and stakeholders should consider a recovery time of at least 20 days to optimise hospital resources.

A large proportion of infected individuals are asymptomatic at the time of testing,34 and it is known that infectiousness is already increasing from the preclinical and subclinical stage.35 Therefore, it is important to test regardless of clinical presentation, especially in healthcare settings. Implementation of screening programmes in healthcare settings will allow testing of all personnel, including the HCWs, who may not report symptoms or may underestimate them.

Author statements

Ethical approval
The research was launched and approved by the Institutional Board of the Veneto Regional Health Authority.

Funding
This research received no external funding.

Competing interests
The authors declare that they have no conflicts of interest.

Acknowledgements
The authors want to thank all colleagues of the Postgraduate Schools of Occupational Medicine, Forensic Medicine and Hygiene who worked with them in the health surveillance and collaborated in collecting these important data, as well as all technicians of the Microbiology Unit. A special thanks goes to all healthcare workers in collecting these important data, as well as all technicians of the Microbiology Unit. A special thanks goes to all healthcare workers

Appendix A. Supplementary data
Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpuhe.2021.05.014.

References
1. European Center for Disease Prevention and Control. Guidance for discharge and ending isolation in the context of widespread community transmission of COVID-19 – first update. Available from: https://www.ecdc.europa.eu/en/publications-data/covid-19-guidance-discharge-and-ending-isolation [Accessed 2020 Dec 2].
2. Cevik M, Bamford CGG, Ho A. COVID-19 pandemic—a focused review for clinicians. Clin Microbiol Infect 2020;26(7):842–7. https://doi.org/10.1016/j.cmi.2020.04.023.
3. World Health Organization. Report of the WHO—China joint mission on coronavirus disease 2019 (COVID-19). Available from: www.who.int/publications/i/item/report-of-the-who-china-joint-mission-on-coronavirus-disease-2019-(covid-19) [Accessed 2 Dec 2020].
4. Widders A, Broom A, Broom J. SARS-CoV-2: the viral shedding vs infectivity dilemma. Infect Dis Health 2020;25(3):210–5. https://doi.org/10.1016/j.idh.2020.05.002.
5. Italian Ministry of Health, National Institute of health. Daily aggregated regional COVID19 Cases Update. Available from: http://www.salute.gov.it/portale/news/p3_2_1_1_1.jsp?lingua=italiano&menu=news&da1&ministero_id=–932 [Accessed 22 Apr 2021].
6. Lombardi A, Bozzi G, Mangioni D, et al. Duration of quarantine in hospitalized patients with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection: a question needing an answer. J Hosp Infect 2020;105(3):404–5. https://doi.org/10.1016/j.jhin.2020.03.003.
7. Mandic-Rjacic S, Masci F, Crespi E, et al. Source and symptoms of COVID-19 among hospital workers in Milan. Occup Med (Lond) 2020;70(3):672–9. https://doi.org/10.1093/occmed/kqaa036.
8. Koh D. Occupational risks for COVID-19 infection. Occup Med (Lond) 2020;70(1):1–5. https://doi.org/10.1093/occmed/kqaa036.
9. Black JRM, Bailey C, Przewrocka J, Dijkstra KK, Swanton C. COVID-19: the case for health-care worker screening to prevent hospital transmission. Lancet 2020;395(10234):1418–20. https://doi.org/10.1016/S0140-6736(20)30917-X.
10. Italian Ministry of Health. Circolare n. 0006607 of the 29 Febbraio 2020. Parere del Consiglio Superiore di Sanità: definizione di Paziente guarito da Covid-19 e di paziente che ha eliminato il virus SARS-CoV-2. Gazzetta Ufficiale. Available from: https://www.gazzettaufficiale.it/ricerca/ArchivioCompleto/serie_generale/2020 [Accessed 2020 Dec 2].
11. Italian Ministry of Health. Circolare n. 0032850 del 12 Ottobre 2020. COVID-19: indicazioni per la durata ed il termine dell’isolamento e della quarantena. Available from: https://www.trovanorme.salute.gov.it/norme/renderNormsanPdf?anno=2020&codleg=76613&parte=1&nora=0&null=–null=true [Accessed 2 Dec 2020].
12. Italian Government. Decreto legge 9 marzo 2020 n. 14, Disposizioni per il potenziamento del Servizio sanitario nazionale in relazione all’emergenza COVID-19. Gazzetta Ufficiale. Available from: https://www.gazzettaufficiale.it/ricerca/ArchivioCompleto/serie_generale/2020 [Accessed 2 Dec 2020].
13. Veneto Region. Nuovo Coronavirus (Sars-CoV-2). Istruzioni Operative per la sorveglianza del personale del Sistema Sanitario Regionale Rev 02 del 22 Aprile 2020. Available from: https://www.regione.veneto.it/web/sanita/covid-19-documenti-regionali-operatore [Accessed 2 Dec 2020].
14. Centers for Disease Control and Prevention. Interim guidelines for collecting, handling, and testing clinical specimens for COVID-19. 2020. Available from: https://www.cdc.gov/coronavirus/2019-ncov/lab/guidelines-clinical-specimens.html [Accessed 2 Dec 2020].
15. Italian National Institute of Health. Rapporto ISS COVID-19 n. 11/2020 Rev. Raccomandazioni ad interim per il corretto prelievo, conservazione e analisi sul tampone rino/orofaringeo per la diagnosi di COVID-19. Available from: https://www.iss.it/rapporti/covid-19 [Accessed 2 Dec 2020].
16. Centers for Disease Control and Prevention. Coronavirus disease 2019 (COVID-19) – information for laboratories. Available from: https://www.cdc.gov/cseis/dis/locs/2020/interim_guidelines_for_handling_and_processing_covid-19_clinical_specimens.html [Accessed 2 Dec 2020].
17. Porra S, Carta A, Monaco MGL, et al. Health surveillance and response to SARS-CoV-2 mass testing in health workers of a large Italian hospital in Verona. Veneto. Int J Environ Res Publ Health 2020;17(14):ES104. https://doi.org/10.3390/ijerph1714ES104.
18. Italian Government. Decreto-legge n. 14 del 9 marzo 2020. Informativa Privativa per emergenza covid-19 a seguito delle disposizioni sul trattamento dei dati personali nel contesto emergenziale. Available from: https://www.gazzettaufficiale.it/ricerca/ArchivioCompleto/serie_generale/2020 [Accessed 2 Dec 2020].
19. Veneto Region. Prevention, Food safety. Veterinary Department. New corona-virus (SARS-CoV-2) regional procedure. Rev 03. Available from: https://hsanamcloni.wp-content/uploads/2020/03/Procedura-regionale-Covid-19_rev_03-13.3.2020.pdf [accessed 2021-02-18].
20. Anderson-Bergman C, iconReg: Regression models for interval censored data in R. J Stat Software 2017;81(12):1–23. https://doi.org/10.18637/jss.v081.i12.
21. Zhuang Z, Jianguo S. Interval censoring. Stat Methods Med Res 2010;19(1):53–70. https://doi.org/10.1177/0962280209351023.
22. Wang X, Zhou Q, Hey E, et al. Nosocomial outbreak of COVID-19 pneumonia in Wuhan, China. Eur Respir J 2020;55(6):2000544. https://doi.org/10.1183/13993003.00544-2020.
23. Schwierzke V, König J, Köhn J, et al. First reported nosocomial outbreak of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in a pediatric dialysis unit. Clin Infect Dis 2020. https://doi.org/10.1093/cid/ciaa491. ciaa491.
24. Hunter E, Price DA, Murphy E, et al. First experience of COVID-19 screening of health-care workers in England. Lancet 2020;395(10234):e77–8. https://doi.org/10.1016/S0140-6736(20)30970-3.
25. Oran DP, Topol EJ. Prevalence of asymptomatic SARS-CoV-2 infection: a narrative review. Ann Intern Med 2020;M20–3012. https://doi.org/10.7326/M20-3012.
26. Xin Y, Jin H. Comparison of transmissibility of coronavirus between symptomatic and asymptomatic patients: reanalysis of the Ningbo COVID-19 data. JIMIR Publ Health Surveill 2020;6(2):e19464. https://doi.org/10.2196/19464.
27. Chen M, Fan P, Liu Z, et al. A SARS-CoV-2 familial cluster infection reveals asymptomatic transmission to children. J Infect Public Health 2020;13(6):883–6. https://doi.org/10.1016/j.jiph.2020.05.018.
28. Li X, Xu S, Yu M, et al. Risk factors for severity and mortality in adult COVID-19 inpatients in Wuhan. J Allergy Clin Immunol 2020;146(1):110–8. https://doi.org/10.1016/j.jaci.2020.04.006.

R. Benoni, I. Campagna, S. Panunzi et al. Public Health 196 (2021) 52–58
29. He W, Yi GY, Zhu Y. Estimation of the basic reproduction number, average incubation time, asymptomatic infection rate, and case fatality rate for COVID-19: meta-analysis and sensitivity analysis. J Med Virol 2020. https://doi.org/10.1002/jmv.26041.

30. Carmo A, Pereira-Vaz J, Mota V, et al. Clearance and persistence of SARS-CoV-2 RNA in patients with COVID-19. J Med Virol 2020. https://doi.org/10.1002/jmv.26103.

31. Ling Y, Xu SB, Lin YX, et al. Persistence and clearance of viral RNA in 2019 novel coronavirus disease rehabilitation patients. Chin Med J (Engl) 2020;133(9):1039–43. https://doi.org/10.1097/CM9.0000000000000774.

32. Zhou F, Yu T, Du R, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. Lancet 2020;395(10229):1054–62. https://doi.org/10.1016/S0140-6736(20)30566-3.

33. Hu X, Xing Y, Jia J, et al. Factors associated with negative conversion of viral RNA in patients hospitalized with COVID-19. Sci Total Environ 2020;728:138812. https://doi.org/10.1016/j.scitotenv.2020.138812.

34. Qi L, Yang Y, Jiang D, et al. Factors associated with the duration of viral shedding in adults with COVID-19 outside of Wuhan, China: a retrospective cohort study. Int J Infect Dis 2020;96:531–7. https://doi.org/10.1016/j.ijid.2020.05.045.

35. To KK, Tsang OT, Leung WS, et al. Temporal profiles of viral load in posterior oropharyngeal saliva samples and serum antibody responses during infection by SARS-CoV-2: an observational cohort study. Lancet Infect Dis 2020;20(5):565–74. https://doi.org/10.1016/S1473-3099(20)30196-1.

36. Xu K, Chen Y, Yuan J, et al. Factors associated with prolonged viral RNA shedding in patients with coronavirus disease 2019 (COVID-19). Clin Infect Dis 2020;71(15):799–806. https://doi.org/10.1093/cid/ciaa351.

37. Bi Q, Wu Y, Mei S, et al. Epidemiology and transmission of COVID-19 in 391 cases and 1286 of their close contacts in Shenzhen, China: a retrospective cohort study. Lancet Infect Dis 2020;20(8):911–9. https://doi.org/10.1016/S1473-3099(20)30287-5.

38. World Health Organization. Criteria for releasing COVID-19 patients from isolation. Available from: https://www.who.int/news-room/commentaries/detail/criteria-for-releasing-covid-19-patients-from-isolation. [Accessed 2 Dec 2020].

39. Chau NVV, Thanh Lam V, Thanh Dung N, et al. The natural history and transmission potential of asymptomatic SARS-CoV-2 infection. Clin Infect Dis 2020. https://doi.org/10.1093/cid/ciaa711. ciaa711.

40. Romagnani P, Gnone G, Guzzi F, et al. The COVID-19 infection: lessons from the Italian experience. J Publ Health Pol 2020;41(3):238–44. https://doi.org/10.1057/s41271-020-00229-y.