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RESEARCH ARTICLE OPEN ACCESS

COVID-19: SARS-CoV-2 susceptibility in healthcare workers – cluster study at a German Teaching Hospital

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Abstract – *Purpose:* The local health department (*in German*: Gesundheitsamt) ordered a shutdown of a teaching hospital due to the severe acute respiratory syndrome coronavirus (SARS-CoV-2) outbreak – one index patient and five infected healthcare workers – and put it under quarantine. For the first time, all patients plus all employees of one German hospital (healthcare providers, physicians, and nurses) were tested to detect silent or asymptomatic carriers.
Methods: A serial polymerase chain reaction (PCR) test for SARS-CoV-2 was performed three times (1) between April 3rd and 5th, 2020 [$n = 1171$], (2) between April 8th and 9th, 2020 [$n = 953$] and (3) between April 14th and 17th, 2020 [$n = 983$].
Results: The teaching hospital's proven coronavirus disease 2019 (COVID-19) patient load on Friday, April 3rd, 2020, was 34 patients, of whom 11 were on ventilation in the intensive care unit (ICU), one in the intermediate care unit (IMC), and 22 in the infectious disease ward. Another 32 patients in a different infectious disease ward were suspected for COVID-19 with test results pending. COVID-19 silent carrier (asymptomatic) positivity rates based on the phases of testing were (1) $n = 24$ (2.1%), (2) $n = 25$ (2.6%) and $n = 9$ (0.9%). The cumulative infection rate for healthcare providers, physical therapists, physicians, and nurses was 1.8%, 4.5%, 4.8%, and 11.9% which were associated with the type and extent of COVID-19 patient contact ($p < 0.05$).
Conclusion: Despite prior proper preparation, a COVID-19 positive patient load of up to 34.8% (46 of 132 hospital beds) resulted in a 10- to 20-fold increase in risk for healthcare workers for SARS-CoV-2 compared to the general population. Because of asymptomatic carriers, a COVID-19-free hospital cannot be expected to exist. Based on our experience, repeated testing of all staff members with patient contact is necessary and is the best option to effectively contain the virus. Those having the most contact with patients had the highest risk of becoming infected (10- to 20-fold higher risk), with nurses being at the highest risk.

Keywords: Anesthesia, Asymptomatic carrier, China, Coronavirus, COVID-19, Elective surgery, Emergency, Epidemic, Epidemiology, Europe, Face masks, Germany, Guidance, Health worker, ICU, IMC, Inflammation, Italy, Morbidity, Mortality, N95 masks, Pandemic, Patient safety, Pediatric surgery, Pneumonia, PPE, Protection, Respiratory, Sepsis, Silent carrier, Surgical critical care, Respiratory masks, SARS, SARS-CoV-1, SARS-CoV-2, Sepsis, Surgery, Virus

Introduction

The World Health Organization (WHO) stated on March 11th, 2020 in its Situation Report – 51, that "… *the assessment that the Coronavirus disease 2019 (COVID-19) can be characterized as a pandemic*" [1]. On Thursday, March 12th, 2020 the German Government decided to postpone all justifiable elective admissions and surgical procedures and directed interventions to increase capacities in terms of patient beds, intensive care unit (ICU) beds, and ventilators [2]. This was followed on March 19th, 2020 by regulations from the Bavarian State Ministry of Health (*in German:* Bayerisches Staatsministerium für Gesundheit und Pflege) based on the Infection Protection

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Act (*in German:* Infektionsschutzgesetz) that "*all elective surgery, as well as all elective outpatient contacts as far as medically justifiable, have to be interrupted or postponed, for the time being, to free up as much capacity as possible for COVID-19 patient care*" (BayMBI) [3].

The coronavirus task force of the Teaching Hospital decided on structural, procedural, and organizational measures to be able to cope with the expected number of COVID-19 patients. Ventilators, availability of personal protection equipment (PPE), and the health of staff were of special concern. On Friday, April 3rd, 2020 an index patient and five health workers were identified to be positive COVID-19 by the polymerase chain reaction (PCR) test. The index patient, all nursing and physician staff of the IMC plus patients and healthcare workers in the regular ward were considered as Category 1 contact persons and isolated.

Based on the definition of "*outbreak*" by German Law – transmission of disease of two or more people with a common cause probable or strongly suspected, §6 IfSG (= Infection Protection Act, *in German*: Infektionsschutzgesetz) – , the health department (*in German*: Gesundheitsamt) ordered a shutdown of the German teaching hospital, Helios Amper Klinikum in Dachau, and put it under quarantine including staff and patients.

Immediately thereafter, the hospital crisis team decided that all patients plus all healthcare workers irrespective of profession – hospital workers without direct patient contact, together with administrative staff, secretaries, physical therapist and ergotherapy, nurses, and physicians – should be tested for COVID-19 thereby providing baseline information between April 2nd and 3rd [n = 1,171], followed by three repeated testing series every 5 days on Apr 8th, 14th and 19th, 2020. In this manner, tests to be carried out were determined on specified days concentrating on patient and employee health without any consideration of costs.

Methods

Hospital workers without direct patient contact, together with administrative staff, secretaries, physical therapist and ergotherapy, nurses and physicians were tested for SARS-Cov-2 by PCR by LigthMix® Modular SARS-CoV (COVID19) E-gene, Roche Company. One PCR-smear swab for nasopharynx and oropharynx was used before RNA extraction followed by amplification and detection as described earlier [4, 5]. The purpose of this testing was threefold:

1. to elucidate the number of silent, asymptomatic SARS-CoV-2 carriers amongst health workers and patients at the time of hospital shut down,
2. to learn about the susceptibility to SARS-CoV-2 infection of health workers over time, and
3. to investigate whether repeated testing with consequent separation (isolation) in positive cases would help to reduce the infection rate amongst staff.

Therefore, serial PCR SARS-CoV-2 testing was performed at three periods between:

1. April 3rd and 5th, 2020 [n = 1171]. All healthcare workers were supplied with written information on quarantine regulations and all who tested negative during this period were invited to repeat testing for the following periods.
2. April 8th and 9th, 2020 [n = 953] (decreasing from n = 1171) and
3. April 14th and 17th, 2020 [n = 983] (with another slight increase from n = 953).

From the midnight occupancy statistics of the hospital on April 3rd, 8th, 14th and 19th, 2020 and the respective number of patients positive for COVID-19 a simple ratio [%] was calculated to depict the COVID-19 patient load of the hospital and used as a surrogate parameter for risk of infection.

The reference number of COVID-19 infection in the population was taken from the online report "*Zeit online Corona ticker*" [6], showing 775 positive people in a district population of 154,544 [7] on April 19th, 2020. Detailed information about the tested numbers including results are provided enabled under Results and in Table 1. SARS-CoV-2 positivity is given later in numbers and in percentage rates in accordance to hospital staff and dates. Anti-SARS-CoV-2 IgG measurements in blood samples and/or viral subgenomic mRNA as described earlier [8] were not performed.

Statistical analysis

Healthcare workers were stratified for χ^2 testing into (1) hospital workers, (2) nurses, (3) physicians, and (4) physical therapists. Categorical variables were described as frequency rates and percentages, and continuous variables were described using mean, median, and interquartile range (IQR) values. The proportions for categorical variables were compared using the χ^2 test. For unadjusted comparisons, a two-sided α of less than 0.05 was considered to be statistically significant. The cut-off values for χ^2, a two-sided α of less than 0.05 being 3.841 and 6.635 for a two-sided α of less than 0.01, 10.828 for $p < 0.001$ [9]. The null hypothesis was that there is no difference in infection rates among different professions of health workers. The analyses have not been adjusted for multiple comparisons and, given the potential for type I error, the findings should be interpreted as exploratory and descriptive.

Results

On April 19th according to the updated "corona map" of the largest German weekly newspaper "*Die Zeit*" the district and city of Dachau ranked 11th among 401 districts and cities all over Germany with confirmed positive COVID-19 of 51.4/10,000 people (infection rate 0.5%) [6]. Figure 1 exemplifies the timeline of increasing number of infections in the District along with the COVID-19 positive patient

Table 1. COVID-19 positive test results; stratification to date, profession and control values.

Cluster	n_{total}	$CV+_{\text{pre}}$	CV+	CV+	CV+	CV+	cIR %
		Apr 2nd	Apr 3rd	Apr 8th	Apr 14th	Apr 19th	
District population	154,544	243	457	555	684	775	0.5
Inpatients Apr 3rd, 2020	136	–	1	–	–	–	0.7
Hospital workers	506	1	4	3	1	9	1.8
Nurses	413	8	16	19	6	49	11.9
Physicians	208	2	3	3	2	10	4.8
Physical therapy	44	1	1	0	0	2	4.5
Healthcare workers, *sum*	*1,171*	*12*	*24*	*25*	*9*	*70*	*6.0*
Date – number of patients							
Apr 2nd, 2020	193	6	–	–	–	–	3.1
Apr 3rd, 2020	197	–	33	–	–	–	16.7
Apr 8th, 2020	132	–	–	46	–	–	34.8
Apr 14th, 2020	203	–	–	–	38	–	18.7
Apr 19th, 2020	172	–	–	–	–	32	18.6
Numbers tested – Apr 3rd, 2020							
Inpatients			136	–	–	–	
Health workers, all professions			1171	953	983	–	

Note: n_{tot} = total number; $CV+_{\text{prae}}$ = PCR positive COVID-19 test until April 2nd, 2020; $CV+_{\text{date}}$ = PCR positive COVID-19 test at the respective test series; April 3rd, 8th, and 14th, 2020; cIR = cumulated infection rate April 20th, 2020, given in percent. The first testing series was mentioned on Page 11, line 42 in [28]. Parts of the results were published at the German journal "*Münchner Medizinische Wochenschrift (MMW)*", a German language journal which is read by general practitioners, with the main focus on continuous medical education [49].

load in the hospital. With a delay of 7 days on March 30th, 2020 the doubling time in the hospital was 4.6 days as compared to the District doubling time of 10.2 days. On April 14th, 2020 doubling time in the District rose to 14 days whereas the number of COVID-positive patients and the number of those requiring ventilation stayed at a constant level.

The teaching hospital's proven COVID-19 patient load on Friday, April 3rd, 2020 was: 34 patients, of whom 11 were on ventilation in the ICU, one in IMC, and 22 in infection ward; another 32 patients in different infection ward within the same hospital were suspicious for COVID-19 with test results pending. Additionally, and importantly, single patient amongst $n = 136$ asymptomatic inpatients from 12 different hospital-departments not suspected to be COVID-19-infected was found upon testing to be PCR SARS-CoV-2 positive.

COVID-19 positive patients occupied the full regular capacity of the ICU on April 3rd, 2020, the day the hospital underwent shutdown. Along with the hospital's changes to cope with the pandemic, only 4 of the additional 20 ventilators in the IMC needed to be used. We lost 13 patients. The official statistics of the community health department counted 18 deceased people, resulting in a case-fatality ratio (CFR) of 2.3% (18/775).

A total of [$n_{\text{total}} = 3243$] tests were performed. Table 1 includes numbers and percentage (%). Healthcare worker stratification [$n = 1171$] for χ^2 testing revealed (1) hospital workers [$n = 506$], (2) nurses [$n = 413$], (3) physicians [$n = 208$] and (4) physical therapists [$n = 44$].

The SARS-CoV2 infection rate in the District population was 0.5%, whereas the infection rate was 6% [70/1.171] in hospital staff compared to 9% [70/775] in the regional District.

The hospital's COVID-19 patient load increased rapidly after April 2nd, 2020 from 3.1% to 16.7%, with a peak on April 8th, 2020 of 34.8%, leveling out to nearly 20% COVID-19 positive patients by April 19th, 2020.

The first PCR testing series (1) between April 3rd and 5th, 2020 [$n = 1171$] yielded SARS-CoV2 positivity in $n = 24$ (2.1%) healthcare workers. The 2nd testing series (2) between April 8th and 9th, 2020 [$n = 953$] revealed $n = 25$ (2.6%), and within the 3rd testing series (3) between April 14th and 17th, 2020 [$n = 983$] $n = 9$ (0.9%). Therefore, the COVID-19 asymptomatic carrier positivity rates in accordance to testing phases were (1) $n = 24$ (2.1%), (2) $n = 25$ (2.6%) and $n = 9$ (0.9%). We acknowledge the limitations of these data, as anti-SARS-CoV-2 IgG measurements in blood samples and/or viral subgenomic mRNA were not performed.

The cumulative infection rate for health care providers, physical therapists, physicians, and nurses were 1.8%, 4.5%, 4.8%, and 11.9%.

χ^2 test values were:

- hospital workers (1) versus physical therapists (4) [*1.58*, $p = 0.208$],
- hospital workers (1) versus physicians (3) [*5.22*, $p = 0.022$],
- hospital workers (1) versus nurses (2) [*39.12*, $p < 0.001$],
- physical therapists (4) versus physicians (3) [*0.001*, $p = 0.94$],
- physical therapists (4) versus nurses (2) [*2.15*, $p = 0.143$] and
- physicians (3) versus nurses (2) [*8.01*, $p = 0.005$].

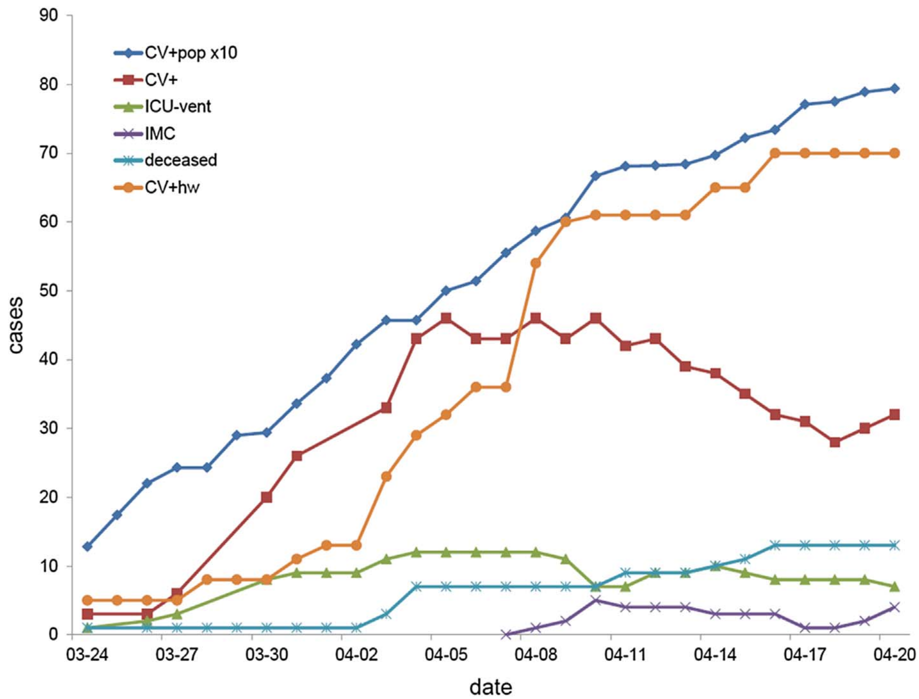

Figure 1. COVID-19 positive patients, allocation and outcome. CV+ pop × 10 = PCR positive COVID-19 test, general district population; n × 10; CV+ = test, patient load in hospital; ICU-vent = ventilated, PCR positive COVID-19 patients in ICU; IMC = PCR positive COVID-19 patients in IMC; deceased = died in spite of intensive care therapy; CV+ hw = PCR positive COVID-19 health workers. The first testing series was mentioned on Page 11, line 42 in [28]. Parts of the results were published at the German journal "*Münchner Medizinische Wochenschrift (MMW)*", a German language journal which is read by general practitioners, with the main focus on continuous medical education [49].

From this analysis, the null hypothesis is rejected: the infection risk for nurses is significantly higher than for physicians or hospital workers. Table 1 summarizes the test results.

Discussion

The teaching hospital normally holds 435 beds. Before the COVID-19 crisis, under extensive construction and complete core renovation of the hospital during full operation, on average 290 beds were available. During shutdown, occupancy was reduced to 132 beds (45%), and every third patient was COVID-19 positive on April 8th. Nearly two weeks earlier we had stopped performing elective surgery, mainly to open up ICU and IMC capacities, to reduce the exposure of surgical staff to the risk of transmission e.g. during airway management and to transfer some of surgical staff to work in the ICU [10].

Reproduction number/How contagious is COVID-19?

On the cruise ship, *Diamond Princess,* a COVID-19 index case occurred around January 21st to 25th 2020; from that experience with 712 positive cases (10 died) among 2666 passengers and 1045 crew members, we learned that under extremely difficult, unforeseen and unprecedented quarantine circumstances, the initial basic reproduction rate R_0 of 14.8 was 4 times (400%) higher than in Wuhan, China. Without any emergency measures implemented, there would have been an infection rate of 79%; quarantine, therefore, prevented the infection of 2214 people. However, the author's main conclusion was that evacuating all passengers and crew early in the outbreak, isolating them in individual quarantine – and not only the ones that tested positive – would have prevented many more passengers and crew members from becoming infected [11].

The effective reproduction number of COVID-19 varies widely depending on the period and the area of the world that is examined. For Wuhan, China, the reproduction number for laboratory confirmed COVID-19 cases showed a time-dependent variation between 3.94 at January 3rd, 2020 and 0.10 on March 8th, 2020 [12].

How must these numbers be classified? The basic reproduction number (R_0) for measles is 12–18 [13], SARS-CoV-2 2–3.5 in the early phase, which is higher than severe acute respiratory syndrome-related coronavirus (SARS) (2.5) and Middle East respiratory syndrome-related coronavirus (MERS) (<1) [14]. In February 2020, the Chinese Center of Disease Control (CCDC) estimated the CFR to be 2.3% [15], identical to that in the District of Dachau.

Infection rate in healthcare workers

An early analysis of 138 patients in Wuhan between January 1st and 28th, 2020 [16] showed the infection of healthcare workers in the hospital (n = 40, 29%) or a nosocomial infection (n = 17, 12.3%) to be the main reason for transmission of the disease.

The detailed analysis of 32,583 COVID-19 cases in China later on revealed a number of 1,496 (4.6%) infected healthcare workers, with 256 (17.4%) of those being severe or critical cases [12].

The consecutive analysis of 82,623 cases proved a high number of COVID-19 positive healthcare workers: n = 3019/82,623 (3.83%). It was postulated, that this loss of the healthcare workforce directly influenced the quality of patient care and hospital mortality [14], but it should be mentioned that the relative risk needs to be subtracted from the overall risk of becoming symptomatic within a hospital. Furthermore, until now, it is not clear whether healthcare workers in some countries actively worked in hospitals and thus their exposure potential remains unverified as of this writing.

All these investigations stating numbers or infection rate refer to the population, i.e. they are a case/infection ratio and do not state the number of healthcare workers being on duty in the hospital setting at a given time. As the rate of infection among healthcare workers is substantially higher than in the general population, SARS-CoV-2 may, in part, be a nosocomial infection [12, 14].

Silent (asymptomatic) carriers

Presymptomatic infectiousness is a concern. The role of asymptomatic carriers is not completely understood [17] and remains unclear [18]. Nothing can be said with certitude about the infection risk of someone doing the opposite of all other people in the country: instead of isolating and socially distancing himself/herself, they indulge in fighting the disease in a hostile, infectious environment. To the best of our knowledge, there is no other publication available today that addresses the question of susceptibility to SARS-CoV-2 in healthcare workers through serial testing. We provide such exploratory data herein.

Using the number of COVID-19 positive district population as a reference size, we would have had twice as much infection as in China [14]: 70/775 as of April 19th, 2020, equivalent to an infection rate of 9%, the general population's infection rate being 0.5% by comparison. Pan et al. [12] differentiated the Wuhan outbreak into five different periods and found that during the most active phase up to 8.7% of all patients were healthcare workers.

At the time of the hospital shutdown in Dachau, acute testing of asymptomatic patients revealed 1/136 positive results (0.7%), identical to the district population infection rate. Working in the hospital setting alone, not even with direct patient contact, increased the infection rate to 1.8%. All healthcare workers with close contact to patients, not just while caring for the upper airways, had a 10- to 20-fold increased risk. This is especially true for nurses where the risk increase is significantly above the risk for physicians or physiotherapists.

On February 21st, 2020 [19], it was proven for the first time that clinically and radiologically asymptomatic people can transmit the virus. The virus load, measured from the swabs of 17 symptomatic patients is higher in the nasopharynx than in the oropharynx and has a tendency to decrease with the duration of the disease [20].

Experimentally induced aerosols containing severe acute respiratory syndrome corona virus 1 (SARS-CoV-1) and SARS-CoV-2 showed viable virus throughout the 3 h duration of the experiment: SARS-CoV-2 was viable, though with greatly reduced viral titers, after 48 h on stainless steel and after 72 h on plastic. Median half-lives were 5.6 h on steel and 6.8 h on plastic [21]. But it has been pointed out, that "*what's more important is the amount of the virus that remains. It's less than 0.1% of the starting virus material. Infection is theoretically possible but unlikely at the levels remaining after a few days. People need to know this*" [22]. Contamination with viral nucleic acid, not necessarily indicative of the amount of viable virus, was greater in ICUs than in general wards. Virus was widely distributed on floors, computer mice, trash cans, and sickbed handrails and was detected in air ≈4 m from patients [23]. Even though daily contact with inanimate surfaces and patient fomites in contaminated areas could be a medium of infection, Colaneri et al. suggested that "*it might be less extensive than hitherto recognized*" [24] which is contrary to SARS-CoV-2 environmental contamination findings 36% of surfaces in two rooms of a quarantine hotel after two presymptomatic persons who stayed there [25].

The analysis of the four major symptoms that may lead to SARS-Cov-2 testing, namely fever, cough, shortness of breath or sore throat missed 17% of asymptomatic health workers [26], one out of 48 health workers examined had nothing more than a headache. In a CDC report on April 14th among 4336 COVID-19 positive healthcare personnel, 8% did not report any symptoms [27].

Several national and international organizations published recommendations on how to prevent the transmission of COVID-19 amongst health workers (see Figure 3 in [28]). A consortium of scientists and clinicians from various specialties provided a compact Pandemic Surgery Guidance to serve as more practical guide during the exponential pandemic COVID-19 spread which could even serve as the basis for other future potential pathogen crises yet to come [28].

Repeat testing

At the Sheffield Teaching Hospitals in the UK, National Health Service (NHS) Foundation Trust symptomatic staff members presenting with an influenza-like illness, defined as a reported fever and one of cough, sore throat, runny nose, myalgia, headache or persistent cough were tested between March 16th and 29th 2020 for COVD-19. Out of 1533 symptomatic staff, n = 282 (18%) were positive for SARS-CoV-2. In only 52 cases information on the profession was available: among staff positive for SARS-CoV-2, 25 were nursing staff, 8 were doctors, 9, other patient-facing clinical staff and 10 were laboratory, secretarial staff or worked in cleaning services. The authors concluded that testing healthcare workers is a crucial strategy to optimize staffing levels during this outbreak. The only study which is vaguely comparable reports on a roll-out of SARS-CoV-2 testing for healthcare workers at a large hospital in the United Kingdom [29].

One urgent task is to implement rapid testing. Even today, a routine test in Bavaria often takes about 36 h, so in suspected cases some physicians prefer to perform thoracic computed tomography (CT) scan [30] in order to get the information whether the patient belongs to the endangered group or not in 15 min. Access to testing even in Germany is still limited, so that it is difficult to draw reliable conclusions about incidence, prevalence, and populations at risk [31], let alone about herd immunity. As of May 20th, herd immunity in the Stockholm region was under 8% and in NY City was about 20% [32]. As this analysis shows, the Stockholm region, as of May 20th, had achieved less than 8% herd immunity and New York City was at 20%. This implies that the buildup of herd immunity is a slower-than-anticipated process. With such small fractions of populations showing antibodies, clusters of outbreaks are predicted to occur for several months to years, until herd immunity is achieved naturally or through the introduction of an effective vaccine.

Repeat testing in our cluster effectively removed potential carriers and showed a massive decrease of silent carriers on the third testing series.

Recently it was stated correctly: "*health-care workers, unlike ventilators or wards, cannot be urgently manufactured or run at 100% occupancy for long periods*" [33]. This means that we must do anything and everything to prevent healthcare workers from becoming infected.

Remarks on SARS-CoV-2 testing

However, limitations in terms of "*PCR vulnerabilities include general preanalytical issues such as identification problems, inadequate procedures for collection, handling, transport and storage of the swabs, collection of inappropriate or inadequate material (for quality or volume), presence of interfering substances, manual errors, as well as specific aspects such as sample contamination and testing patients receiving antiretroviral therapy*" [34].

Furthermore, analytical as well as structural problems and limitations or RT-PCR performance by time since symptom onset may affect testing accuracy as well why interpretation of predictive value of tests avoiding falsely negative results increasingly get into focus. Investigating seven studies [35] with heterogeneity in the design provided [8, 36–41] suggested being careful when interpreting RT-PCR SARS-CoV-2 tests particularly early in the course of infection.

This reveals the dilemma in a new pandemic. There is until today no RT-PCR SARS-CoV-2 test gold standard available and this is why detailed information on sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and overall accuracy information are limited. Therefore, the degree of agreement between tests with the same sampling and repeated testing of the same individuals provides a greater degree of confidence. Furthermore, in this situation cross-reactivity testing important, as high titers of the potentially cross-reacting microorganisms might result in false positive rates [42–46].

"*The cornerstone of the next phase will require massive testing, in 2 forms: serologic testing that detects immunoglobulins (IgG and IgM) specific for SARS-CoV-2 to provide estimates of population exposure, and virologic polymerase chain reaction testing that detects active disease to effectively stop transmission*" [47]. Here, detailed information about accuracy is available [48].

We should be aware that a more accurate assessment of the all available data will be possible within the next 12–15 months, especially after each country has reopened for work and other activities. Furthermore, data from various countries will have to be re-evaluated in terms of reproducibility, specificity, sensitivity, and validity which might result in new findings and/or judgments. For example, later it will need to be addressed if healthcare workers within some countries all worked within hot-spot areas and/or hospitals or just were listed as being affiliated but wrongly counted with hospital staff for reaching a more valuable basis in comparing data from one country to another.

Conclusion – Lessons learned

To answer the questions of this study: asymptomatic patients show the same infection rate as the general population (0.5–0.7%), but healthcare workers have an increased risk as asymptomatic carriers (0.9–2.6%). The susceptibility to SARS-Cov-2 infection of healthcare workers over time is highly dependent on the type of work performed: in those having contact with patients, the infection risk is increased 10- to 20-fold, and as shown by our data, nurses bear the highest risk. Repeat testing with its consequences works to reduce COVID-19 infection rates amongst healthcare workers. However, we are still living in a time of continuously increasing COVID-19 knowledge. Only time will show if strict travel restrictions and home quarantines will be the dominant factors associated with reducing the effective reproduction numbers in the future and/or if additional testing protocols will need to include IgG analysis for receiving information in terms of immunity status and/or prophylactic effective vaccine programs of high quality and safety can be developed.

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Conflict of interest

The author reports the following conflict of interest: Björn LDM Brücher is Editor-in-Chief in Life Sciences-Medicine of *4open* by EDP Sciences. Ijaz S. Jamall is Senior Editorial Board member and Michael A. Scherer Editorial members in Life Sciences-Medicine of *4open* by EDP Sciences. The authors, of their own initiative, suggested publishing the manuscript as a Rapid Publication with online reviewing including to the Managing Editorial to perform a transparent peer-review of their submittals. No author took any action to influence the standard submission and peer-review process, and all report no conflict of interest. The authors alone are responsible for the content and writing of the manuscript. The authors declare no conflicts of interest whatsoever: no benefits in any form from a commercial party related directly or indirectly to the subject of this manuscript were received or will be received by any of the authors.

Availability of data and material

All original data are available on request. The first testing series was mentioned on Page 11, line 42 in [28]. Parts of the results were published at the German journal "*Münchner Medizinische Wochenschrift (MMW)*", a German language journal which is read by general practitioners, with the main focus on continuous medical education [49]. Each single author contributed to acquisition and/or analysis and interpretation of data. Every single author read, reviewed and edited the manuscript. All authors contributed to the manuscript and its discussion and conclusion and approved the final manuscript. Each author agrees to be accountable for all aspects of the work.

Code availability

Not applicable.

Author's contribution

Scherer designed of the work, acquired data, did the analysis, interpreted data and wrote the manuscript. *Von Freyburg* is the hospital's physician responsible for organization and structural prerequisites of all aspects of COVID-19 pandemic; he revised the manuscript critically and acquired data. *Hagedorn* is the hospital's medical director, responsible for official communication with the community and state officials, he revised the manuscript critically. *Brücher* and *Jamall* continuously were in exchange from the beginning of the COVID-19 crisis with the group, did the re-analysis and critically revised the manuscript critically for content as well in regard to intellectual content. *Schmidt* revised the manuscript critically for important intellectual content and reviewed statistical analysis and also performed a re-analysis.

Ethics approval

Not applicable.

Nomenclature

CCDC	Chinese Center of Disease Control
CDC	Center of Disease Control
CFR	Case-fatality rate
COVID-19	Coronavirus disease 2019
CT	Computed tomography
NHS	National Health Service
ICU	Intensive Care Unit
IMC	Intermediate Care Unit
IQR	Interquartile range
MERS	Middle East respiratory syndrome-related coronavirus
PCR	Polymerase chain reaction
PPE	Personal Protection Equipment
R_0	Basic reproduction number
SARS	Severe acute respiratory syndrome-related coronavirus
SARS-CoV-1	Severe acute respiratory syndrome corona virus 1
SARS-CoV-2	Severe acute respiratory syndrome corona virus 2
WHO	World Health Organization

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