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SARS-CoV-2 infections in patients, health care workers and hospital outbreaks during the first 3 waves of the pandemic: a retrospective analysis in a secondary care hospital network in Germany

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Abstract

Background Hospital infections with SARS-CoV-2 continued during the initial waves of the pandemic worldwide. So far, Data on the dynamics of these infections and the economic burden of outbreaks are rare.

Methods We retrospectively analysed SARS-CoV-2 infections in patients, hospital employees and nosocomial infections resulting in outbreaks in two hospitals of a secondary care hospital network in Germany during the initial 3 pandemic waves (03/2020–06/2021). In addition to hospital infections, we evaluated infection prevention strategies and the economic burden of hospital outbreaks.

Results A total of 396 patients with SARS-CoV-2 infection were hospitalized in both hospitals. The risk factors for severe disease and death increased with age, male sex and a CRB-65 score > 0. The most frequent symptom was dyspnoea (30.1%). Sixty-five patients died, most of whom were in the 2nd wave. A total of 182 (12.5%) hospital employees were infected, 63 (34.6%) of whom were involved in outbreaks. An occupational risk of infection during outbreaks was particularly common among nurses and HCWs working on regular wards. Eleven hospital outbreaks led to high economic impact on both hospitals through the loss of manpower as result of infected employees, temporary locked wards, blocked beds, a reduced number of total hospitalized patients and increased personnel costs.

Conclusion Continuously adaptation of infection prevention strategies is a valuable tool to keep hospitals safe places for patients and employees. We do need more analyses of the different pandemic waves and applied infection prevention strategies to learn from weak points.

Trial registration This research was conducted in accordance with the Declaration of Helsinki and national standards. The study protocol was approved by the relevant ethics committee of the Chamber of Physicians Westphalia-Lippe and University of Münster (no. 2021–475-f-S). The study was registered on 25th August 2021 at the German Clinical Trials Register (DRKS00025865).

Keywords SARS-CoV-2, COVID-19, Patients, Healthcare workers, Nosocomial transmission

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Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has emerged as the cause of coronavirus disease 2019 (COVID-19) [1]. The WHO declared a global health emergency on 31 January 2020; subsequently, on 11 March 2020, there was a pandemic [2]. The first pandemic year in 2020 in Germany was dominated by the wild type virus (up to March 2021), followed by the alpha type virus (up to June 2021) [3].

The SARS-CoV-2 pandemic has become a worldwide challenge for the medical sector. Healthcare workers (HCWs) across the world are at specific risk for SARS-CoV-2 infection. At the beginning of the pandemic, HCWs were approximately ten times more likely to acquire a SARS-CoV-2 infection than was the general population [4–6]. Data on the dynamics of hospital infections in different pandemic waves are rare. Understanding and evaluating the risk factors for HCWs to become infected are essential for developing targeted protection strategies and ensuring adequate healthcare provision during pandemics.

Despite an increasing understanding of transmission mechanisms and infection prevention strategies, outbreaks have continued to occur in hospitals and care facilities during the initial pandemic waves [7–11]. Most hospital outbreaks in Germany occurred in the 1st and 2nd waves of the pandemic [12]. Infection prevention strategies have been adapted continuously, and now, it is time to evaluate them to be prepared for further challenges related to SARS-CoV-2 and other infections.

The primary objective of this study was to analyse SARS-CoV-2 infections in two hospitals in a secondary care hospital network in North Rhine-Westphalia (NRW), Germany, during the first 3 pandemic waves (from March 2020 to June 2021). We retrospectively evaluated the data of infected patients and hospital employees with respect to age, risk of infection, source of infection, course of the disease and outcome. Secondary aims were (i) the analysis of hospital outbreaks to evaluate the infection prevention and control strategies to identify possible weak points to learn from, and (ii) to obtain an impression of the economic impact of nosocomial transmissions.

Methods

Study design

The study was a single center longitudinal cohort study conducted at the "Vestische Caritas Kliniken GmbH" in Germany. The following two hospitals in the secondary care hospital network were included: (i) St. Vincenz-Hospital Datteln (VHD): 1085 employees, 316 beds and the main departments internal medicine, surgery, gynecology, obstetrics, and urology; and (ii) St.-Laurentius-Stift Waltrop (LSW), with 375 employees and 172 beds (geriatric and psychiatric departments). Both hospitals have one management structure, so that raising data took place as single center study. The study time was retrospectively chosen from March 2020 to June 2021 to cover the first 3 pandemic waves: 1st wave: March 2020-September 2020; 2nd wave: October 2020-January 2021; and 3rd wave: February 2021-June 2021.

Data management

We retrospectively analysed the data collected in our electronic data system with the following program: HyBASE (version V6.2022.04.R14), JiveX Enterprise PACS (Picture Archiving and Communication System, version 5.2.0.43 RC01), Meierhofer-Krankenhaus-Informationssystem (M-KIS, version M-KIS 2020 SP10 Hotfix 07), and Swisslab (version 2.23.3.00).

Data from infected patients

We included all patients with the International Classification of Disease (10th edition Clinical Modification: ICD-10-CM) code U7.01 (SARS-CoV-2 virus detected) as main or secondary diagnosis. We retrospectively evaluated patient-specific data in the clinical data system M-KIS: sex, age, social background, date of COVID-19 diagnosis (including diagnosis-specific information such as positive antigen test, PCR), number of medical risk factors according to the Robert Koch-Institute (RKI) definition [13], number of prescribed drugs on admission, possible source of infection, symptoms, including X-ray findings and signs of bacterial superinfection, CRB-65 score (confusion, respiratory rate, blood pressure), COVID-19-specific therapy, duration of stay, stay in regular or intensive care units, artificial respiration, and status at discharge.

According to the endpoints of several analyses [13, 14], a severe course of COVID-19 was defined if any kind of artificial respiration, including high-flow oxygen, intensive care treatment or death, was temporally related to SARS-CoV-2 infection.

Data from infected employees

The Department of Hygiene documented and included all SARS-CoV-2-positive employees in their own registers and in the clinical data system M-KIS. In this study, we analysed these data according to sex, age, profession, occupational risk for SARS-CoV-2 infection, reason for PCR testing, possible source of infection, clinical symptoms and course of COVID-19.

Outbreaks

An outbreak was defined according to the German Infection Protection Law IfSG §6 (3), by two or more positive SARS-CoV-2 test results with temporal and spatial correlation, e.g., in patients who were hospitalized and/or employees working on the same ward. In outbreak situations, data from the involved patients and employees were collected in the clinical data system M-KIS. We analysed the location, ward, date, involved department, number and symptoms of involved patients and employees, profession of employees, days of isolation, and number of blocked beds or days the wards were closed in total.

Statistical analysis

In descriptive analyses, patient and employee demographics, employee professions, patient and employee symptoms and other attributes of COVID-19 were determined and compared for the whole cohort and stratified by the 1st, 2nd and 3rd waves of the pandemic using absolute and relative frequencies. Clinical characteristics and test results were compared by Pearson's chi-square test or Fisher's exact test. Characteristics that appeared more frequently in the 2nd or 3rd pandemic wave were estimated by univariate logistic regression, and odds ratios (ORs) and 95% confidence intervals (CIs) were calculated versus the reference level for each main category of the characteristics. The risk of a severe course of the disease was estimated by multivariate logistic regression with a combined endpoint of the need for artificial respiration, intensive care unit stay or death. We applied a significance level of 0.05. The data were analysed with the statistical software R [15].

Results

Characteristics of SARS-CoV-2-infected patients

Table 1 summarizes the characteristics of SARS-CoV-2-infected patients from March 2020 to June 2021. Overall, 396 patients were treated in both hospitals: 357 patients (90.2%) in the VHD and 39 patients (9.9%) in the LSW. The majority (76.5%) of the hospitalized patients were older than 60 years (166 females, 137 males), and 71.6% (130 females, 87 males) of them were admitted to hospitals in the 2nd pandemic wave.

Among the hospitalized patients with SARS-CoV-2 females were significantly more common than males comparing the 2nd and the 3rd wave (OR 0.57, 95% CI 0.35; 0.93) (Table 1).

Medical situation at admission

A total of 171/396 patients (43.2%) were admitted with diagnoses other than SARS-CoV-2 infection, 194 patients (49%) had 1–3 medical risk factors, and 85 patients (21.5%) had more than 3 medical risk factors according to the RKI definition [13]. Only 62 patients (15.7%) had no prescribed drugs on admission, whereas the majority of patients (52.8%) had more than 3 drugs.

More than half of the patients (51%) acquired SARS-CoV-2 infection in private contacts. The difference between the 2nd and 3rd wave was statistically significant for hospital-acquired infection (OR 0.20, 95% CI 0.09; 0.41) and for infection acquired in residential care homes for the elderly (OR 0.20, 95% CI 0.08; 0.44) (Table 1). Among the infected patients, 16.9% (67/396) were involved in hospital outbreaks..

The risk of undiagnosed infected patients being the source of nosocomial transmissions is difficult to estimate. Two hundred twenty-one patients (55.8%) were hospitalized with the suspicion of COVID-19 or already known COVID-19, 171 patients (43.2%) had other diagnoses on admission. We diagnosed 88 patients with SARS-CoV-2 infection during the hospital stay (Table 1), 67 of them were PCR-positive tested in outbreaks (Supplementary Table 1).

Since we adapted our infection prevention strategy continuously (e.g. testing of patients on admission, on 3rd day after admission, then once a week since November 2020), it is difficult to say if and what proportion of incidentally diagnosed infections led to nosocomial transmissions.

Symptoms

The majority of patients (60.6%) were clinically symptomatic, and 53% had 1–3 symptoms. Among the symptomatic patients, two groups of symptoms were the most common: flu-like symptoms (72.1%), especially dyspnoea (49.6%) and unspecific symptoms (67.9%). Fewer patients had gastrointestinal symptoms (11.7%) or taste or smell disorders (11.3%) (Table 1).

Course of disease

Of the 396 positive patients, 192 (48.5%) received COVID-19-specific drugs according to the current recommendations, which changed over time. The specific treatment used included hydroxychloroquine at the beginning of the pandemic and subsequently administered remdesivir, dexamethasone, tocilizumab and vitamin D.

Of all infected patients, 37 (9.3%) needed intensive care; in 30 (7.6%) patients artificial respiration, including high-flow oxygen, was necessary. The duration of hospitalization was up to 14 days for the majority of patients (59.1%), and 112 patients (28.3%) were hospitalized longer. Fifty patients were outpatients, i.e., they did not need admission. In the initial three pandemic waves, 65 COVID-19-positive patients (16.4%) died, 72.3% of whom (47/65) died in the 2nd wave. Hospitalized male patients (36/172, 20.9%) had a greater risk of death than female patients did (29/224, 12.9%) (Fig. 1).

Table 1 Characteristics of SARS-CoV-2-infected patients

Variable	Pandemic waves				Analysis	
	1st wave 03/2020—09/2020 *n*=19	2nd wave 10/2020 – 01/2021 *n*=274	3rd wave 02/2021 – 06/2021 *n*=103	total number (%) *n*=396	2nd and 3rd wave OR (95% CI)	2nd and 3rd wave *p* value
Total number of COVID-19 patients						0.115
St. Vincenz-Hospital Datteln	19	241	97	357 (90.2%)	Reference	
St.-Laurentius-Stift Waltrop	0	33	6	39 (9.8%)	0.45 [0.15;1.14]	
Sex						0.022
female	7	168	49	224 (56.6%)	0.57 [0.35;0.93]	
male	12	106	54	172 (43.4%)	Reference	
Age						0.001
0–17 years	0	2	1	3 (0.8%)	2.50 [0.04;49.7]	
18–39 years	2	29	11	42 (10.7%)	1.90 [0.76;4.56]	
40–59 years	3	26	19	48 (12.1%)	3.65 [1.66:8.05]	
60–79 years	7	86	46	139 (35.1%)	2.69 [1.50;4.89]	
> 80 years	7	131	26	164 (41.4%)	Reference	
COVID-19 diagnosis on admission						0.031
already known	5	70	41	116 (29.3%)	Reference	
suspicion of COVID-19	4	74	27	105 (26.5%)	0.62 [0.33;1.16]	
other diagnosis	10	126	35	171 (43.2%)	0.48 [0.27;0.84]	
not known	0	4	0	4 (1.0%)	0.00 [0.00;2.72]	
Number of medical risk factors						
0	6	44	23	73 (18.4%)	Reference	0.001
1–3	8	125	61	194 (49.0%)	0,93 [0.50;1.77]	
> 3	5	63	17	85 (21.5%)	0.52 [0.23;1.15]	
not known	0	42	2	44 (11.1%)	0.09 [0.01;0;41]	
Number of drugs on admission						< 0.001
0	4	34	24	62 (15.7%)	Reference	
1–3	4	35	18	57 (14.4%)	0.73 [0.31;1.69]	
> 3	11	143	55	209 (52.8%)	0.55 [0.29;1.06]	
not known	0	62	6	68 (17.2%)	0.14 [0.04;0.39]	
Possible source of infection						< 0.001
hospital	2	75	11	88 (22.2%)	0.20 [0.09;0.41]	
residential care home for the elderly	4	60	9	73 (18.4%)	0.20 [0.08:0.44]	
private (incl. family contacts + journey)	7	112	83	202 (51.0%)	Reference	
not known	6	27	0	33 (8.3%)	0.00 [0.00;0.21]	
symptoms[a]	**15**	**158**	**67**	**240 (60.6%)**		
Unspecific symptoms[a]	**10**	**109**	**44**	**163 (41.2%)**	1.13 [0.69;1.83]	0.689
unspecific malaise	*2*	*63*	*33*	*98 (24.8%)*		
headache	*2*	*5*	*5*	*12 (3.0%)*		
fever	*7*	*65*	*19*	*91 (23.0%)*		
Flu-like symptoms including[a]	**11**	**106**	**56**	**173 (43.7%)**	1.89 [1.16;3.06]	0.009
common cold	*2*	*3*	*1*	6 (1.5%)		
myalgia	*2*	*12*	*7*	*21 (5.3%)*		
sniffle	*0*	*3*	*0*	*4 (1.0%)*		
sore throat	*1*	*5*	*5*	*11 (2.8%)*		
cough	*7*	*61*	*31*	*99 (25.0%)*		
dyspnoea	*7*	*71*	*41*	*119 (30.1%)*		
Gastroenterological symptoms[a]	**3**	**19**	**6**	**28 (7.1%)**	0.83 [0.26;2.25]	0.878
diarrhoea	*2*	*9*	*4*	*15 (3.8%)*		
vomiting	*1*	*6*	*1*	*8 (2.0%)*		
nausea	*1*	*8*	*1*	*10 (2.5%)*		

Table 1 (continued)

Variable	Pandemic waves				Analysis	
	1st wave 03/2020—09/2020 *n* = 19	**2nd wave 10/2020 – 01/2021 *n* = 274**	**3rd wave 02/2021 – 06/2021 *n* = 103**	**total number (%) *n* = 396**	**2nd and 3rd wave OR (95% CI)**	**2nd and 3rd wave *p* value**
Taste and smell disorders[a]	**3**	**16**	**8**	**27 (6.8%)**	1.36 [0.49;3.49]	0.655
taste disorders	*3*	*14*	*8*	*25 (6.3%)*		
smell disorder	*0*	*7*	*2*	*9 (2.3%)*		
Not known	**0**	**43**	**6**	**49 (12.4%)**		
CRB-65 score						0.471
0	5 (26.3%)	64 (23.4%)	31 (30.1%)	100 (25.3%)	Reference	
1	7 (36.8%)	111 (40.5%)	43 (41.7%)	161 (40.7%)	0.80 [0.44;1.45]	
2	4 (21.1%)	50 (18.2%)	14 (13.6%)	68 (17.2%)	0.58 [0.26;1.27]	
3	0	6 (2.2%)	0	6 (1.5%)	0.00 [0.00;1.88]	
4	0	1 (0.4%)	0	1 (0.3%)	0.00 [0.00;81.7]	
Not analysable	3 (15.8%)	42 (15.3%)	15 (14.6)	60 (15.2%)	0.74 [0.33;1.61]	
CRB-65 score without age						0.702
0	11 (57.9%)	174 (63.5%)	67 (65.0%)	252 (63.6%)	Reference	
1	5 (26.3%)	51 (18.6%)	21 (20.4%)	77 (19.4%)	1.07 [0.57;197]	
2	0	6 (2.2%)	0	6 (1.5%)	0.00 [0.00;2.27]	
3	0	1 (0.4%)	0	1 (0.3%)	0.00 [0.00;102]	
	0	0	0	0	0	
Not analysable	3 (15.8%)	42 (15.3%)	15 (14.6%)	60 (15.2%)	0.93 [0.45;1.84]	
Intensive care unit (ICU)						0.117
patients not on ICU	17	253	89	359 (90.7%)	0.53 [0.24;1,18]	
patients needed ICU	2	21	14	37 (9.3%)	Reference	
number of days on ICU	30	297	269			0.136
1–14	1	13	7		Reference	
> 14	1	8	7		1.60 [0.34;7.86]	
Artificial respiration						0.112
patients without artificial respiration	17	256	90	363 (91.7%)	Reference	
patients needed artificial respiration	2	16	12	30 (7.6%)	2.13 [0.88;5.01]	
not known	0	2	1	3 (0.8%)	1.42 [0.02;27.6]	
Discharge status						< 0.001
recovered	5	88	55	148 (37.4%)	Reference	
still in isolation	12	139	32	183 (46.2%)	0.37 [0.21;0.63]	
dead altogether	2	47	16	65 (16.4%)	0.55 [0.26;1.10]	
St. Vincenz-Hospital Datteln	*2*	*43*	*16*	*61 (15.4%)*	n.a	n.a
St.-Laurentius-Stift Waltrop	*0*	*4*	*0*	*4 (1.0%)*	n.a	n.a
males	*2*	*25*	*9*	*36 (55.4%)*	n.a	n.a
females	*0*	*22*	*7*	29 (44.6%)	n.a	n.a

[a] more than one option as an answer, *n.a.* not applicable

Among the 65 patients who died, 81.5% were older than 70 years, 83.1% had cardiovascular disease, and 50.8% had 3 or more than 3 medical risk factors according to the RKI definitions of 32 comorbidities for a severe course of COVID-19 [13]. Twenty-six patients who died (40%) needed intensive care, 20 of whom (76.9%) needed artificial ventilation, including high-flow oxygen (Table 2).

Risk factors for severe disease and death

The risk factors for hospitalized patients to develop severe COVID-19 disease (need for artificial respiration or intensive care unit stay or death) were age, male sex and CRB-65 score. The results of the multivariate logistic regression are shown in the forest plot in Fig. 1. Patients had a 29% greater risk for having a severe course of disease per additional 10 years of age (OR 1.29, 95% CI 1.09;

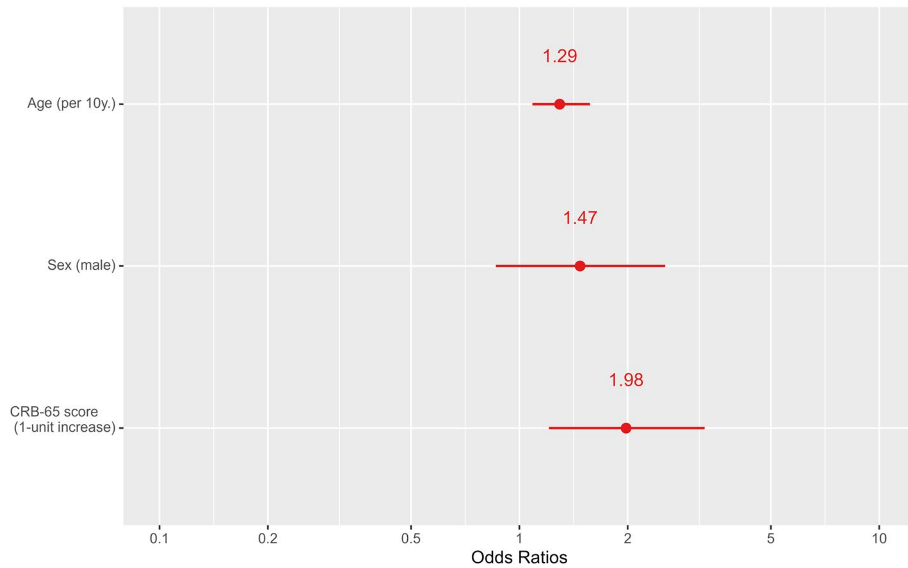


Fig. 1 Risk factors for severe disease. Age, sex and CRB-65 score without age were analysed in a multivariate logistic regression model as risk factors for severe disease (combined endpoint of artificial respiration, intensive care unit admission or death). The results are displayed in a forest plot showing odds ratios with 95% confidence limits. Effect estimates for severe disease were a 29% higher risk per 10 years of age, 47% a higher risk for males, and a 98% risk per point in the CRB-65 score

1.57), a 47% greater risk for male patients than for female patients (OR 1.47, 95% CI 0.86; 2.54), and a 98% greater risk for each additional point in the CRB-65 score (OR 1.98, 95% CI 1.21; 3.27). The results for the risk factor age and CRB-65 score were statistically significant (Fig. 1).

Characteristics of SARS-CoV-2-infected employees

Altogether, 1460 employees were working in both hospitals at the beginning of the study. During the first 3 pandemic waves, 182 employees (12.5%) were tested positive according to the SARS-CoV-2 PCR, 157 (86.3%) of whom tested positive in the 2nd wave. Infections were distributed equally among all age groups. Approximately 1/3 of the infected employees (34.6%) were involved in hospital outbreaks (Table 3). In outbreaks, employees working in hospital VHD and in the intermediate-risk group were more frequently infected than employees working in hospital LSW, in the low-risk or high-risk group. Nurses had the highest risk of becoming infected during outbreaks (Supplementary Table 2).

Among the professionals, 107 (58.8%) infected employees were nurses. The occupational risk for infection was significantly greater for HCWs in the intermediate-risk group (regular wards with patient contact) than for those in both the low-risk and high-risk groups ($p=0.017$).

Among all infected employees, 108 (59.3%) were symptomatic, most frequently with flu-like symptoms ($n=97$), unspecific symptoms ($n=50$), taste and smell disorders ($n=20$) and gastroenterological symptoms ($n=4$). For 3 infected employees, hospital admission was necessary (Table 3). The total number of infected employees in isolation were at least 2548 days. The exact duration of health-related absence was longer than the time of isolation in employees with prolonged periods of COVID-19 associated illness.

Characteristics of outbreaks

1st pandemic wave: March 2020 – September 2020

During the 1st pandemic wave we only diagnosed SARS-CoV-2-positive patients in the VHD, not in the LSW (Table 1). Only 4 of 1460 employees had positive PCR results (Table 3). In a seroprevalence study that was running during the same time we found 13 employees with antibodies against SARS-CoV-2 [16]. We had no outbreaks in either hospital (Fig. 2a), and we did not document transmission of the infection that clearly resulted from contact with SARS-CoV-2-positive patients.

2nd pandemic wave: October 2020 – January 2021

With ≥ 2 positive SARS-CoV-2 test results in patients and/or employees on the same ward, the health authority imposed an admission stop for new patients and closed the affected ward for new admittances to prevent further transmissions.

Overall, 274 COVID-19-positive patients were hospitalized in the 2nd pandemic wave (Table 1). In addition, PCR-positive employees were detected (Table 3).

Nine documented outbreaks occurred in both hospitals on different wards: 8 outbreaks on non-COVID

Table 2 Patients died with SARS-CoV-2 infection during the first 3 waves of the pandemic

Variable	Total number = *n* (%)
Sex	*n* = 65
male	36 (55.4%)
female	29 (44.6%)
Age	*n* = 65
50 – 59 years	5 (7.7%)
60 – 69 years	7 (10.8%)
70 – 79 years	17 (26.2%)
80 – 89 years	22 (33.8%)
90 – 99 years	14 (21.5%)
Possible source of infection	*n* = 65
hospital	15 (23.1%)
private	28 (43.1%)
residential care home for the elderly	19 (29.2%)
not known	3 (4.6%)
Medical risk factors grouped into diseases[a]	
cardiovascular diseases	54 (83.1%)
tumor diseases	15 (23.1%)
diabetes	14 (21.5%)
renal diseases	12 (18.5%)
dementia	12 (18.5%)
pulmonary diseases	8 (12.3%)
psychological diseases	5 (7.7%)
rheumatoid diseases	3 (4.6%)
neurological diseases	2 (3.1%)
liver diseases	1 (1.5%)
Number of risk factors	*n* = 65
0	5 (7.7%)
1	11 (16.9%)
2	16 (24.6%)
3	16 (24.6%)
< 3	17 (26.2%)
Most common therapy on admission[a]	
antihypertensives	42 (65.6%)
anticoagulants	31 (47.7%)
lipid-lowering drugs	19 (29.2%)
antidepressants	10 (15.4%)
neuroleptics	8 (12.3%)
antidiabetics	7 (10.8%)
Number of drugs on admission	*n* = 65
0	2 (3.1%)
1–5	13 (20.0%)
5–10	21 (32.3%)
> 10	10 (15.5%)
not known	19 (29.2%)
Most common symptoms[a]	
dyspnoe	31 (47.7%)
unspecific malaise	19 (29.2%)
fever	16 (24.6%)
cough	12 (18.5%)
taste disorders	2 (3.1%)
sore throat	2 (3.1%)
nausea	2 (3.1%)
Bacterial superinfection	*n* = 65
superinfection	48 (73.8%)
no superinfection	15 (23.1%)
not known	2 (3.1%)
Patients died on intensive care unit (ICU)	*n* = 26 patients
number of days on ICU:	
1—7 days (average = 2.7 days)	13 (50.0%)
8—14 days (average = 11 days)	3 (11.5%)
> 14 days (average = 21.3 days)	10 (38.5%)
ventilated patients (included high-flow oxygen)	20 (76.9%)
not ventilated patients	6 (23.1%)

[a] more than one option as an answer

wards (4 × surgical ward, 2 × geriatric ward, 1 × urological ward, 1 × psychiatric ward) and 1 outbreak on the COVID-19 ward (Fig. 2b). Sixty of the 274 patients (21.9%) were detected PCR-positive in outbreaks, and 33 (55%) of them had COVID-19-specific symptoms. Among the employees, 63/157 were positive HCWs (40.1%) in outbreaks, and 39 (61.9%) of them were symptomatic. The involved HCWs were in isolation or, if still symptomatic, stayed at home longer. Altogether, these outbreaks resulted in at least 896 days of isolation for employees. Affected wards were closed for 137 days, resulting in 2582 free beds that were blocked for admission of new patients (Fig. 3).

3rd pandemic wave: February 2021 – June 2021

Altogether, 103 COVID-19-positive patients were hospitalized at this time (Table 1). In the 3rd pandemic wave, we only registered 2 outbreaks: 1 × geriatric day clinic, and 1 × internal ward (Fig. 2c).

A total of 7/103 patients (6.8%) were involved in outbreaks, and only 1 (14.3%) of them was symptomatic. Fortunately, we had no PCR-positive employees involved in either outbreak. Affected wards were closed for 17 days, resulting in 140 free beds that were blocked for admission of new patients (Fig. 3).

Epidemiological context

In the 1st pandemic wave both hospitals had low exposure to SARS-CoV-2-positive patients, and the surrounding region itself was not a SARS-CoV-2 hotspot (Fig. 4).

In the 2nd and 3rd waves, the 7-day incidence in the general population of the city and district of

Table 3 Characteristics of SARS-CoV-2-infected employees

Variable	Pandemic waves				Analysis	
	1st wave 03/2020 – 09/2020 *n* = 4	**2nd wave 10/2020 – 01/2021 *n* = 157**	**3rd wave 02/2021 – 06/2021 *n* = 21**	**total number (%) *n* = 182**	**2nd and 3rd wave OR (95% CI)**	**2nd and 3rd wave *p* value**
Number of infected employees						1.000
St. Vincenz-Hospital Datteln	3	116	16	135 (74.2%)	Reference	
St.-Laurentius-Stift Waltrop	1	41	5	47 (25.8%)	0.88 [0.24;2.74]	
sex						0.279
female	3	122	14	139 (76.4%)	Reference	
male	1	35	7	43 (23.6%)	1.74 [0.55;5.04]	
Age						0.421
16–25 years	1	49	4	54 (29.7%)	0.47 [0.10;1.65]	
26–40 years	1	40	5	46 (25.3%)	0.71 [0.18;2.37]	
> 40 years	2	68	12	82 (45.1%)	Reference	
Profession						0.003
nurse	4	95	8	107 (58.8%)	Reference	
medical doctor	0	18	1	19 (10.4%)	0.66 [0.01;5.48]	
care worker	0	22	2	24 (13.2%)	1.08 [0.10;5.95]	
cleaning service	0	4	1	5 (2.8%)	2.92 [0.05;34.8]	
administration staff	0	5	3	8 (4.4%)	6.90 [0.91;44.0]	
kitchen	0	1	3	4 (2.2%)	32.8 [2.35;1861]	
therapists	0	4	0	4 (2.2%)	0.00 [0.00;20.7]	
other profession without contact to patients	0	7	3	10 (5.5%)	4.97 [0.70;27.9]	
not known	0	1	0	1 (0.6%)	0.00 [0.00;465]	
Occupational risk for SARS-CoV-2 infection						0.017
low-risk (no contact to patients)	0	24	11	35 (19.2%)	6.50 [2.06;22.0]	
intermediate-risk (working on non-COVID-19 wards)	3	101	7	111 (61.0%)	Reference	
high-risk (working on emergency room, ICU or COVID-19 ward)	1	32	3	36 (19.8%)	1.35 [0.21;6.35]	
Possible source of infection						0.017
private (including family contacts, journey)	2	75	15	92 (50.6%)	Reference	
hospital (nosocomial)	1	61	2	64 (35.2%)	0.17 [0.02;0.75]	
not known	1	21	4	26 (14.3%)	0.95 [0.21;3.44]	
Symptoms[a]	**2**	**94**	**12**	**108 (59.3%)**		
Unspecific symptoms[a]	**2**	**44**	**4**	**50 (27.5%)**	0.61 [0.14;2.00]	0.543
unspecific malaise	*0*	*14*	*1*	*15 (8.2%)*		
headache	*2*	*31*	*1*	*34 (18.7%)*		
fever	*1*	*17*	*2*	*20 (11.0%)*		
Flu-like symptoms[a]	**2**	**86**	**9**	**97 (53.3%)**	0.62 [0.22;1.71]	0.426
common cold	*0*	*24*	*0*	*24 (13.2%)*		
myalgia	*1*	*23*	*3*	*27 (14.8%)*		
sniffle	*0*	*25*	*1*	*26 (14.3%)*		
sore throat	*1*	*25*	*3*	*29 (15.9%)*		
dyspnoea	*0*	*5*	*2*	*7 (3.8%)*		
cough	*1*	*30*	*5*	*36 (19.8%)*		
Gastroenterological symptoms[a]	**0**	**4**	**0**	**4 (2.2%)**	0.00 [0.00;11.7]	1.000
diarrhoea	*0*	*3*	*0*	*3 (1.7%)*		
vomiting	*0*	*0*	*0*	*0*		
nausea	*0*	*1*	*0*	*1 (0.6%)*		
Taste and smell disorders[a]	**0**	**18**	**2**	**20 (11.0%)**	0.81 [0.09;3.86]	1.000
taste disorders	*0*	*17*	*2*	*19 (10.4%)*		
smell disorder	*0*	*8*	*1*	*9 (5.0%)*		
Not known	**1**	**38**	**6**	**45 (24.7%)**		

[a] more than one option as an answer, *n.a.* not applicable

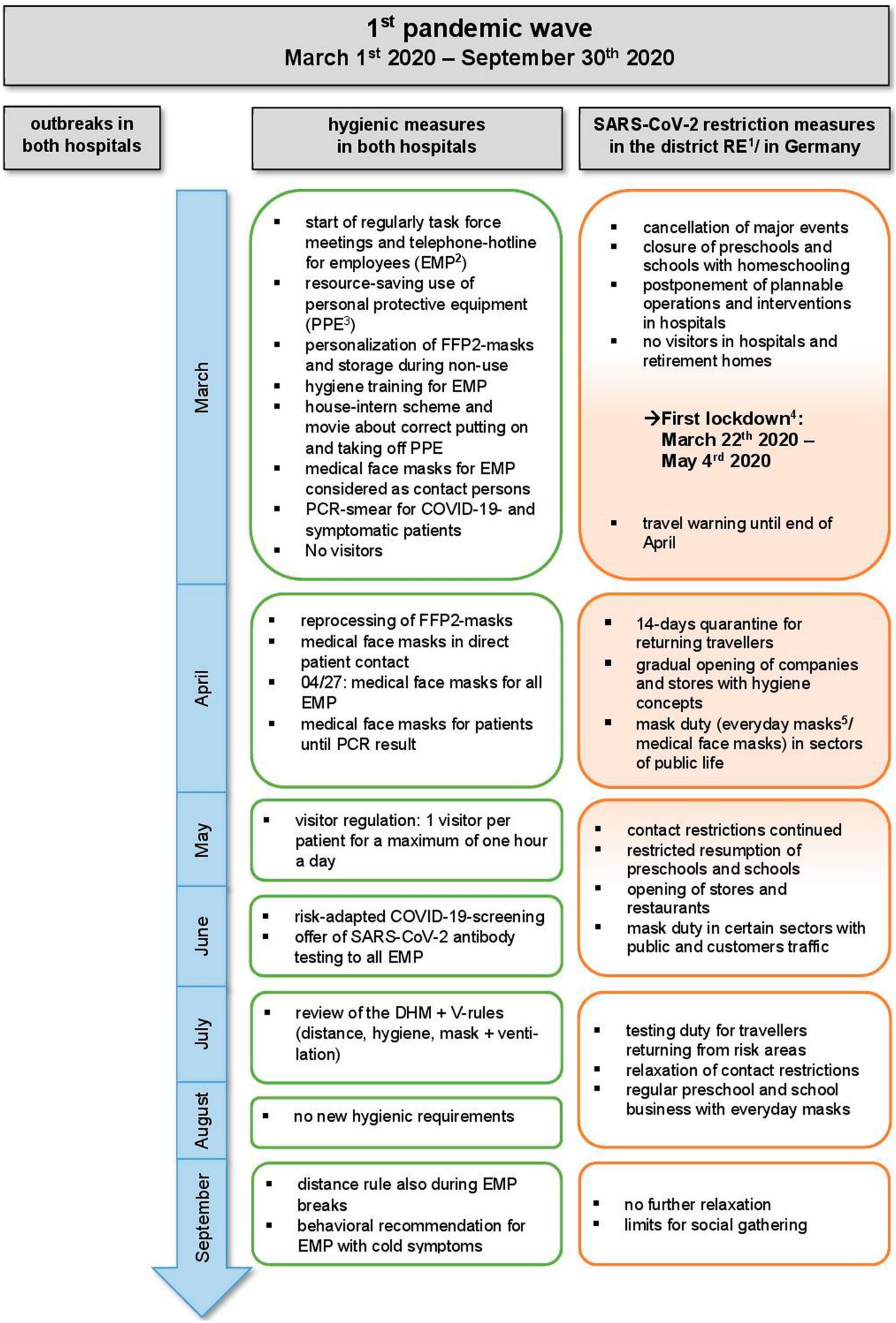


Fig. 2 **a** Hospital and local infection prevention strategies in the 1st wave of the pandemic. **b** Hospital and local infection prevention strategies in the 2nd wave of the pandemic. **c** Hospital and local infection prevention strategies in the 3rd wave of the pandemic [17–21]

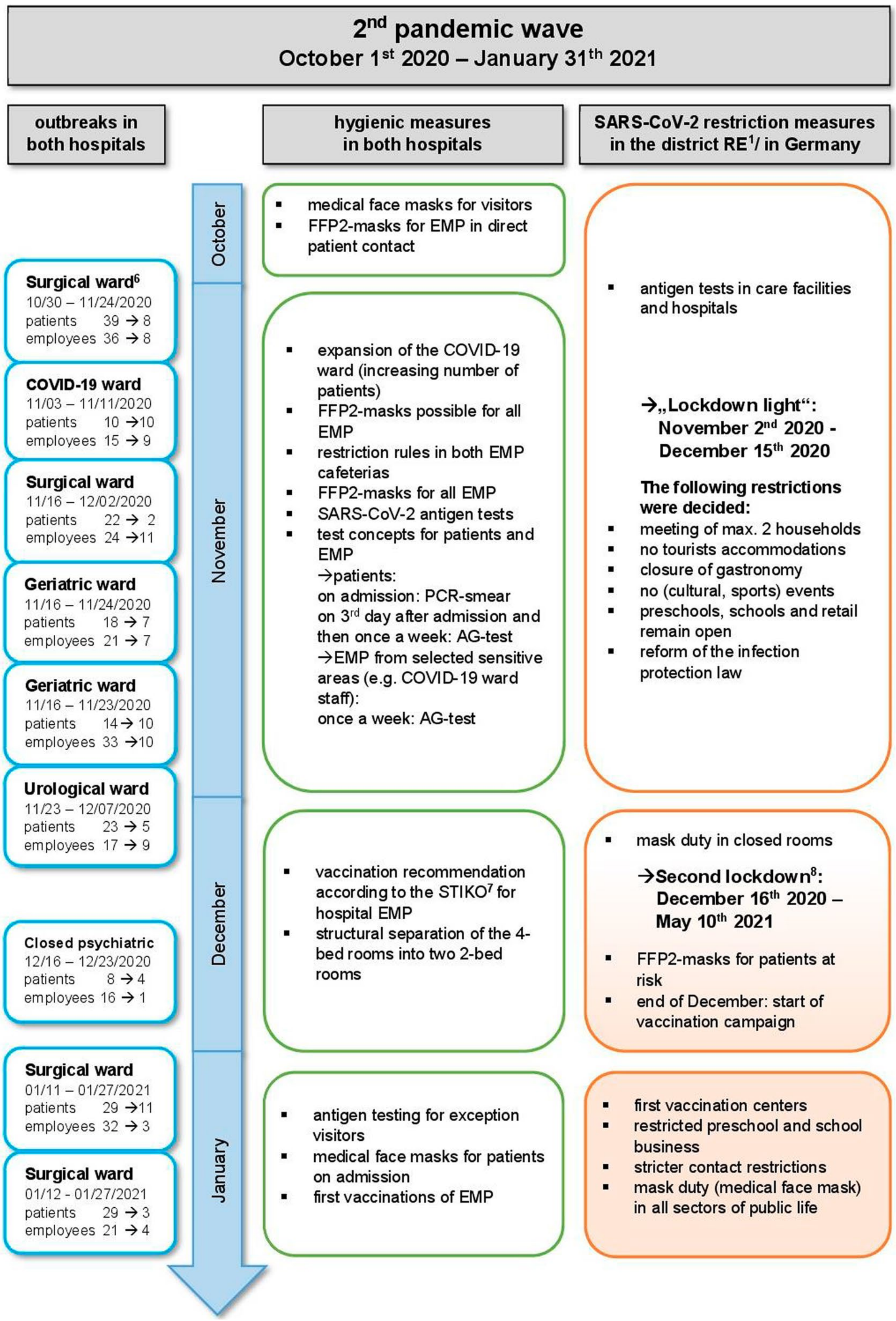
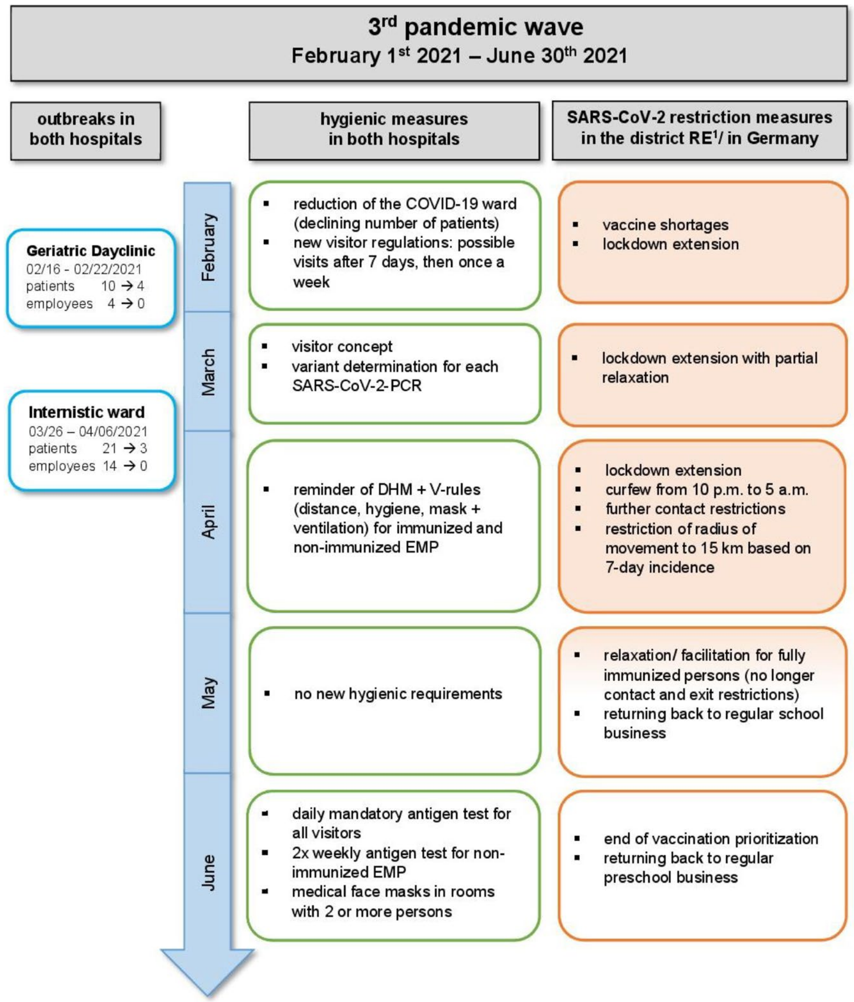


Fig. 2 continued



[1] RE = Recklinghausen (a German district in the state of North Rhine-Westphalia (NRW) with a population of approximately 630.000 people)

[2] EMP = employees

[3] PPE = personal protective equipment

[4] **First lockdown:**

- closure of federal borders
- travel restrictions
- closure of preschools and schools, retail (shops for groceries and daily needs remain open), gastronomy and public facilities
- no church services
- closure of sports and playgrounds

[5] everyday mask = mouth and nose cover out of fabric

[6] speciality of the ward,
date of closure and opening of the ward,
patients: number of patients involved in the outbreak→ PCR-positive patients
employees: number of employees involved in the outbreak→ PCR-positive employees

[7] STIKO = "Ständige Impfkommission" = German Commission for Vaccination

[8] **Second lockdown:**

- closure of retail (shops for groceries and daily needs remain open), gastronomy and public facilities
- restricted business of preschools and schools (partly homeschooling)
- homeoffice (if possible)
- travel restrictions according to the Robert Koch-Institut (RKI) recommendations

Infection prevention strategies in both hospitals followed the recommendations of regular task force meetings. SARS-CoV-2 restriction measures in the district RE and Germany were available on the following official websites: [17-21]

Fig. 2 continued

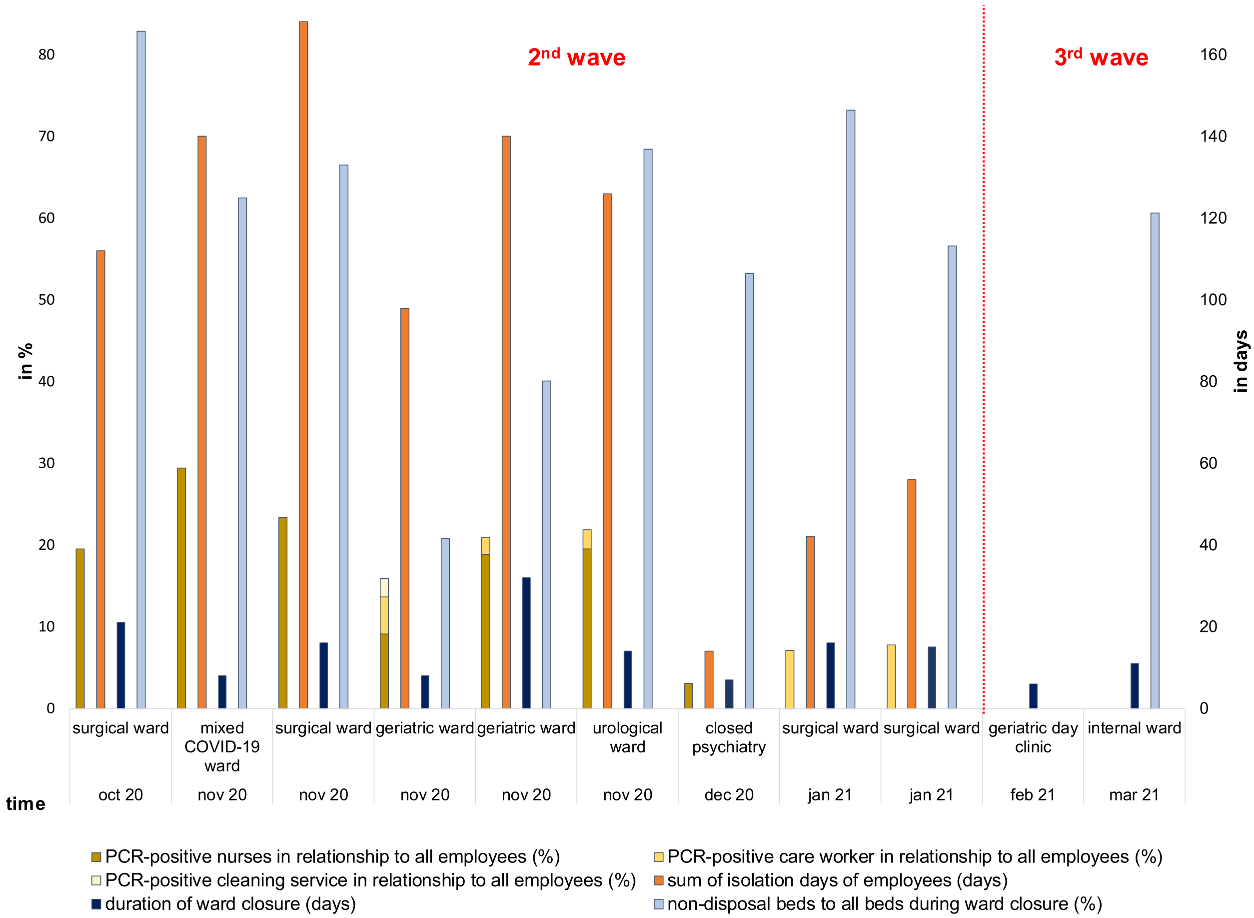


Fig. 3 Impact of SARS-CoV-2 hospital outbreaks on individual wards and employees. The percentage of PCR-positive hospital employees (nurses, care workers and cleaning service) who were involved in outbreaks is shown in relation to all employees in %. Additionally, the sum of days resulting from the isolation of positive employees, the duration of ward closure in days and the percentage of blocked beds during ward closure are shown as indicators of the impact of SARS-CoV-2 hospital outbreaks

Recklinghausen (RE), in NRW and in Germany increased markedly. Moreover, we had a rising number of hospitalized SARS-CoV-2-positive patients and a rising number of SARS-CoV-2-positive employees (Fig. 4). Both community-acquired and nosocomial transmission were present at that time.

Discussion

In this retrospective analysis of the initial 3 waves of the SARS-CoV-2 pandemic, we analysed hospital infections of patients and employees, infection prevention measures, the epidemiological context of infections, hospital outbreaks and their economic impact.

Age and male sex were identified as factors associated with severe COVID-19 disease in many previous studies in Germany [22, 23], England [24], Denmark [25] and in a worldwide meta-analysis [26]. Patients with medical risk factors were more frequently hospitalized than patients without comorbidities in our hospitals. Other studies have described specific risk factors, such as cardiovascular disease [27], elevated C-reactive protein [22], smoking [28] and diabetes [29], as predictors of severe COVID-19. Scoring systems are often used as predictors for severe COVID-19, mainly as prospective methods. The COVID-GRAM score, which has been validated to predict the risk of critical illness or death in the Chinese population, was one of the first reported scores [30]. The CURB-65 score includes urea as an additional predictor compared to the CRB-65 score. It is widely used for predicting 30-day mortality in patients with community-acquired pneumonia [31] and has been proposed as a reference prognostic tool for SARS-CoV-2 pneumonia [32]. The Charlson Comorbidity Index (CCI) was introduced in 1987 as a standardized score to estimate the likelihood of death in various medical situations, taking into account the impact of coexisting medical conditions on the outcome [33]. To date, the association between the CCI and the severity of pneumonia caused by SARS-CoV-2

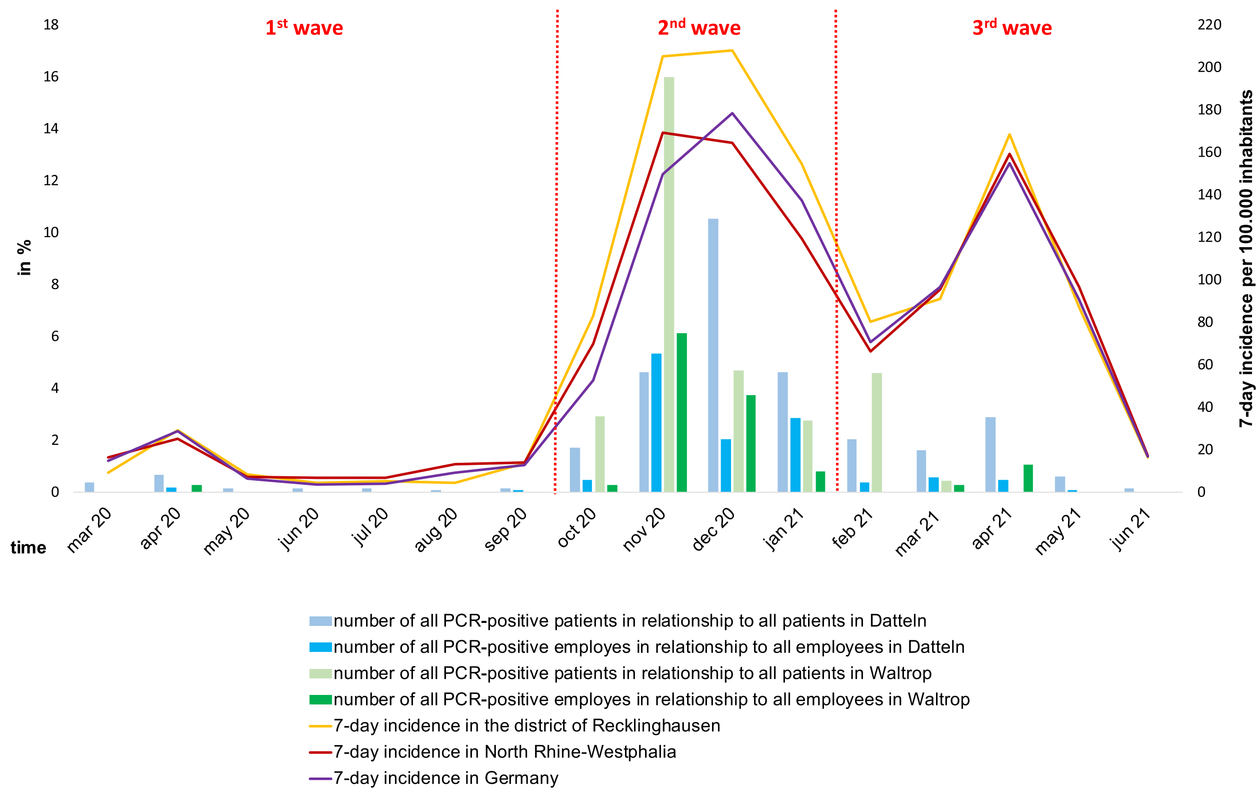


Fig. 4 Hospitalized patients and infected employees in the epidemiological context. The percentages of all PCR-positive patients in both hospitals and employees are compared to the 7-day incidence of SARS-CoV-2 infections in the district of Recklinghausen (RE), in North Rhine-Westphalia (NRW) and throughout Germany

has not been widely explored. The International Severe Acute Respiratory and Emerging Infections Consortium (ISARIC) Coronavirus Clinical Characterisation Consortium (4C) Mortality Score was developed in an ongoing prospective study in 260 hospitals across England, Scotland, and Wales [34]. Parameters for the mentioned scores, for instance, serum urea for the CURB-65 score, were not available for any of our patients. Therefore, we retrospectively analysed our data using the CRB-65 score with age as separate risk factor in combination with the RKI definition of 32 possible comorbidities that are associated with severe COVID-19 [13]. The 2nd pandemic wave had the highest number of hospitalized patients and the highest mortality rate (17.2%), which was also reported in another study in Germany in which different time periods were evaluated [27].

The percentage of employees with a positive SARS-CoV-2 PCR test was 0.3% in the 1st wave, 10.8% in the 2nd wave and 1.4% in the 3rd pandemic wave. Employees definitely had an additional occupational risk of contracting SARS-CoV-2. All 63 PCR-positive employees who were involved in outbreaks were detected in the 2nd wave. Nurses had an increased occupational risk of infection in our study (58.8%) compared to other professionals (e.g., 10.4% medical doctors, 2.2% therapists). This result is consistent with the findings of other studies investigating hospital employees [6, 35, 36] and may be attributed in part to their more frequent contact with and longer contact times with COVID-19 patients than physicians and other occupational groups.

We were looking for reasons why employees working on the COVID-19 ward acquired infection. As they were wearing personnel protective equipment in all patient contacts, other structural factors were likely responsible for nosocomial transmission. During the 2nd wave, the COVID-19 ward was relocated within the hospital. Additionally, we had a high turnover of patients on this ward. Patients who died had longer retention times on the ward due to a temporary lack of storage capacity. After adapting the screening strategy for employees with high occupational risk in November 2020, nosocomial transmissions on the COVID-19 ward stopped.

Furthermore, infected high-risk HCWs have led to personnel shortages, personnel shifts, a high workload, less time for correct self-protection and a shortage of manpower for carefully instructing new personnel [37]. Ongoing infections on regular wards in both hospitals led to an additional occupational risk of infection in intermediate-risk HCWs. The identification of colleagues as important sources for nosocomial transmission resulted in the recommendation to limit the number of colleagues sitting together at breaks to a smaller amount and, if possible, always with the same colleagues. While eating, drinking and smoking, employees should minimize speaking and increase the distance between each other. The use of lifts was limited to 2 people per cabin at the same time. Similar recommendations were described in the university hospital in Jena [35].

Both hospitals included in the study were also included in the seroprevalence study of employees during the first year of infection. The seroprevalence rates of COVID-19-positive employees increased sharply from 1.1% (first wave) to 13.2% in the second wave, and to 29.3% in the third wave [37]. PCR was used to detect the highest infection rate in HCWs working at intermediate-risk in this study, but the seroprevalence study revealed a greater occupational risk of infection in HCWs working at intermediate and high-risk than in non-HCWs in low-risk group [37]. Occupational risk in other studies varies according to the investigated period of infection. A nationwide seroepidemiological study in Germany, called the "RKI-SOEP-Study" revealed a clearly increased risk of SARS-CoV-2 infection for employees in healthcare professions (4.6%) compared to non-healthcare employees (1.8%) from October 2020 to February 2021 [38]. In contrast, Bahrs et al. (2022) described non-patient-related SARS-CoV-2 exposure from colleagues and household members as the highest risk of infection for hospital employees in the University Hospital Jena, Germany, in the first pandemic year [35]. The main limitation of all seroepidemiological studies in contrast to PCR testing is that the exact time of infection could not be determined.

We found a clear correlation between the infection rate in the general population, hospitalized patients and nosocomial transmission. Among all the hospitalized COVID-19-positive patients, 21.9% were involved in outbreaks in the 2nd wave, and 6.8% (7/103) were involved in the 3rd wave. A study that analysed outbreaks in hospitals and long-term facilities in Germany up to September 2021 supported this finding. Suwono et al. (2023) described the strongest association of outbreaks with weekly cases of SARS-CoV-2 infections in the general population in the 2nd wave [12]. Accordingly, the majority of the outbreaks (9/11) occurred on different wards in both hospitals during this time period. The risk factors for severe disease and death in hospitalized patients were age, male sex and a CRB-65 score (without age) > 0 on admission.

It is difficult to evaluate the total costs of the SARS-CoV-2 pandemic in Germany for the health system, all hospitals and the individual hospital itself. The economic burdens that resulted from nosocomial transmissions, such as the isolation time of employees, ward closures and blocked beds, were politically predetermined by health authorities. Therefore, infection prevention urgently needs to be improved to avoid nosocomial transmission. A national observation study investigated SARS-CoV-2 outbreaks in hospitals and long-term care facilities in Germany. The authors reported that hospitals experienced a learning curve throughout the pandemic. As a result, outbreaks could be stopped efficiently, and fewer people were involved in outbreaks if they occurred compared to long-term care facilities [12].

Strengths of our study are the observation of SARS-CoV-2 infections in two hospitals in the first 3 pandemic waves and the determination of the exact time of SARS-CoV-2 infection with PCR testing compared to serological studies. Furthermore, only few analyses of hospital outbreaks with respect to the economic impact have been published so far.

The main limitation of the study is its retrospective nature. As single center study with a small number of infected individuals, data is not representative to the general population due to differences in patient and employee profiles, healthcare structures and resources. Unfortunately, the study period was too short to get meaningful information on the effect of general vaccination and different variants of SARS-CoV-2 viruses. Infection prevention and restriction measures, based on RKI recommendations, were valid in Germany and not necessarily applicable to other countries. Nevertheless, impact of nosocomial transmissions was probably similar in most hospitals in Germany since the health authority rules were uniform.

Conclusions

Nosocomial transmission of SARS-CoV-2 was strongly associated with infection dynamics in the general population but also with structural limitations in the hospital, such as the availability of personnel protective equipment in the early pandemic, personnel shortages and high workloads. The lessons learned will help us to manage further waves of SARS-CoV-2 but also similar infections. We must adapt our infection prevention concept continuously to avoid nosocomial infections, keep hospitals safe for patients and employees and minimize the economic impact on the health system.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12879-024-09641-1.

Supplementary Material 1.

Supplementary Material 2.

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Author declarations
All named authors have seen and agreed to the submitted version of the paper "SARS-CoV-2 infections in patients, hospital employees and nosocomial transmissions during the first 3 waves of the pandemic: a retrospective analysis in a secondary care hospital network in Germany"; that all who are included in the acknowledgements section, or as providers of personal communications, have agreed to those inclusions; and that the material is original, unpublished and has not been submitted elsewhere. There are no previous or pending publications of the material in conference proceedings, letters to journals and brief communications etc.

Informed consent statement
Not applicable.

Authors' contributions
Conceptualization, A.H. and K.D.; Methodology, A.H. and K.D.; Validation, A.H., K.D. and L.U.; Formal analysis, A.H. and S.G.; Investigation, K.D.; Resources, L.U.; Data curation, A.H. and K.D.; Writing—original draft preparation, A.H.; Writing—review and editing, A.H., K.D., L.U. and S.G. All authors have read and agreed to the submitted version of the manuscript.

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Availability of data and materials
Data is provided within the manuscript and supplementary tables. Further datasets and materials analysed in this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This research was conducted in accordance with the Declaration of Helsinki and national standards. Due to the retrospective nature of the study and the anonymisation, the need for informed consent was waived by the relevant ethics committee of the Chamber of Physicians Westphalia-Lippe and University of Münster (approval no. 2021–475-f-S). The study was registered at the German Clinical Trials Register (DRKS00025865).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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