Reopening the Bavarian State Opera Safely: Hygiene Strategies and Incidence of COVID-19 in Artistic Staff During Theater Season 2020/2021

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Summary: Due to the drastically rising coronavirus disease (COVID-19) incidence since March 2020, social life was shut down across the globe, and most opera houses were closed. As a result, there are limited data on SARS-CoV-2 infections among artists. The Bavarian State Opera has been reopened in September 2020. This study aimed to identify the incidence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection among employees in the Bavarian State Opera. In addition, the various hygiene strategies for the work groups within the institution are described. During the study period from September 1, 2020 to July 31, 2021, 10,061 nasopharyngeal swabs were obtained from 1,460 artistic staff members in a rolling system. During the entire study period, 61 individuals tested positive for SARS-CoV-2. None of the patients had a severe disease course. Compared to the seven-day-incidence per 100,000 German inhabitants, the estimated corresponding incidence among employees was lower at 37 weeks and higher or equal at 9 weeks. Among the infected individuals, 58.3% were symptomatic, 23.3% were presymptomatic, and 18.3% were asymptomatic. Forty-five percent of employees reported that they had been infected in their private environment, 41.7% suspected that their colleagues were the main contact, and 13.3% were unsure about the origin of their infection. Twenty-four diseased employees were ballet dancers, eight from the orchestra, seven from the administration, seven from the choir singers, six from the costume department, 10 from technical support, and one guest solo singer. In the 2020/2021 theater season, increased SARS-CoV-2 infections and large disease outbreaks were avoided at the Bavarian State Opera. Hygiene strategies, that existed since the beginning, was specifically designed for various work areas in the opera. Regular, mandatory PCR testing and follow-up of positive cases with the issuance of quarantine were performed. Using this disease management approach, artistic work at and reopening of the Bavarian State Opera was feasible with a well-controlled risk.

Key Words: Incidence of SARS-CoV-2−Musician−Ballet dancer−Singer−Asymptomatic COVID-19 infection.

INTRODUCTION

The novel coronavirus disease was first identified as a case of pneumonia in Wuhan, China, in December 2019 and was designated as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The associated clinical manifestations were named coronavirus disease 2019 (COVID-19).[1] The World Health Organization (WHO) declared the outbreak a pandemic on March 11, 2020.[2–4] As COVID-19 incidence was increased, social life was shut down in different countries, and most opera houses were closed. However, no standardized procedure for the management of this disease has been established to date.

The Metropolitan Opera in New York has been closed since March 12, 2020, and the employees have not received their salaries. It is scheduled to reopen in the autumn of 2021, with a significant cut in salaries for many artists. In San Francisco, the opera has also been closed since spring 2020. Donations have enabled the company to continue paying employees a large portion of their salaries. Due to the great advances in vaccination in California, all restrictions have been canceled since June 15, 2021; and major stage productions are scheduled to return in autumn 2021.[44] In contrast to the U.S., the Teatro Real in Madrid, Spain, has been consistently open since May 2020 with an auditorium occupancy rate of 65%. Although Madrid has twice as high incidence rate as in Germany (800/100000 population in September 2020), only sporadic outbreaks but no clusters of infection were observed in the Theater there[5,43]

The Munich National Theater is one of the largest opera houses in the world. On March 11, 2020, the performance at the Bavarian State Opera was stopped due to the coronavirus pandemic. At the end of the 2019/2020 season, certain events with small audiences could be held. A reopening of the Bavarian State Opera with the audience in the

Accepted for publication November 8, 2021.

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Journal of Voice, Vol. ■■, No. ■■, pp. ■■−■■
0892-1997

https://doi.org/10.1016/j.jvoice.2021.11.012

auditorium took place on September 1, 2020, with the start of the 2020/2021 season.

Among the employees of the Bavarian State Opera, a significant proportion of its artistic staff cannot comply with the usual protective measures because of their instrumental, singing, and dancing activities. These include maintaining a minimum distance of 1.5 m and/or wearing mouth-nose protection and/or performing aerosol-forming activities (eg, singers, wind instruments). Mainly due to the increased generation of aerosols and work with colleagues at close distances, this group of staff is also exposed to an elevated risk of infection with SARS-CoV-2, and requires special occupational safety and health protection. This group comprises employees from the chorus, orchestra, and ballet.

During the coronavirus pandemic, opera houses were closed in many countries around the world. There are sparse data on SARS-CoV-2 infections among artists. Therefore, the aim of this study was to systematically assess early infection incidence among artistic staff at the Bavarian State Opera by conducting regular SARS-CoV-2 reverse-transcription polymerase chain reaction (RT-PCR) tests. Transmission by asymptomatic carriers, that is, people who do not show any or only very mild symptoms of the disease, is a problem of the pandemic.[3,6–8] Therefore, we aimed to identify artistic employees without presenting symptoms. Furthermore, the risk factors of suffering a severe course of a COVID-19 infection for the artistic staff were documented, as well as symptoms in case of the disease. The main aim was to ensure performances and general artistic work at the theater without increasing the risk for the artistic staff and the audience being infected.

MATERIALS AND METHODS

This study was a prospective exploratory study.

Hygiene guideline

The Bavarian State Opera has continuously updated its hygiene guideline since May 2020. These were divided to form a general part (eg, never go to work ill, wear mouth-nose protection, keep 1.5 m minimum distance, etc.) and separate versions specifically designed for various work areas in the opera. In addition, advice and training for employees were provided by the Institute of Virology, Institute of Medical Microbiology, Immunology and Hygiene, Department of Otorhinolaryngology/Phoniatrics, and Department of Internal Medicine II at the Technical University of Munich/Helmholtz Center, School of Medicine, Munich, Germany. A Hygiene Task Force has been in place at the State Opera since August 2020, responsible for specific hygiene rules, their implementation, contact tracing in case of infections, and COVID specific communication.

For each (new) staging, a risk assessment was prepared in which the risk of infection was evaluated for each individual staged action. In case of high risk, appropriate compensatory measures were taken (eg, mouth-nose protection on stage, increased testing frequency, immediate disinfection of props). External guests, eg, guest singers, stage directors or choreographers had to present an externally performed negative PCR test result before they started rehearsing at the Bavarian State Opera.

Regarding rehearsals, the presence of only those people who absolutely had to be present was permitted. Similarly, defined teams/staff were established with attendance lists, intensive ventilation and cleaning after rehearsals were routinely performed, and visitors were not permitted during rehearsals. Furthermore, in certain cases the stage space had been enlarged by adapting the stage set as far as artificially justifiable. Extras, children's extras and (children's) chorus in the productions have been reduced as far as artistically justifiable. For group scenes separate and clearly regulated entrances and exits for group scenes were defined and additional dressing rooms created.

In addition to the general hygiene guideline, the individual areas in the high exposure group received a special, continuously updated hygiene guideline. Among other things, musicians were only allowed to remove their face mask while sitting at their respective music stand.

Only one player was seated per music stand and until the musicians played again in the orchestra pit, they were positioned in such a way that there was always a distance of 1.5 m to the next musician (and 2 m in the direction of the wind for wind players). Regarding orchestral rehearsals with the participation of singers, the rule was that singers preferably should not be placed behind the orchestra or sing in the direction of the musicians.

The choir also had a clearly defined seating plan for musical rehearsals, whereby the required minimum distances of 2 m in the direction of singing were complied with or even exceeded. After each 40 to 60 minute rehearsal, rehearsal rooms were ventilated. Furthermore, singers were obliged to wear face masks as long as they were not singing in pure scenic rehearsals. The music sheets were given to the choir singers individually and were not exchanged among each other. Those artists, who were participating in a rehearsal, had to arrive only immediately before the start of and had to quickly leave the building at the end of the rehearsal. For acting rehearsals, keeping general distance, wearing masks, and omitting physical contact were applied where feasible. In principle, it was only permitted to go below the required minimum distances within the defined groups of 10 persons. Choral scenes were often reduced in size, extras were waived, and the staging was altered in order to remain within the group logic.

Dancers also worked in defined groups. Rehearsals and performances permitted up to ten people dancing from each other. Choreographies were modified, and cast decisions were made accordingly. A training or rehearsal session lasted for a maximum of 90 minutes, followed by extensive airing. In the same manner, there was a special hygiene guideline for the area of costumes and makeup, following a risk assessment by the team of physicians from the hospital Klinikum rechts der Isar. In addition, training was provided by hygiene physicians. A general mask obligation (FFP2

masks) was applied during costume and wig rehearsals. The use of the same costume was avoided by different artists. Makeup and hairdressing services were to be as brief as possible and performed in strict compliance with all hygiene regulations.

The following guidelines were applied to the audience: personalized ticket sales, visitor guide, zoning of the opera, separation of audience and performers, a strictly regulated entrance and exit, and the obligation for visitors to wear a surgical face mask. However, audience numbers and associated governmental restrictions changed several times during the 2020/2021 theater season

Study population

Figure 1 shows the stratification of all staff members of the Bavarian State Opera into four different risk groups: "High exposure," "medium exposure," "low exposure", and "audience exposure." Risk group stratification was based on an algorithm, implemented in accordance with the advice of the Institute of Virology, Technical University of Munich. Staff members were assigned to the "high exposure" group when adherence to wearing a surgical face mask and/or maintenance of 1.5 m social distance was infeasible and/or aerosol-generating activities were inevitable due to their profession. These exceptional situations were permitted only during rehearsals and performances for artistic reasons. Stratification into the "medium exposure" group was done according to profession-specific proximity closer than 1.5 m to the members of the "high exposure" group. In each of the different sections of the choir, orchestra and ballet small subgroups were formed (eg, ballet groups, choir groups, related to specific productions). Only within these subgroups increased interaction without a mask and 1.5 m distance was permitted. In a rolling system, an attempt was made not to test everyone from each subgroup simultaneously, but rather in a time-shifted manner. The assignment criterion for audience exposure was a professional-

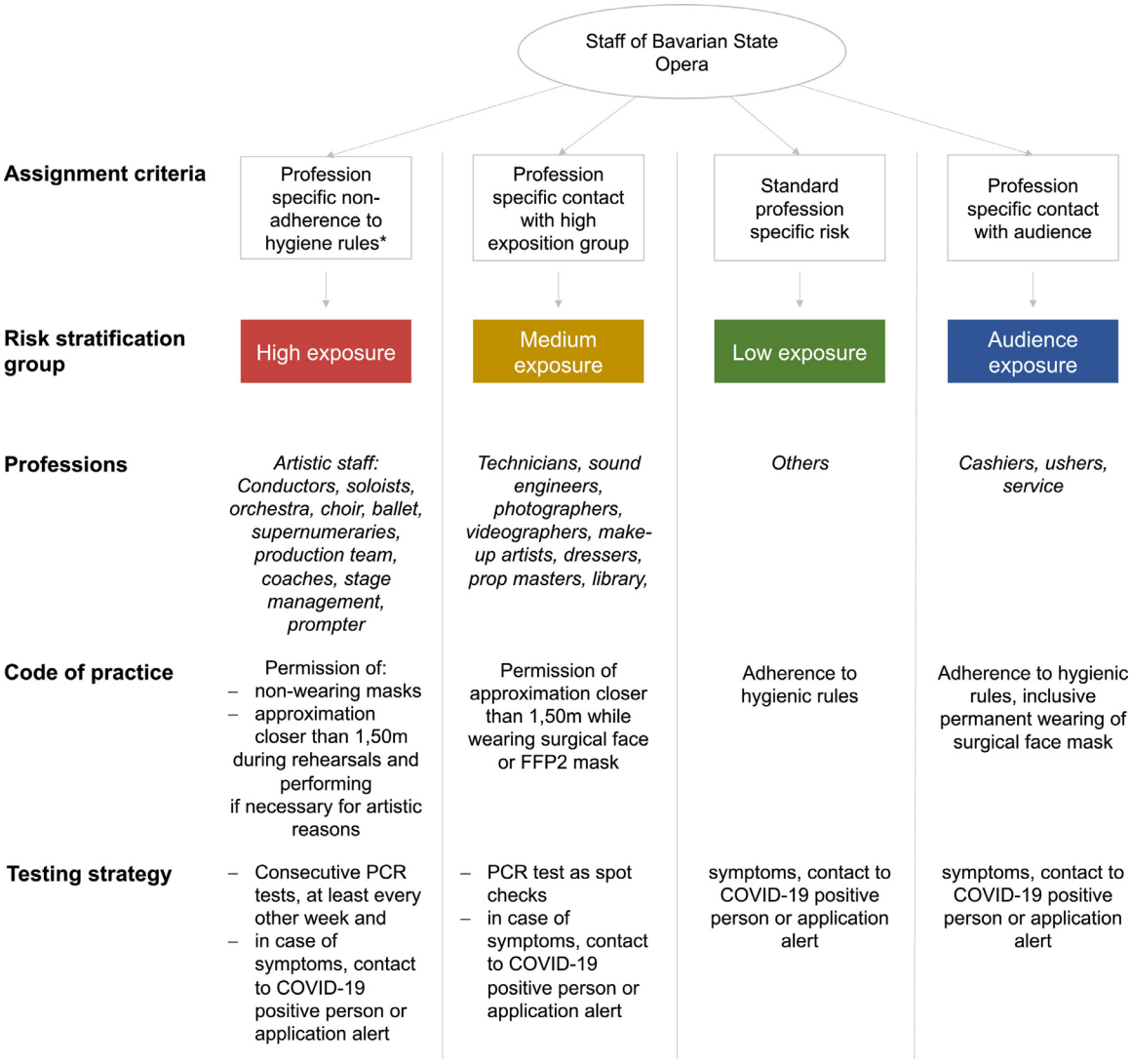

FIGURE 1. Visualization of individual risk stratification. Abbreviations: PCR, polymerase chain reaction. "(For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)"

specific contact with the audience. All staff members who did not fulfill any of the above listed assignment criteria were stratified into the "low exposure" group. Staff members, assigned to the red "high exposure" group who were willing to participate in the study and signed informed consent were prospectively included in the study. Moreover, staff members who tested positive for SARS-CoV2 during the study period and did not participate in the study were interviewed and signed an informed consent form.

Consecutive testing for SARS-CoV-2

Members of the high exposure group were tested consecutively using PCR every other week from September 2020 on, in some cases, more often than in the others. The testing frequency was adapted continuously depending on the current artistic requirements and individual work situation, as well as the current situation of the pandemic in Bavaria and Germany.

Because in May 2021, the orchestra pit was used again, maintaining the distance of 1.5 m between the staff members was no longer feasible. As the orchestra casts grew larger, it was not possible to form small groups with the fixed number of members. Therefore, all orchestra musicians were tested twice a week until the end of the season. Due to more frequent performances and changing casts in different productions during the Munich Opera Festival, choir singers were tested weekly in July 2021. Dancers were tested every 7 −10 days at the beginning of March 2021, owing to extensive rehearsals, especially for the new production of "Der Schneesturm'/' The Blizzard'. Additionally, due to intense rehearsals and close proximity of performers, the test frequency was elevated up to three times per week if required for a particular production. Those assigned to the "medium exposure" group were tested at the beginning of the season and in the form of spot checks. In case of symptoms, a contact with a COVID-19 positive patient or warning alert of the German national "CORONA Warn"-application, employees, independently of their risk group, were tested as well.

Preexisting conditions

A questionnaire was used to record the medical history to detect pre-existing conditions that were considered to be risk factors for severe COVID-19 infections. Risk factors include age over 65 years, male sex, smoking, cardiovascular disease, chronic respiratory disease (bronchitis, bronchial asthma), diabetes mellitus, active neoplasia disease, immunodeficiency, and chronic infection.[9]

Confirmed SARS-CoV-2 infesctions

Real-time reverse transcription-PCR assays were used to detect SARS-CoV-2 in nasopharyngeal swabs. The swabs were drawn by the ear nose and throat specialists to ensure consistent sample quality. RT-PCR assays are the gold standard for SARS-CoV-2 detection with high sensitivity and specificity.[10,11]

The mSample Preparation System DNA kit identical to the Promega Maxwell Viral Total Nucleic Acid Extraction Kit (Promega, Medison, WI) was used for nucleic acid extraction following a standard protocol on an m2000sp device for RNA and DNA extraction (Abbott, Wiesbaden, Germany), SARS-CoV-2 RT PCR was performed using SARS-CoV-2_N1 and SARS-CoV-2_N3 primer and probe sets for amplification on an ABI 7500 real-time PCR cycler (Thermofisher Scientific, Darmstadt, Germany) following the protocol of the Division of Viral Diseases, National Center of Immunization and Respiratory Diseases, Centers for Disease Control and Prevention Atlanta, GA.[12] Quantitative SARS-CoV-2 PCR results were calculated using a standard curve generated from 10e6, 10e4, 10e2, and 10e1 standards. The standard consists of a complete cloned capsid gene and is produced in-house. Results in copies/mL represented viral loads in swab samples. Viral loads less than the lowest standards of 10 copies per reaction could not be quantified and were thus labeled <500 cps/mL. For statistical evaluation of such samples, 250 cps/mL was assumed to be the viral load.

Study period

The study period was from September 1, 2020, to July 31, 2021, for an overall period of 48 weeks.

Tracking of positive SARS-CoV-2 cases

To ensure systematic tracking of positive SARS-CoV-2 cases, all employees and guests were instructed to complete a health and contact diary on a daily basis. This diary always remained in the hands of the person filling it out, even in the event of an infection, but in this case, it was used for the rapid tracking of close contacts. For meaningful tracking, it is also important that the contact persons of all employees, especially in the groups, can be traced through rehearsal schedules, presence lists, or duty rosters.

The study was approved by the ethics board of the Medical Faculty of Technical University of Munich 521/20S in August 2020 and conducted in accordance with the Declaration of Helsinki.

Evaluation of the 7-day incidence per 100,000 people and comparison with 7-day incidence per 100,000 inhabitants in Bavaria and Germany

We aimed to determine a comparable value for the proportion of the infected staff at the Bavarian State Opera. Therefore, all staff members infected with COVID-19 during the study period were determined, including those, who were not part of the red "high exposure" group and thus not included in the study initially and were counted per week. To determine a comparable value, an estimated 7-day incidence per 100,000 staff members of the Bavarian State Opera was calculated. A total number of 1,700 employees

of the Bavarian State Opera was estimated by the administration of the Bavarian State Opera. This number included all permanently employed staff members (998), as well as temporarily employed staff and guests involed in various productions. Referring to the total number of 1,700 employees by the Bavarian State opera in the indicated study period, the estimated 7-day incidence per 100,000 people was calculated using formula 1 for all 48 weeks within the study period.

$$\frac{n(\textit{infected staff members per week}) \times 100,000}{1700}$$

$$\left[\frac{\textit{infected persons}}{100,000\ \textit{staff members} \times 7\ \textit{days}}\right]$$

Moreover, data indicating the incidence of inhabitants who tested positive for SARS-CoV2 in 7 days per 100,000 inhabitants in Bavaria and Germany, respectively, published online by the Robert Koch Institute (www.rki.de) for all weeks of the study period were collected. The estimated 7-day incidence per 100,000 staff members of the Bavarian State Opera, as well as the 7-day incidences per 100,000 Bavarian and German inhabitants were plotted.

We further aimed to determine whether the overall proportion of infected staff members in the Bavarian State Opera differed significantly from the total proportion of infected Bavarians or Germans in the indicated timespan. Therefore, we performed a two-tailed z-score (95% confidence interval [CI]) comparing the number of infected staff members from September 01, 2020, until July 31, 2021 per 1,700 staff members per 11 months with the total number of notified cases in Bavaria for the same timespan per 13,100,000 Bavarians per 11 months, as well as with the total number of notified cases in Germany per 83,200,000 Germans per 11 months. The analysis was performed with the aid of the open-access online tool openepi.com. The respective epidemiologic data on German and Bavarian infections were obtained from the official website of the Robert Koch Institute (www.rki.de).

RESULTS

With the opening of the 2020/2021 theater season, all permanent employees were initially tested by a laboratory in Munich using RT-PCR for SARS-CoV-2 when resuming work in mid-August 2020. No person tested positive.

From September 1 to November 11, 2020, the Bavarian State Opera performed to an audience, until cultural events were prohibited because they exceeded the 7-day incidence of 100 new infections per 100,000 population in Munich. Normally, an audience of 2,101 people can attend performances at the Bavarian State Opera. Due to the precautionary situation of the coronavirus SARS-CoV-2 infection incident, the number of visitors was reduced to 500 from September 1 to October 26, 2020, and 50 visitors were allowed from October 27 to November 1, 2020.

Thereafter, performances occurred at a much lower frequency, without audiences, and were only transmitted virtually at the online platform of the Bavarian State Opera staatsoper.tv from November 2, 2020, to May 12, 2021. As the 7-day incidence in Germany steadily decreased in spring and theater performances were permitted again, the Bavarian State Opera reopened to an audience of 683 spectators on May 13, 2021. On June 29, 2021, the permitted number of auditors per performance increased to 1,037.

In case of symptoms, close contact to a COVID-19 positive person in private or professional environment or warning alert of the German national "CORONA Warn"-application, all concerned members of staff, independently of risk group assignment, were tested as well. A total of 1,460 persons were tested, and 10,061 swabs were obtained during the course. This number of 1,460 employees differed from the estimated 1,700 employees as employees, who were tested only once in the beginning by the external laboratory and thereafter never within the regular testing scheme as well as employees, who claimed that they were tested by their family doctors, were excluded. The latter had to present negative SARS-CoV-2 PCR tests at the same frequency as that at which the testing was performed by their colleagues.

The details of the study population and risk factors are shown in Table 1. From the high exposure group, 467 employees participated in the study: 192 (41.2%) women and 274 (58.3%) men. The mean and median ages of the participants were 42 and 42.4 years, respectively. They were grouped into different professional fields. The largest group was represented by the orchestra with 170 people, followed by the choir with 83 people, 62 ballet dancers, 54 solo singers, 57 supernumeraries, and 24 employees from the artistic field (eg, stage managers and coaches) as well as 16 employees from the costume, technical, and administrative departments participated. Pre-existing conditions that may have led to a more severe course of COVID-19 were identified. The majority of the staff (n = 403) were non-smokers. The 62 smokers consumed an average of 8.3 cigarettes per day. Chronic respiratory disease affected 33, cardiovascular disease 40, diabetes mellitus 5, active neoplasia disease 4, immunodeficiency 8, and other chronic disease 3 participants.

Furthermore, the risk factors were identified separately in each group. These details are shown in Table 2. The risk factors that were present in more than 10% of cases in each group were as follows: 11 (17.8%) smokers in ballet, 21 (12.4%) in the orchestra, 5 (20.8%) in artistical administration, 12 (20.8%) supernumeraries, 3 (33.3%) technicians and 1 (20%) employees at the administration. From chronic respiratory disease, 6 (11%) supernumeraries and one (50%) member of the costume department and from cardiovascular disease 10 (12.0%) singers in choir, 4 (44.4%) persons from the technical group, and 1 (50%) from the costume department.

During the entire study period, 61 staff members tested positive for SARS-CoV-2. In Germany, this is a notifiable

TABLE 1.
Study Population and Risk Factors

Participants	n = 467		
Median age	42 years		
Mean age	42.4 years		
Sex	female	n =192	
	male	n = 274	
Occupational groups			
	Ballet	n = 62	
		Soloists	n = 17
		Corps de Ballet	n = 35
		Other (management, choreographers)	n = 10
	Orchestra	n = 170	
		Strings	n = 67
		Woodwind	n = 33
		Brass	n = 28
		Other instruments, management	n = 42
	Choir	n = 83	
		Soprano	n = 21
		Alto	n = 22
		Tenor	n = 18
		Bass	n = 21
		Management	n = 1
	Soloist singer	n = 54	
	Artistic field	n = 24	
	Supernumeraries	n = 57	
	Technical department	n = 9	
	Administration	n = 5	
	Costume department	n = 2	
Preexisting conditions			
	Smoker status		
		Non-smoker	n = 403
		Smoker	n = 62
		Thereof on average	8.3c/d
	Chronic respiratory disease		
		No preexisting condition	n = 433
		Bronchial asthma	n = 26
		Other	n = 7
	Cardiovascular diseases		
		No preexisting condition	n = 427
		Arterial hypertension	n = 33
		Other diseases	n = 7
	Diabetes mellitus		
		No preexisting condition	n = 462
		Diabetes mellitus I	n = 2
		Diabetes mellitus II	n = 3
	Active neoplasia disease	n = 4	
Immunodeficiency	n = 8		
	Chronic infection	n = 3	

TABLE 2.
Preexisting Conditions of Artistic Staff in Different Groups

	Ballet	Orchestra	Choir	Soloist Singers	Artistic Administration	Supernumeraries	Technical Department	Administration	Costume Department
Number	62	170	83	54	24	57	9	5	2
Mean age (years)	30	44	49	38	39	46	48	47	43
Sex									
Male	28 (45.2%)	114 (67.1%)	40 (48.2%)	36 (66.7,%)	11 (45.8%)	34 (59.6%)	8 (88.9%)	3 (60.0%)	0 (0%)
Female	34 (54.8%)	56 (33.0%)	43 (51.8%)	18 (33.3%)	13 (54.2%)	23 (40.4%)	1 (11.1%)	2 (40.0%)	2 (100%)
Preexisting conditions									
Smoker	11 (17.8%)	21 (12.4%)	6 (7.2%)	3 (5.6%)	5 (20.8%)	12 (21.1%)	3 (33.3%)	1 (20.0%)	0 (0%)
Chronic respiratory disease	4 (6.5%)	10 (5.9%)	6 (7.2%)	7 (15.9%)	1 (4.2%)	6 (10.5%)	1 (11.1%)	0 (0%)	1 (50%)
thereof bronchial asthma	3 (4.8%)	7 (4.1%)	6 (7.2%)	4 (7.4%)	1 (4.2%)	4 (7.0%)	1 (11.1%)	0 (0%)	0 (0%)
Cardiovascular disease	1 (1.6%)	14 (8.2%)	10 (12.0%)	5 (9.3%)	1 (4.2%)	5 (8.8%)	4 (44.4%)	0 (0%)	1 (50%)
thereof arterial hypertension	1 (1.6%)	12 (7.1%)	7 (8.4%)	4 (7.4%)	1 (4.2%)	5 (8.8%)	3 (33.3%)	0 (0%)	1 (50%)
Diabetes mellitus	0 (0%)	1 (0.6%)	2 (2.4%)	1 (1.9%)	1 (4.2%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
thereof D.M. I	0 (0%)	1 (0.6%)	0 (0%)	0 (0%)	1 (4.2%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
thereof D.M. II	0 (0%)	0 (0%)	2 (2.4%)	1 (1.9%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Immunodeficiency	1 (1.6%)	4 (2.4%)	1 (1.2%)	2 (3.7%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
active neoplasia disease	0 (0%)	3 (1.8%)	2 (2.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Chronic infection	0 (0%)	3 (1.8%)	1 (1.2%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

Abbreviation: DM, diabetes melittus.

disease. One infected person did not wish to participate in the study (number 46). Overall, approximately 1,700 people were employed at the Bavarian State Opera, comprising

TABLE 3.
Artists Tested Positive for SARS-CoV2: Italics Indicate Persons that do not Belong to the " the High Exposure Group "

N°	Sex	Working field	Date of positive PCR	Pre-existing conditions	Symptoms	Suspected origin of infection
1	F	Orchestra	October 12, 2020	None	symptomatic	Family
2	M	Ballet	October 19, 2020	None	presymptomatic	Family
3	M	Ballet	October 20, 2020	Smoker	asymptomatic	Workplace
4	M	Ballet	October 20, 2020	None	presymptomatic	Workplace
5	M	Ballet	October 20, 2020	None	presymptomatic	Workplace
6	M	Ballet	October 20, 2020	None	presymptomatic	Workplace
7	M	Ballet	October 20, 2020	None	asymptomatic	Workplace
8	F	Ballet	October 20, 2020	None	symptomatic	Workplace
9	F	Ballet	October 21, 2020	None	symptomatic	Workplace
10	F	Ballet	October 21, 2020	None	symptomatic	Workplace
11	M	Ballet	October 21, 2020	None	symptomatic	Workplace
12	*M*	*Technical dept.*	October *23, 2020*	*Smoker*	*symptomatic*	*Workplace*
13	*F*	*Administration*	October *25, 2020*	*None*	*symptomatic*	*Family*
14	M	Ballet	October 27, 2020	None	symptomatic	Workplace
15	F	Ballet	October 28, 2020	None	asymptomatic	Workplace
16	M	Ballet	October 28, 2020	None	*symptomatic*	Workplace
17	M	Ballet	October 28, 2020	Smoker	symptomatic	Workplace
18	F	Ballet	October 28, 2020	None	asymptomatic	Workplace
19	M	Ballet	October 28, 2020	None	symptomatic	Workplace
20	F	Ballet	October 28, 2020	None	presymptomatic	Workplace
21	*M*	*Administration*	*November 02, 2020*	*None*	*symptomatic*	*Family*
22	F	Orchestra	November 02, 2020	Smoker	symptomatic	Family
23	*M*	*Technical dept.*	*November 02, 2020*	*None*	*symptomatic*	*Family*
24	*M*	*Technical dept.*	*November 22, 2020*	*None*	presymptomatic	*Family*
25	M	Orchestra	November 25, 2020	None	asymptomatic	Family
26	*F*	*Technical dept.*	*November 27, 2020*	*None*	symptomatic	*Family*
27	M	Orchestra	December 04, 2020	None	presymptomatic	Friends
28	M	Orchestra	December 13, 2020	None	asymptomatic	Friends
29	M	Technical dept.	December 17, 2020	None	symptomatic	Family
30	F	Orchestra	December 23, 2020	None	symptomatic	Friends
31	*M*	*Technical dept.*	*January 05, 2021*	*Smoker*	symptomatic	*Family*
32	*M*	*Technical dept.*	*January 09, 2021*	*None*	symptomatic	*Journey*
33	*M*	*Costume dept.*	*January 14, 2021*	*None*	symptomatic	*Family*
34	F	Ballet	January 18, 2021	None	symptomatic	Unknown
35	F	Ballet	January 18, 2021	None	symptomatic	Workplace
36	M	Ballet	January 18, 2021	None	symptomatic	Workplace
37	M	Ballet	January 19, 2021	None	asymptomatic	Workplace
38	F	Ballet	January 19, 2021	None	presymptomatic	Workplace
39	F	Ballet	February 02, 2021	None	presymptomatic	Workplace
40	*F*	*Administration*	*March 08, 2021*	*None*	symptomatic	*Unknown*
41	*M*	*Costume dept.*	*March 12, 2021*	*Smoker*	symptomatic	*Unknown*
42	*F*	*Costume dept.*	*March 15, 2021*	*None*	symptomatic	*Unknown*
43	*F*	*Costume dept.*	*March 15, 2021*	*None*	symptomatic	*Workplace*
44	M	Orchestra	March 15, 2021	None	presymptomatic	Family
45	*F*	*Costume dept.*	*March 15, 2021*	*None*	presymptomatic	*Workplace*
46		Refused Information	March 23, 2021			
47	*F*	*Administration*	*March 29, 2021*	*None*	presymptomatic	*Family*
48	F	Choir	April 08, 2021	None	symptomatic	Family
49	*M*	Soloist/ singer	April 16, 2021	None	presymptomatic	Friends
50	*M*	*Administration*	*April 16, 2021*	*None*	asymptomatic	*Unknown*
51	F	Choir	April 20, 2021	None	asymptomatic	Unknown
52	M	Choir	April 20, 2021	Arterial hypertension	symptomatic	Friends
53	*F*	*Administration*	*April 23, 2021*	*None*	symptomatic	*Family*
54	F	Orchestra	April 25, 2021	None	symptomatic	Family
55	*M*	*Technical dept.*	*May 03, 2021*	*None*	symptomatic	*Family*
56	*M*	*Technical dept.*	*May 07, 2021*	*None*	symptomatic	*Friends*
57	M	Choir	May 10, 2021	None	asymptomatic	Family
58	M	Choir	May 11, 2021	None	presymptomatic	Family
59	M	Choir	May 14, 2021	Chronic disease	asymptomatic	Unknown
60	M	Choir	May 17, 2021	None	symptomatic	Workplace
61	M	Ballet	July 16, 2021	None	symptomatic	Unknown

Abbreviations: dept, department; F, female; M, male.

temporarily employed staff members (eg, solo singers) or self-employed workers (eg, directors, stage, costume designers). This corresponds to a cumulative incidence of 0,036 during the study period of eleven months.

Table 3 provides additional details for the infected individuals. There were 41 (68.3%) employees from the high exposure group. Twenty-four employees were ballet dancers, eight from the orchestra, seven from the

administration, seven choir singers, six from the costume department, seven from technical support, and one guest solo singer. Three positively tested individuals did not work in the main Opera House, but in workshops located 10 km from the opera house.

Among the positively tested staff members, 24 (40.0%) were female and 36 (60.0%) male. The mean age was 38 years, and none of those tested positive for SARS-CoV-2 were older than 65 years (range, 20 − 61 years). Among the infected staff members, the following risk factors were identified: six were active smokers (10.0%), one had chronic disease (1.7%), and one had arterial hypertension (1.7%).

Among the infected employees who were asked about the possible origin of their infection, 27 (45.0%) reported that they had been infected in their private environment, mainly in their family, 25 (41.7%) staff members suspected that their colleagues were the main source of infection, and 8 (11.7%) were unsure where they might have been infected.

At the time of testing, 35 of 60 patients showed symptoms (58.3%) and 25 did not show any symptoms (41.7%). Of these individuals without symptoms, 14 employees were presymptomatic (23.3%), thus developing symptoms in the course, and 11 remained asymptomatic (18.3%) (without symptoms during the entire COVID-19 course). Overall, 49 SARS-CoV-2 positively tested patients (81.7%) developed various symptoms (cough, rhinitis, fatigue, vomiting, diarrhea, and hyposmia). Patients infected with COVID-19 who require hospitalization are usually classified into mild, severe, and critical illnesses according to the clinical manifestation and severity of the disease.[49] None of the patients had a severe course, and no hospitalization was necessary.

Twenty-four ballet dancers tested positive for SARS-CoV2. This corresponded to 40.0% of the total number of infected individuals (Figure 2). Furthermore, 30.3% of the 79 permanently employed people working in the ballet company were infected during the study period. Eight people from the orchestra were infected with SARS-CoV2, corresponding to 6.1% of the total number of 131 permanently employed orchestra staff and additional 7 people from choir were infected, corresponding to 7.1% of the total number of 98 permanent employees of the choir; in addition, 20 persons (3.8%) from other areas (administration, technical, and costume department), and 1 guest solo singer were infected. However, it must be stated that the numbers for overall permanent employees did not include temporarily employed staff and guest performers. The overall number of

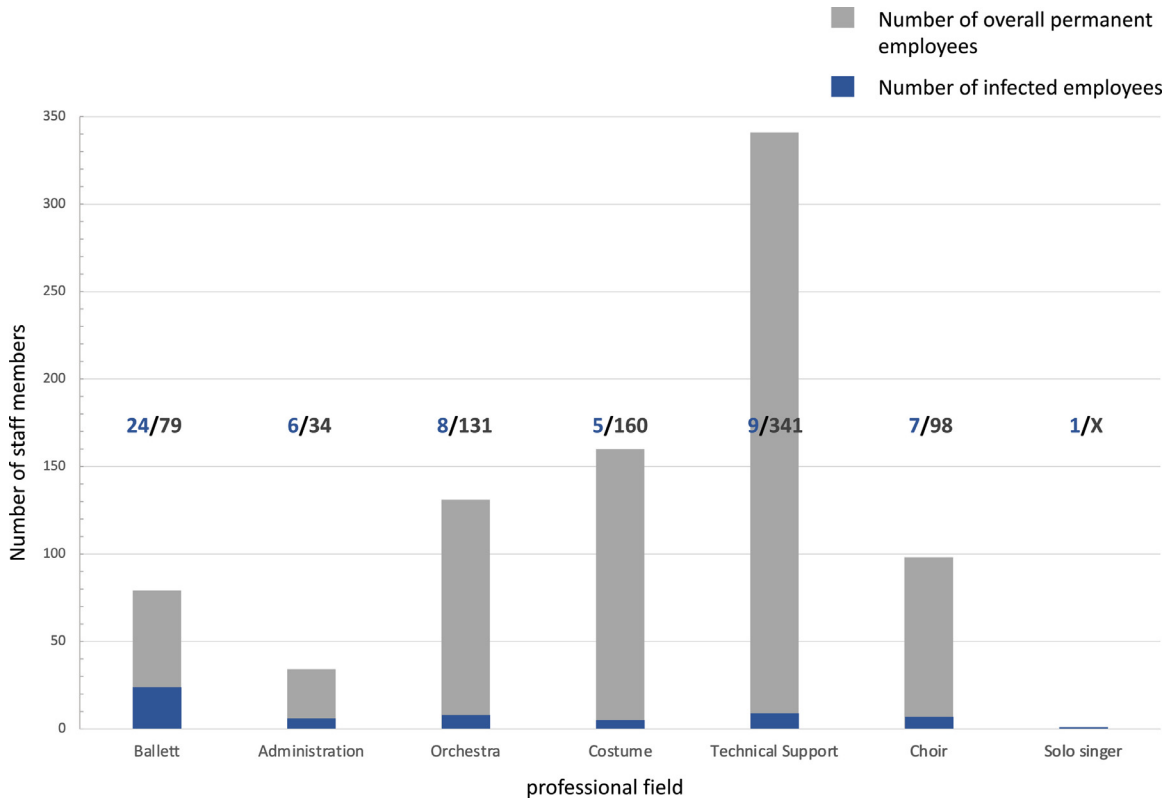

FIGURE 2. Distribution of SARS-CoV-2 positive tested artistic employees per professional field. Grey bars indicate the total number of permanently employed staff per professional field at the Bavarian State Opera; blue bars indicate the respective number of with SARS-CoV2 infected employees from September 1, 2020, until July 31, 2021. As there are no guest solo singers who are permanently employed, this value cannot be indicated. "(For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)"

temporarily and permanently employed staff in this time period was estimated by the human resources department of the Bavarian State Opera to correspond to 1,700 employees compared to 998 permanently employed staff members.

Figure 3 A shows the incidence per 7 days per 100,000 employees at the Bavarian State Opera in comparison to Bavaria and Germany. The mean value was 73.7 infections per7 days per 100,000 employees (range 0−705,6). The mean values of the seven-day incidence per 100,000 Bavarian inhabitants for the respective time period were 94.8 and in Germany 88.1%, respectively. Thus, the mean value at the Bavarian State Opera was only 0.78 times as high as that of Bavaria and 0.84 times as high as that of Germany for the indicated timespan.

The z-score at the 95% CI revealed no significant difference between the number of infected staff of the Bavarian State Opera (61 per 1,700 staff members) compared to the proportion of infected Bavarians (597,397 per 13.1 million Bavarians) from September 01, 2020 until July 31, 2021 with a two-tailed p-value of 0.06020. The z-score at the 95% CI, comparing the infected staff of the Bavarian State Opera with the proportion of infected Germans (3,521,501 per 83.2 million Germans) in the indicated time period showed a significant difference with a two-tailed *P*-value of 0.1588.

In a total of 23 weeks of 48 weeks, the incidence per seven days per 100,000 employees at the Bavarian State Opera was zero, as there was no single case of COVID-19. In 39 of 48 weeks, the value was lower than the incidence per 7 days per 100,000 Bavarians and at 7 weeks higher or equal for the respective timespan. Compared to the incidence per 7 days per 100,000 German inhabitants, the estimated incidence was lower at 37 weeks and higher or equal at 9 weeks (Figure 3A).[51]

Figure 3 B shows the infection chain of the 61 infected staff members over time, summarized per week. Therefore, it indicates the infections in the private, unknown and professional environment and the possible index patients. The data of the possible source of infection was self-reported by the staff members. This shows three, possibly four, outbreaks that had occurred most probably at work. Likewise, asymptomatic or presymptomatic as well as symptomatic cases were labeled in Figure 3B.

DISCUSSION

The aim of the study was to generate first data on the incidence of SARS-CoV-2 infections among artistic staff at an opera house for the time period of one entire season (11 months). Furthermore, a survey of asymptomatic SARS-CoV-2 infected artistic staff at the Bavarian State Opera was conducted. The monitoring period was from September 1, 2020 to July 31, 2021.

Since May 2020, the Bavarian State Opera has implemented elaborate hygiene guidelines in various working fields, which were continuously updated in accordance with the current situation of the pandemic in Bavaria and Germany and the constantly changing regulations. In September 2020, intermissions and theater catering were omitted during performances. Initially, special plans for the placement of 500 people were prepared to guarantee a distance of 1.5 meter between the auditors (with the exception of three rows where a so-called checkerboard seating was tested). This was continued from September 1 to October 26, 2020, and for one additional week until November 1, 2020, a total of 50 visitors were allowed to perform the Bavarian State Opera.

Owing to the exceeding the 7-day incidence per 100,000 inhabitants in Germany and Bavaria in autumn 2020, performances occurred at a much lower frequency, without audiences, and were only transmitted virtually at the online platform of the Bavarian State opera staatsoper.tv from November 2, 2020, to May 12, 2021. Owing to the steadily decreasing 7-day incidence per 100,000 inhabitants in Germany in spring 2021, theater performances were permitted again; thus, the Bavarian State Opera could reopen to an audience of 683 spectators on May 13, 2021. On June 29, 2021, the permitted number of auditors per performance was increased to 1,037 at the beginning of the Munich Opera Festival 2021.

During these periods, no person from the audience tested positive for SARS-CoV-2 was reported. However, this could not be evaluated conclusively, because the audience was not systematically tested.

With the opening of the 2020/2021 theater season, all permanent employees were initially tested by a laboratory in Munich using RT-PCR for SARS-CoV-2 when resuming work in mid-August 2020. No person tested positive. Risk stratification was implemented in the Bavarian State Opera. The focus was on highly exposed artists in the so-called "high exposure" group.

In a judgment dated March 24, 2021, the Munich Labor Court confirmed the obligation of the tests for the plaintiff who belonged to the high exposure group in order not to endanger the other artists. This decision was confirmed by a judgement of the Bavarian Labor Court Munich from octobre, 19 2021. Now, there is no legal remedy against it.

A total of 1,460 employees were involved in the testing carried out by the University Hospital rechts der Isar, 467 of whom participated in the study. For this purpose, the artists were tested in a rolling system every 9 to 14 days using SARS-CoV-2 PCR testing via an oral swab, and a nasal swab was used to increase the sensitivity of the test results.[13] During the Munich Opera Festival, due to more frequent performances and rehearsals, a group of about 200 artistic staff was tested weekly to twice weekly starting in May 2021. Moreover, all persons who had contact with colleagues or in their private environment who had been tested positive for SARS-CoV-2 were tested after notification, taking into account the incubation period.

The study was conducted over 48 weeks. A total of 1,460 people were tested and 10,061 swab tests were performed during the course. A total of 61 staff members tested positive for SARS-CoV-2 from September 1, 2020, to July 31, 2021. This corresponds to a prevalence or cumulative

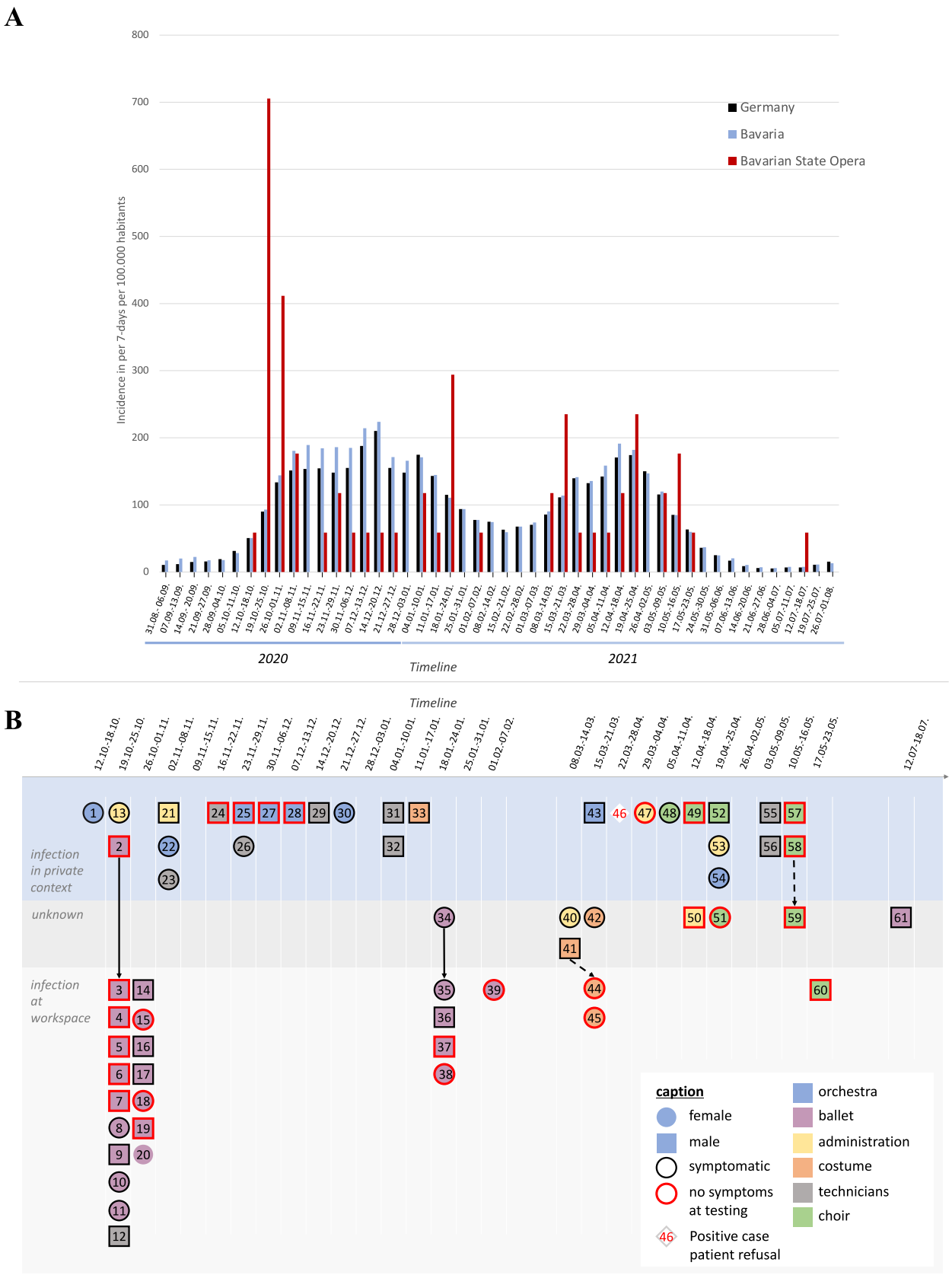

FIGURE 3. **(A)** Bar chart of the estimated 7-day incidence per 100,000 staff members of the Bavarian State Opera (red bars) compared with the 7-day incidence per 100,000 habitants in Bavaria (light blue) and Germany (dark blue) from August 31, 2020 until July 31, 2021. **(B)** Infection chain of 61 infected staff members over time, summarized per week. Female individuals are depicted with a circle and males with a quadrangle. The indicated numbers correspond to the respective case numbers. For cases placed in the blue upper field, it is suspected

incidence 0 of 036 during the period studied. This value was even lower than the respective incidence of cases in Bavaria and Germany for the respective timespan.

In the study population, the risk factors for developing a severe course of COVID-19 were evaluated. Namely these were male gender,[14] positive smoker status,[15] age over 65,[16,47] chronic diseases such as respiratory and cardiovascular disease, diabetes mellitus, active neoplasia disease, immunodeficiency, and chronic infection.[17–19] None of the infected employees required hospitalization, and no patient suffered a severe course according to the definition of severe pneumonia by the WHO.[13,50]

This might be due to the fact that our study cohort was relatively young: the average age of the "the high exposure group" was 42 years (range, 18−77 years) and only 13 out of 467 (2.8%) participants were 65 years or older. Thus, the "the high exposure group" was not generally at risk for severe COVID-19 with respect to age. The mean age of the infected staff members was 37.9 years (range, 20−61 years) and therefore clearly under the age of 50. A study of 131 million Europeans shows that, from the age of 50 years, at least 57% have a risk factor for severe COVID-19.[20]

However, regarding the small number of overall infected staff, especially regarding the absence of severe courses in our cohort, we cannot draw any clear conclusions about the impact of risk factors on the development of a severe course of COVID-19.

The strategy for reopening the Bavarian State Opera specifically was to conduct PCR SARS-CoV-2 testing. While antigen tests have a sensitivity in symptomatic patients of 72% in the first week of symptoms, in persons in the second week of symptoms, it is only 51%. Evidence for antigen testing in asymptomatic cohorts is limited because there is no standard reference for infectiousness, to differentiate those who are infectious and require isolation from those who pose no risk.[21] It is known that the risk of infection is the highest in the period before and after symptom onset, and asymptomatic virus carriers are probably responsible for more than half of the new infections.[22,45] Among the 60 infected participating individuals, 41.7% (23.3% presymptomatic and 18.3% asymptomatic) had no symptoms at the time of testing, indicating that PCR testing was sensitive in detecting asymptomatic as well as presymptomatic SARS-CoV-2 carriers.

Presymptomatic and asymptomatic COVID-19 tested individuals have a particularly high risk of infecting others without realizing it.[23] This means that only routine, rolling, and mandatory testing can detect these individuals without symptoms or detect them faster. By immediately tracing contacts, quarantining, and testing contacts, further infections of colleagues or others in the surrounding area were prevented.

In four independent outbreaks, transmission occurred at the Bavarian State Opera between different employees. The first two outbreaks in October 2020 and January 2021 occurred mainly in the ballet and affected 19 and 6 employees, respectively. The third was an outbreak in March 2021 affecting four employees from the costume department, although the chain of infection remained fraught with doubt, and the last outbreak in May 2021 presumably affected four choir singers. However, for this fourth outbreak in the choir, it remains unclear who exactly the index person was, as two independent cases (57 and 58) were most likely infected simultaneously and independently in their private environment. Of the 25 employees that were most likely infected at their workspace, 14 were presymptomatic or asymptomatic (56.0%) compared to 41.7% among all infected employees and 34.3% among infections that occurred most probably privately. Thus, immediate testing of contact persons within the Bavarian state opera seems to have been fast and effective. In both outbreaks concerning the ballet, a quarantine was established immediately for all dancers. Moreover, entrance testing before restarting dance rehearsing allowed the detection of one more case (case 39) of the second outbreak. Compared to these four outbreaks, 29 of the cases with unknown origin have not lead to any further infection at the Bavarian State Opera.

A large proportion (38.9%) of SARS-CoV-2 positive individuals belonged to the ballet. This is in agreement with previous studies showing that there is an increased risk of infection through dance.[24,25] Immediate quarantine of the entire ballet ensemble prevented further infections inside and outside the ballet. With the exception of one technician who was in close contact with ballet staff, no people from other departments tested positive, such as dressers from the costume department or technicians. The ballet is positioned at the stage behind the orchestra. No infections have been reported from either the orchestra or the audience in this context. However, there is a high risk of infection among the dancers, as well as among ballet pianists and ballet masters who work closely and for several hours per day together with the dancers in the same room. Furthermore, it should be mentioned that, especially in the ballet company, social-private and professional contacts often overlap, which was most likely reflected in the infection chain of the second outbreak; infected ballet members had no contact either in training or in rehearsals but privately, notified in the context of contact tracing. Scientific data on the number of

that the infection occurred in the private environment. For cases placed in the lower gray field, infection was suspected to have occurred because of working contacts. For cases that were placed in the middle light gray field, the infected individuals had no specific suspicion about the origin of their SARS-CoV2-infection. The respective index patients are indicated by arrows. Black contours indicate symptomatic patients at the time of testing, and red contours indicate either presymptomatic or asymptomatic cases. "(For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)"

infections in ballet companies are rare. A limited number of published articles about fitness centers, dancing, and ice hockey reports showed increased SARS-CoV-2 infection or transmission rates in athletes.[24–27] This was probably caused by physical proximity and deep exhalation during physical exercise, which produces increased level of aerosols.[28]

Aerosol generation from different wind instruments is thought to increase the risk of infection in the orchestra.[29] In a normal orchestra formation, musicians do not keep a minimum distance of 1.5 m. The Bavarian State Opera has therefore not played in the orchestra pit with the usual orchestra setting until May 2021, but has removed rows of stalls and played in an expanded space. Thus, the opera achieved sufficient distance between the musicians and singers by reducing the orchestra cast and redesigning the regular orchestra seating. Overall, seven orchestra musicians tested positive for SARS-CoV-2 at six different time points, and independently of each other. In those cases, either life partners, other family members, or friends were likely index persons. Due to the quarantine and testing of all contact persons, no other people tested positive in this context in the Bavarian State Opera. Therefore, the concepts were successful in containing further infections among the artists.

In enclosed rooms, droplets containing pathogens can spread through the airflow and diffusion. They are produced by the vaporization of the water coat of the exhaled aerosol. Due to their low weight, they can remain floating in the air over a long period of time.[30] During speaking and singing, aerosols or droplets are produced by exhalation from the pulmonary alveoli.[28] Evidence of increased aerosol production through physiological voice production mechanisms is known. Considering emissions, an increased sound pressure level during singing, that is, greater loudness and vowels, seem to increase aerosols.[31,46] Terrifyingly high COVID-19 transmission rates in choirs with deaths in closed rooms have been reported.[32] In particular, a high number of emitted droplets can be observed in the near environment of the mouth during singing. Protection by wearing mouth-nose masks can be concluded therefore.[33] Singers are both culprits and victims because of their aerosol-forming activity. The aerosols of an asymptomatic or presymptomatic singer may contain viruses, leading to a "super-spread" of COVID-19 in the singer's environment.[34] However, despite numerous theoretical studies and calculations, the exact concentration of infectious droplets distributed in enclosed spaces cannot be predicted.[30,35]

It is very interesting to note that from eight singers (soloist or choir) who had been tested positive during the entire study period, only one presumably caused two further infections within the Bavarian State Opera (cases 59 and 60). Especially considering that singing has been shown to generate significantly more aerosols than normal talking and breathing described in the literature.[36–40]

We consider that this was due to various factors: the hygiene concept, seating with appropriate distance in musical rehearsals, and good ventilation conditions in the rehearsal rooms and on the stage. Another important factor is the good compliance of the singers. They are aware of the increased risk of infecting themselves and others with the virus. Therefore, this group seems to be very cautious about professional and private contacts.

Moreover, increasing the vaccination of the Bavarian State Opera staff should be mentioned. A vaccination offer organized by the Bavarian State Opera open to all members, started on May 29, 2021. The information provided by employees regarding their vaccination status was voluntary.

On June 18, 2021, 20% of orchestras were vaccinated/recovered, 10% had been vaccinated twice, but not yet 14 days passed, and 20% received the first vaccination. At that time, 24% of choir singers were vaccinated/recovered, 21% had been vaccinated twice, but not yet 14 days passed, and 23% had received initial vaccination. In July, 2021 these figures were significantly higher.

Interestingly, the incidence of SARS-CoV-2 positive cases in the investigated time period was lower in the Bavarian State Opera than in Bavaria and Germany, respectively. This is even more astounding since weekly up to 300 of 1,700 employees (17.6%) were tested at least once and thus testing frequency was much higher than that in overall Germany (maximum 0,5%). [48,49]It is well known the real number of SARS-CoV-2 infections is up to 8.35 compared to the amount of tested people[41] and if the test frequency is elevated a higher incidence is expected. Over time, in 39 of 48 weeks, the estimated 7-day incidence per 100,000 employees of the Bavarian State Opera was lower than the respective 7-day incidence per 100,000 Bavarians, and in 23 weeks, no single case had been detected. After 9 weeks, the value was higher (up to 7.8 fold from October 19 to 25, 2020). However, this has to be seen as a local outbreak, because the total number of staff at the Bavarian State opera is much lower than that of the Bavarian population, and every single positive case counts enormously. For such local outbreaks in smaller cohorts of hotspot areas, it is known that of up to 15% of inhabitants have been infected.[42]

The limitation of the study is that the audience was not systematically tested; therefore, no conclusion can be drawn regarding the incidence of potentially SARS-CoV-2 positive audience members.

As all our positive cases were either confirmed or presumably caused by the Alpha variant or Wuhan strain, we cannot prove that the presented data and conclusions can be extrapolated to the Delta Variant. However, after the study period we have not seen more cases with the advent of the Delta variant indicating that our hygiene strategy was also effective for viruses with higher transmission rates.

CONCLUSIONS

Our data show that artistic work at and reopening of the Bavarian State Opera was feasible with a well-controlled risk. Different factors contributed to this success. A comprehensive hygiene concept had already been established

in May 2020 and has been continuously updated and adapted during the course of the pandemic. In addition, regulations had been modified to account for department-specific requirements. Attention has been paid to well-ventilated rooms. There was an open communication between the Hygiene Task Force team and the artists. During 2020/2021, consultations by physicians from the Hospital of the Technical University of Munich from the departments of Virology, Phoniatrics/ENT, Infectiology, and Hygienic took place, especially in the events of infections. Since the beginning of the season, rolling PCR-SARS-CoV-2 tests in the so called " the high exposure group " have been performed by the physician team. The tests were also available to employees of other groups in the case of COVID-19 infection without the burden of administrative work. Regular testing identified both pre- and asymptomatic individuals. Contact diaries and detailed rehearsal schedules enabled a rapid follow-up. Infections were avoided, except for a small outbreak during this time period. Ultimately, the discipline and high motivation of the artists to protect others and themselves contributed to the success of the hygienic measures and measures as well as the reopening.

DECLARATIONS OF INTEREST

COI: Funded by the BMBF via the Network University Medicine (NUM), project B-FAST to UP and GS CDS reports grants, personal fees and non-financial support from Braun Melsungen, grants, personal fees and non-financial support from Braun Melsungen, grants, personal fees and non-financial support from Gilead Sciences, grants and personal fees from Janssen-Cilag, personal fees from Eli Lilly, personal fees from Formycon, other from Apeiron, grants and personal fees from MSD, grants from Cepheid, personal fees from GSK, personal fees from Molecular partners, other from Eli Lilly, during the conduct of the study; personal fees from AbbVie, personal fees from MSD, grants and personal fees from ViiV Healthcare, outside the submitted work. AMC reports research support, clinical study grants, fees for advisory boards speaker honoraria and other via Technical University Munich (TUM) from ALK-Abello, Allergopharma, ASIT Biotech, AstraZeneca, Bencard/Allergen Therapeutics, European Institute of Technology (EIT Health), German Federal Ministry of Education and Research, GSK, Immunotek, LETI, Lofarma, Novartis, Regeneron Pharmaceuticals Inc., Roche, Sanofi Genzyme, Zeller outside the submitted work. UP reports grants from ALiOS and VirBio, and personal fees from AbbVie, Arbutus, Gilead, GSK, Johnson & Johnson, Roche, Sobi, and Vaccitech, outside the study. UP is co-founder and shareholder of SCG Cell BW reports grants from: Astra Zeneca, Novartis, Cassella Med, Repha Pharma, fees for advisory boards speaker honoraria: MSD, BMS, ROCHE, Astra Zeneca,personal fees from: MSD, BMS, ROCHE, Astra Zeneca, Sanofi, Novartis outside the submitted work SG reports Pharma fees for advisory boards speaker honoraria: Biogen, from outside the submitted work.

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