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ORIGINAL ARTICLE

Nosocomial outbreak of COVID-19 in an internal medicine ward: Probable airborne transmission☆

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KEYWORDS
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Outbreak;
Airborne transmission;
Nosocomial infection

Abstract
Background and objectives: Despite the increasing evidence supporting the importance of airborne transmission in SARS-CoV-2 infection, it has not been considered relevant in the vast majority of reported nosocomial outbreaks of COVID-19. The aim of this study is to describe a nosocomial outbreak of SARS-CoV-2 infection whose features suggest that aerosol transmission had an important role.
Methods: This is a descriptive analysis of a nosocomial outbreak of SARS-CoV-2 infection in an internal medicine ward that occurred in December 2020. All cases were confirmed by a positive PCR test for SARS-CoV-2.
Results: From December 5 to December 17, 21 patients and 44 healthcare workers (HCWs) developed a nosocomial SARS-CoV-2 infection. Fifty-one of the 65 cases (78.5%) were diagnosed between December 6 and 9. The attack rate in patients was 80.8%. Among HCWs, the attack rate was higher in those who had worked at least one full working day in the ward (56.3%) than in those who had occasionally been in the ward (25.8%; $p = 0.005$). Three days before the first positive case was detected, two extractor fans were found to be defective, affecting the ventilation of three rooms. Sixteen cases were asymptomatic, 48 cases had non-severe symptoms, and 2 cases required admission to the intensive care unit. All patients eventually recovered.

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Conclusion: The high attack rate, the explosive nature of the outbreak, and the coincidence in time with the breakdown in air extractors in some rooms of the ward suggest that airborne transmission played a key role in the development of the outbreak.

PALABRAS CLAVE
COVID-19;
SARS-CoV-2;
Brote;
Transmisión aérea;
Infección nosocomial

Brote nosocomial de COVID-19 en una planta de medicina interna: probable transmisión aérea

Resumen
Antecedentes y objetivos: A pesar de los datos cada vez mayores que respaldan la importancia de la transmisión aérea en la infección por el SARS-CoV-2, en la inmensa mayoría de los brotes nosocomiales descritos de COVID-19 no se ha considerado relevante. El objetivo de este estudio consiste en describir un brote nosocomial de infección por el SARS-CoV-2 cuyas características indican que la transmisión por aerosoles desempeñó un papel importante.
Métodos: Se trata de un análisis descriptivo de un brote nosocomial de infección por el SARS-CoV-2 en una planta de Medicina Interna que tuvo lugar en diciembre de 2020. Todos los casos se confirmaron mediante una PCR positiva para SARS-CoV-2.
Resultados: Entre el 5 y el 17 de diciembre, 21 pacientes y 44 profesionales sanitarios contrajeron una infección nosocomial por el SARS-CoV-2. De los 65 casos, 51 (78,5%) se diagnosticaron entre el 6 y el 9 de diciembre. La tasa de ataque en los pacientes fue del 80,8%. Entre los profesionales sanitarios, la tasa de ataque fue mayor en los que habían trabajado al menos una jornada laboral completa en la planta (56,3%) que en los que habían estado ocasionalmente en ella (25,8%; p = 0,005). Tres días antes de detectar el primer caso positivo se identificó una avería en dos extractores de aire, que afectó a la ventilación de tres habitaciones. Dieciséis casos cursaron de forma asintomática, 48 manifestaron síntomas leves y 2 precisaron ingreso en la unidad de cuidados intensivos. Todos los casos se recuperaron finalmente.
Conclusiones: La elevada tasa de ataque, la naturaleza explosiva del brote y la coincidencia en el tiempo con la avería de los extractores de aire en algunas habitaciones de la planta indican que la transmisión aérea desempeñó un papel fundamental en el desarrollo del brote.

Introduction

Since the emergence of COVID-19, a significant number of SARS-CoV-2 infections have occurred in healthcare workers (HCWs)[1]. In the first pandemic wave, 12% of the confirmed infections in Italy occurred in HCWs, while in Spain this percentage exceeded 16%[2]. Several nosocomial outbreaks of COVID-19 were also reported, affecting both HCWs and inpatients[3].

Respiratory droplets and direct contact (person-to-person), or more rarely indirect contact (fomites), have been considered to be the main routes of transmission of SARS-CoV-2[4], whereas potential transmission via aerosols has been a subject of controversy[5–8].

The aim of this study is to describe a nosocomial outbreak of SARS-CoV-2 infection whose features suggest that aerosol transmission played an important role, and to detail the measures taken to control it.

Methods

Setting

The outbreak occurred in an Internal Medicine ward of a 350-bed teaching hospital serving a population of about 200,000 inhabitants. The ward can hold 28 patients in 13 double rooms and two single rooms and is located on the seventh floor of an eleven-storey building that was opened in 1989 (Fig. 1).

There is a shared air conditioner located in the hospital terrace for both the rooms and working areas, and this supplies primary air to the inductors located in the entrance area of each room. This inductor mixes the primary air under pressure with the room air. The air supply for the corridor and ward hallway is provided by another air conditioner. Extraction of air from the rooms occurs in the toilet of the rooms through a vertical box that ends on the terrace where the extractor fan is located.

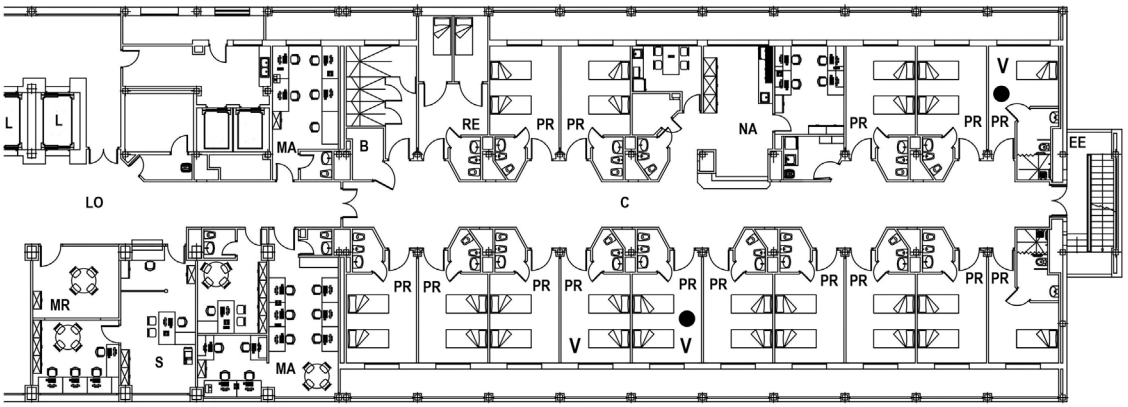

Figure 1 Hospitalization ward floor plan where the SARS-CoV-2 infection outbreak occurred.
PR: patient room; EE: emergency exit; NA: nursing area; MA: medical area; C: corridor; MR: meeting room; LO: lobby; RE: room for explorations; B: bathroom; S: secretariat; L: lift. V: room with faulty ventilation; Black dot: rooms where bronchodilator therapy by nebulisation was carried out.

When the outbreak took place, the incidence of SARS-CoV-2 infection in the previous 14 days was about 200 cases per 100,000 inhabitants in the area served by the hospital. Therefore, some measures had already been taken at the hospital before the outbreak occurred. Family visits had mostly been banned and limited to end-of-life situations or patients requiring special care.

Universal polymerase chain reaction (PCR) testing of patients prior to hospital admission was implemented. Protection of HCWs had also been stepped up with the use of FFP2 respirators and distancing measures had been adopted in shared workspaces and dining areas.

All SARS-CoV-2 infected patients were admitted to specific wards with enhanced personal protection measures. All HCWs received additional training on the use of personal protective equipment through videos and face-to-face sessions. The frequency of cleaning and disinfection of surfaces was increased.

Case definition

Persons under investigation (PUI) were defined as patients hospitalized on the ward between 30 November and 6 December 2020 and HCWs working the ward during this same period. Permanent HCWs were defined as those who had worked at least one full working day on the ward, and occasional HCWs were defined as those who had worked less than a full working day on the ward where the outbreak occurred. A confirmed case was defined as a PUI with a positive PCR test for SARS-CoV-2 regardless of symptomatic status.

Subjects with a history of confirmed SARS-CoV-2 infection in the last three months were excluded from the study. SARS-CoV-2 reverse transcription PCR (RT-PCR) was performed on mucus obtained from nasopharyngeal swabs by a commercial kit (Allplex™ 2019-nCoV Assay, Seegene, Republic of Korea) according to the manufacturer's instructions.

Statistical analysis

Descriptive analysis was performed using attack rates expressed as the percent of individuals with positive PCR among the persons at risk. Attack rates were compared using the chi-squared test or Fisher's exact test as appropriate. A value of $p < 0.05$ was considered to indicate significance. The SPSS software package (version 15.0) was used for the statistical analysis.

Compliance with ethical standards

The local ethics committee (reference number 02-21-101-045) approved this study. Both patients and HCWs gave verbal informed consent for PCR samples to be obtained. Written informed consent for participation was waived because all the interventions and collected data were included in the hospital infection control protocols for care purposes.

No identifying information about the participating patients or HCWs has been included. The study complied with the principles of the 1964 Helsinki Declaration and its later amendments.

Results

Description of the outbreak

On 6 December 2020, a PCR for SARS-CoV-2 was performed on a patient who was admitted to the ward on 2 December due to the presence of respiratory superinfection. The result was positive. The antigen test and PCR for SARS-CoV-2 performed on admission had been negative in this patient, as well as in all patients admitted to the ward. The patient was being treated with bronchodilators by nebulisation. During the same period another patient was receiving nebulisation in another room (Fig. 1). Three other patients presented with low-grade fever on the same day.

According to the hospital infection control protocols, all patients admitted to the ward were screened with PCR

Table 1 Attack rates in patients and healthcare workers in a nosocomial outbreak of COVID-19.

	Positive PCR (N)	Performed PCR (N)	Attack rate (%)
Patients	21	26	80.8
Admitted during the outbreak	19	22	86.3
Discharged in the previous 5 days	2	4	50.0
Permanent healthcare workers on the ward[a]	36	64	56.3[b]
Nurses	12	23	52.2
Nurse assistants	11	20	55.0
Doctors	3	5	60.0
Medical students	8	13	61.5
Cleaning personnel	1	1	100
Administrative staff	1	2	50.0
Occasional healthcare workers on the ward	8	31	25.8[b]
Doctors	1	5	20.0
Nurses	2	2	100
Cleaning personnel	1	10	10.0
Physical resources personnel	2	7	28.6
Physiotherapists	2	4	50.0
Others	0	3	0

[a] Workers who were working at least one full working day on the ward during the 7 days prior to the detection of the outbreak.
[b] The attack rate was significantly higher in permanent healthcare workers on the ward than in those with occasional presence ($p = 0.005$). No significant differences were observed between the different professional categories.

on 6 December and 13 patients tested positive. A second PCR performed 24 h later on all patients on the ward confirmed positivity in these 13 patients and was positive in 6 more patients. PCR was also performed on four patients discharged from the ward over the previous five days and was positive in two of them. In the following days, PCR screening was carried out on all HCWs who had worked the ward during the previous week at any time. Overall, 21 patients and 44 HCWs tested positive. None of the HCWs reported having recent community contact with a person with COVID-19.

The screening results and attack rates are shown in Table 1. The attack rate in patients was 80.8% and only five tested negative. Among HCWs, the attack rate was significantly higher in those who had worked at least one full working day on the ward (56.3%; 95% CI 44.1–68.4) than in those who had occasionally been on the ward (25.8%; 95% CI 10.4–41.2; $p = 0.005$). On the other hand, from December 4 to 13, only five (0.2%) of the approximately 2300 HCWs who worked in other areas of the hospital were diagnosed with COVID-19.

Overall, 17 cases (9 patients and 8 HCWs) were asymptomatic, and 46 cases (11 patients and 35 HCWs) had a low-grade fever; some of them also had headache and/or cough. One patient and one HCW developed severe pneumonia requiring admission to the intensive care unit. Both cases eventually recovered. Fig. 2 shows the epi curve of cases by PCR confirmation date and by date of onset in symptomatic cases. In all symptomatic cases, symptoms appeared between December 4 and 13.

The Physical Resources Department reported that on 3 December (three days before the first positive case was detected) two extractor fans were found to be defective, affecting the ventilation of three rooms, and they had been replaced. Therefore, for a few days (the precise moment when they stopped working is unknown) the three affected rooms lacked an adequate number of air changes. In two of these rooms, patients were receiving bronchodilator therapy by nebulisation (Fig. 1).

Samples from one of the outbreak patients were sent to a reference centre (Hospital Universitari Germans Trias i Pujol, Badalona, Spain) for molecular study of SARS-CoV-2. This analysis identified variant B.1.177/20A.EU1, ruling out the possibility of variant B.1.1.7, with greater intrinsic transmission capacity, which at that time was starting to circulate in Spain.

Control measures adopted

Many actions were taken. The ward where the outbreak occurred was closed, the infected patients were transferred to a COVID ward and the three uninfected patients were quarantined. All affected HCWs were placed on sick leave and their contacts quarantined. The PCR screening protocol was modified by screening the HCWs throughout the hospital every two weeks. In addition, a second screening of all patients at five days post-admission was established. Personal protection was enhanced to perform aerosol-generating procedures. A nebulisation system, with vibrating mesh devices which keep the masks airtight, was implemented, and extra protection with surgical masks over the nebuliser masks was added.

Regarding ventilation, a horizontal air extraction system was installed in the window area of the rooms in order to pull all the air in the room from the door to the window, and the air extractors located on the terrace were replaced by more powerful ones.

Discussion

Since the emergence of COVID-19, several hospital outbreaks of SARS-CoV-2 infection have been reported, though

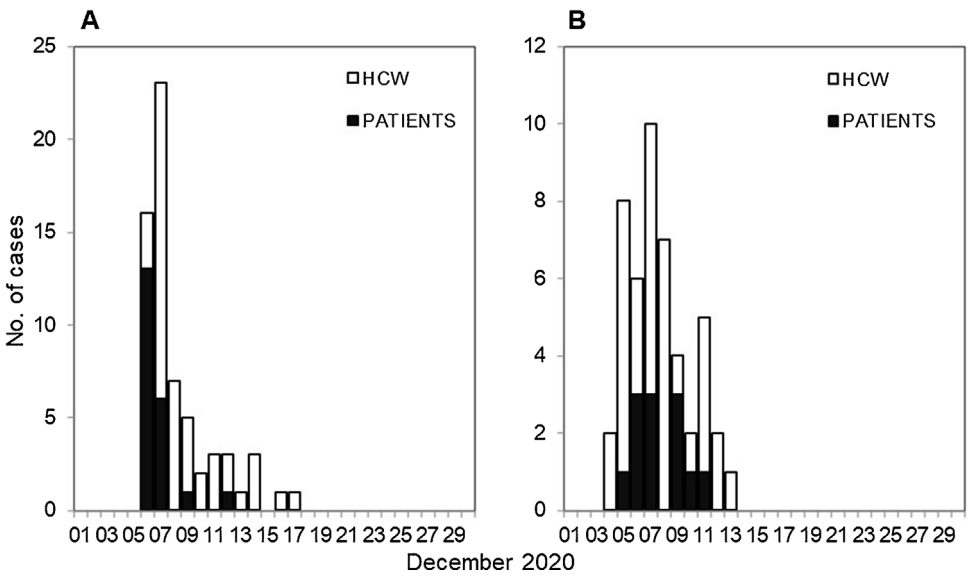

Figure 2 Epi curve of confirmed cases of SARS-CoV-2 infection by date of PCR confirmation (A), and symptomatic cases by date of onset (B), for COVID-19 outbreak in a medical ward.
HCW: healthcare workers.

for most of them the attack rate was much lower than that observed in the current study[3,9–11]. Higher attack rates have been reported in nursing home outbreaks, although in these cases disease transmission had occurred over an extended period of time[3,12].

In the literature on hospital outbreaks, the proposed mechanism of transmission is by droplet or direct contact, either between patients, between HCWs, or between both groups, while possible transmission by aerosols does not seem to be considered[3,11,13], except in two recently reported outbreaks[14,15]. However, there is increasing evidence for the possibility of aerosol transmission of SARS-CoV-2[5,16–18]. As such, aerodynamic studies provide evidence supporting this form of transmission[19].

In addition, community outbreaks of COVID-19 have been reported in which infection is difficult to explain without aerosol transmission[20,21]. In these outbreaks, the transmission rate has been very high. The nosocomial outbreak we describe is characterised by a high attack rate, as well as explosive development in a few days, in addition to the coincidence in time of a breakdown in the air extractors in some rooms of the ward, which could have caused an increase in pressure in these rooms and the spread of contaminated aerosols to the corridor and the rest of the ward. In two rooms affected by the breakdown, patients were receiving bronchodilator therapy by nebulisation, which is an aerosol-generating procedure. All these features make it very likely that airborne transmission played a determining role in the development of the outbreak.

The initial source of the outbreak could have been a HCW who had acquired the infection in the community or, more likely, a patient who at admission was in the pre-symptomatic phase of the disease and still had a negative PCR.

This study has a number of limitations. The main limitation is that molecular typing of SARS-CoV-2 strains was not performed in all cases, and it is possible that some of the infected HCWs may have acquired the infection outside the hospital. Another limitation of the study is that air sampling of the ward where the outbreak occurred was not conducted to investigate the presence of SARS-CoV-2. However, it should be noted that when the outbreak was detected, the defective extractor fans had already been repaired, so there was little chance of detecting the presence of the virus in the ward air.

In conclusion, with this study we report a nosocomial outbreak of SARS-CoV-2 infection whose characteristics make it very likely that airborne transmission contributed to the high attack rate observed in the affected ward. Efforts for the prevention of nosocomial outbreaks should take into account the possible airborne dissemination of the virus, and the importance of properly functioning ventilation systems and architectural design.

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Conflicts of interest

The authors declare that they have no conflict of interest.

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