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Risk of SARS-CoV-2 Transmission in Health Care Personnel Working in a Pediatric COVID-19 Unit

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Dr Lo Vecchio and Dr Pierri conceived the study.

Dr Pierri, Dr Vassallo, Dr Poeta and Dr Bruzzese were involved in the study design and data collection.

Dr Varelli performed serological analysis.

Dr Guarino and Dr Montella reviewed the manuscript and provided substantial support to the project.

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ABSTRACT

Objectives: The paucity of symptoms and the difficulties in wearing personal protective equipment make children a potential source of SARS-CoV-2 infection for health-care workers (HCW). Previous experience in pediatric settings reported high rate of intra-hospital SARS-CoV-2 transmission in HCWs caring for children. We aimed at investigating the rate and determinants of SARS-CoV-2 infection among HCWs working in a Regional reference center in the Southern Italy.

Methods: A prospective observational study was conducted to monitor the occurrence of SARS-CoV-2 infections among HCWs, and to investigate the relation between infection rate and hours of exposure or number and characteristics of procedures, including nasopharyngeal swab, high-flow oxygen delivery, suctioning of airway secretions, sputum induction, nebulizer administration.

Results: After 5 months of monitoring, 425.6 hours of SARS-CoV-2 exposure (18.5 hours/person) and 920 hospital procedures, no case of nosocomial transmission was reported among the 23 HCWs enrolled in the study.

Conclusion: The application of stringent preventive measures, also outside the area dedicated to patients' care, can effectively control infection spreading also in pediatric settings.

INTRODUCTION

Severe Acute Respiratory Syndrome-Coronavirus-2 (SARS-CoV-2) pandemic challenged health systems worldwide, and exposed healthcare workers (HCWs) to an increased risk of infection and death. Hospital setting had a major role in sustaining pandemic, and authorities recommended adoption of adequate prevention and control measures for HCWs [1].

The Italian Health Institute reported 30835 diagnosis of Coronavirus infectious diseases (COVID-19) and over 200 deaths in HCWs, up to July 2020 [2].

Pediatric patients show a mild disease course in most cases, and rarely require hospital care.

However, the paucity of symptoms and the difficulties in wearing personal protective equipment (PPE) make children as a source of transmission for families, health-care personnel and environment [3, 4].

A previous experience in Northern Italy, the area majorly struck by COVID-19, reported an intra-hospital SARS-CoV-2 transmission rate of 24% among pediatricians and 31% among pediatric nurses in less than one month of activity [5].

We aimed at investigating the risk of SARS-CoV-2 dissemination among HCWs caring for COVID-19-affected children in a tertiary-care hospital.

METHODS

A prospective observational study was conducted (March 23rd - August 23rd 2020) at the Referral Center for Pediatric COVID-19 in Campania Region, the most populous region in the Southern Italy accounting for about 5 million inhabitants. The unit consists of 5 in-patient beds and an area dedicated to triage of suspected children. The health-care staff consists of 2 senior pediatric

infectious disease specialists, 6 fellows mainly involved in triage and support activities, 12 nurses, a head-nurse, a pharmacist and a cleaning man. All HCWs were exclusively dedicated to the care of children with suspected or confirmed SARS-CoV-2 infection during the study period.

Anonymized data were obtained from the hospital monitoring of HCWs working in COVID-19 units, after approval of the Institution's Health Department. All HCWs involved in the study signed a written informed consent.

Infection control measures

The ward is organized in two distinct sections: a *contaminated area* dedicated to patient's care, and another *clean area* dedicated to HCWs activities. Health-care personnel were specifically trained, and anyone wore PPE during their stay in the ward, according to the indication reported in **Table 1**.

Patients (if tolerated) and caregivers were asked to wear surgical mask during HCWs access in the room and a single caregiver was allowed for each child. Contact with patients was limited as much as possible. Entrance in the *contaminated area* was scheduled to merge principal activities, including medical visits, blood withdrawal, chest X-ray, distribution of foods and administration of treatments. All medical devices (i.e. stethoscope, pulse oximeter, otoscope) were dedicated to single patients.

HCWs used walkie-talkie to communicate between the *contaminated* and *clean area*, and mobile phones were used to communicate with patients when direct contact was not needed.

Social distancing between HCWs was promoted also in the *clean area*.

Health-care workers monitoring

A standardized registration form was used to collect the following data every time an HCW entered a single patient's room (a 13 squared meters room): time of exposure (minutes recorded through a chronometer, then normalized to hours), type and number of procedures including medical visits, blood samples, nasopharyngeal or rectal swab, airways aspiration, contact with stools or urine, and possible issues with PPE or during undressing procedures. The time spent in the contaminated area, but outside the patient's room (i.e. time needed to move from a room to another, prepare drugs, interact with other colleagues) was not included in the total amount.

In addition, the presence of cough or crying, the use of non-invasive ventilation and the use of PPE by patients and caregivers was recorded.

In accordance with local health management procedures, HCWs were continuously monitored for COVID-19-suggestive symptoms and screened every week by using a rapid Lateral Immunofluorescence test (LIFA) for SARS-CoV-2 IgM/IgG, with 85% (IgM) - 100% (IgG) sensitivity and 96% (IgM) – 98% (IgG) specificity, according to manufacture label (Screen Test COVID –Screen Italia srl) (**Table 2**). In addition, before the opening of COVID-19 Unit (baseline) and after 3 and 5 months of observation, SARS-CoV-2 serology was performed by using Chemiluminescent Immunoassay (CLIA) reporting sensitivity of 79-100% and specificity 97.5-99.6% for IgM (Snibe Diagnostics) and IgG (Abbott), respectively (**Table 2**) [6].

SARS-CoV-2 was searched by real-time reverse-transcriptase polymerase chain reaction (rRT-PCR [7]) of nasopharyngeal swabs in case of symptoms or positivity to antibodies screening test, and at the end of observation.

A diagnosis of SARS-CoV-2 infection (by rRT-PCR or IgM/IgG antibody) in HCWs was considered as primary outcome. Proportion of events were reported as percentages, mean and

standard deviation or median with interquartile ranges were used to describe continuous variables with normal or skewed distribution, accordingly.

RESULTS

Among the 1193 children seen by the COVID-19 pediatric team, most of them were managed in telemedicine, 164 accessed the triage and 27 needed hospital admission due to moderate-to-severe clinical presentation or presence of underlying at risk conditions (mean duration of hospitalization: 9.1 ± 7.1 days). During their stay all caregivers were tested for SARS-CoV-2, and 9 resulted positive to nasopharyngeal swab.

Among the 23 HCWs involved in the study (15, 68% female, median age 29 years, IQR 26-36), 22 had a direct contact with patients. The median of monthly working days and workhours were 18 (IQR, 15-18) and 186 (IQR, 170-187) for each HCW.

During the study period, 920 procedures, 302 aerosol-producing procedures (i.e. nasopharyngeal swab, high-flow oxygen delivery, suctioning of airway secretions, sputum induction, nebulizer administration) and a total of 425.6 hours of exposure to SARS-CoV-2 (18.5 hours/HCW in average) were recorded.

Twenty HCWs reported at least one issue during undressing procedures including difficulties during removal of leg cover boots (n=20) or mask (n=3), and 15 HCWs testified at least one issue in wearing the PPE during patient assistance, including neck cover repositioning (n=10) or mask fitting (n=7).

The number of issues was directly related to the hours of exposure (Spearman's correlation: $r=0.872$ p value <0.05) and the number of procedures ($r=0.975$ p value <0.05).

At the baseline serological evaluation (March 26th) one nurse resulted IgG positive (1.48 sample/cut off [S/Co], reference value < 1.4). He reported a single day history of headache and low-grade fever after traveling in a high prevalence area (Lombardy region in Northern Italy) at the end of February, before the opening of the COVID-19 Unit and notification of other regional cases.

At the first screening test (April 3rd), the positivity of IgG was confirmed and another nurse resulted IgM and IgG positive. Both were totally asymptomatic and resulted negative to SARS-CoV-2 nasopharyngeal swab performed the same day of rapid test screening. Of note, the two nurses do not share work shift but, became housemates since the beginning of pandemic to prevent infection spreading to family. Both eventually resulted positive to follow-up screening tests and showed a complete seroconversion with positive IgG (4.86 and 1.44 S/Co) at week 5.

Due to the timing, the house sharing and the demonstration of early seroconversion against SARS-CoV-2, it is likely that the index colleague could have been the source of infection for the secondary case.

The agreement between LIFA rapid tests and CLIA serology was excellent either at baseline or after five months of observation.

DISCUSSION

Children represent a source of SARS-CoV-2 infection for families and hospital personnel. In our experience, no case of intra-hospital SARS-CoV-2 infection was observed. A single new infection was reported in an HCW who likely contracted SARS-CoV-2 outside the work setting, sharing home with a previously infected colleague.

These findings suggest that the application of stringent prevention measures is effective in preventing intra-hospital transmission in pediatric health-care settings, and that social distancing and PPE need to be maintained also outside the patients' area.

The high rate of nosocomial contagiousness reported in institutions caring for children [5] might be related to different factors.

In the first months of pandemic and in low-prevalence settings, the paucity of symptoms and the presence of extra-respiratory manifestations (i.e. diarrhea, vomiting, abdominal pain or skin rash) in pediatric age hampered an early identification of cases and enhanced SARS-CoV-2 transmission in hospital settings [8, 9].

Secondly, infants and young children, who usually do not wear/tolerate masks, largely contaminate the environment through crying or drooling, even in absence of respiratory symptoms [4]. In addition, the concomitant presence of caregivers (often infected) increase the risk of SARS-CoV-2 exposure.

The identification of controlled pathways for COVID-19 children and caregivers, and the stringent application of infection precautions reduced the transmission rate.

In a previous report in Northern Italy, 22 HCWs were infected in a pediatric ward, but less than 20% contracted SARS-CoV-2 infection after application of distancing and prevention measures. Similar experience in highly exposed HCWs caring for adults in Hong Kong and United States reported none or very few infections [10, 11]. The present report confirmed the effectiveness of infection control measures and proper use of PPE in protecting healthcare workers in a pediatric setting [12, 13]. However, the application of prevention measures, even more stringent than that recommended by the Center for Diseases Control (i.e. FFP3 masking during all procedures,

recommended neck covering or use of protective coveralls), might have had an impact on the lack of intra-hospital SARS-CoV-2 infection reported in our study population.

The present study was conducted in a low COVID-19 prevalence scenario (about 80 cases/100.000 inhabitants), where the contact with SARS-CoV-2 was substantially limited to clinical activities. In this setting, two nurses contracted SARS-CoV-2 infection asymptotically. The first resulted positive before the opening of COVID-19 Unit, and after a recent history of traveling in a high prevalent region, and the second nurse showed positive rapid serological test during the first week of clinical activity when he was protected by PPE and exposed to a single positive patient for about 30 minutes.

Both SARS-CoV-2 IgM and IgG antibodies rapidly increase after 6–7 days from the symptom onset, and reach 88% and 100% sensitivity on day 12, respectively [14]. Hence, it is highly likely that the second nurse contracted SARS-CoV-2 outside the work setting, sharing home with the index case. However, although both resulted negative to nasopharyngeal swab, a transitory exposure of the rest of personnel to SARS-CoV-2 may be plausible during the first week of work. In this scenario, the application of social distancing and PPE also outside the *contaminated area* avoided infection spreading to other HCWs. Although exposed to a negligible risk of re-infection, both HCWs who showed positive serology during follow-up continued to be included in the active surveillance and respected the protocols of prevention measures.

Finally, although outside our goal and small sample-sized, our report provides useful information about the screening measure applied to HCWs engaged in COVID-19. Active surveillance of HCWs changed over time during the pandemic period, according to the availability of diagnostic tests, research input and epidemiological scenario. The low sensitivity of SARS-CoV-2 rapid serologic tests hamper their use as screening tool. However, we found a complete correspondence

between rapid screening test and serology. In our experience a surveillance system based on COVID-19 symptoms monitoring, weekly rapid test and nasopharyngeal swabs for symptomatic or screen-positive personnel, appeared an effective and affordable algorithm for HCWs screening.

The application of stringent preventive measures, also outside the area dedicated to patients' care, and protocols of active surveillance can effectively control infection spreading also in pediatric settings.

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Table 1. Pediatric COVID-19 Unit structure, organization and prevention measures.

	Contaminated Area	Clean Area
Health-care facilities	<ul style="list-style-type: none"> - 5 single rooms with ante-room (no negative pressure) - Triage area - Undressing area - Nurse station 	<ul style="list-style-type: none"> - Meeting room - Storage room - Dressing room - Nurse Station
Personal Protective Equipment	<ul style="list-style-type: none"> - Respirator: FFP2* respirator or FFP3* during invasive or aerosol-inducing procedures[§] - Goggles and face shield - Hair net - Double disposable gloves - Waterproof gown - Leg cover boots (not-waterproof) 	<ul style="list-style-type: none"> - Surgical mask - Disposable gloves
Additional precautionary measures	<ul style="list-style-type: none"> - Remote communication (walkie-talkie or mobile phones) - Dedicated medical devices in each patient's room (i.e. stethoscope, pulse oximeter, otoscope) - Patients (if tolerated) and caregivers wearing mask - Single caregiver for each patient 	<ul style="list-style-type: none"> - Social distancing[°]

*FFP: Filtering Face Piece. FFP2 provides 94-95% filter capacity comparable to N95 respirator, and FF3 provides 99% capacity comparable to N99.

§: nasopharyngeal swab, high-flow oxygen delivery, suctioning of airway secretions, sputum induction, nebulizer administration.

°Social distancing was defined by maintenance of a 3-to-6 feet distance between HCWs in the ward, warning for assemblies of people, use of web platform for journal meeting and case discussion, limiting ward access only to HCWs on duty.

Table 2. Monitoring of procedures and health-care workers' SARS-CoV-2 infections.

	Baseline evaluation	1st mo.	2 nd mo.	3 rd mo.	4 th mo.	5 th mo.	Total
HCWs' exposure							
Total children, n (%)	-	14 (7.3)	20 (10.5)	22 (11.5)	67 (35.1)	68 (35.6)	191 ⁱ
Hospitalized children, n (%)	-	10 (37)	6 (22.2)	2 (7.4)	2 (7.4)	7 (26)	27 ⁱ
Triaged children, n (%)	-	4 (2.4)	14 (8.5)	20 (12.2)	65 (39.6)	61 (37.2)	164
Children wearing mask, n (%)	-	6 (4.3)	15 (10.9)	15 (10.9)	55 (39.9)	47 (34.1)	138 ⁱⁱ
Positive caregivers of admitted patients, n (%)	-	2 (22.2)	1 (11.1)	0	2 (22.2)	4 (44.5)	9 ⁱ
Caregivers wearing mask, n (%)	-	14 (7.4)	20 (10.6)	20 (10.6)	67 (35.6)	67 (35.6)	188 ⁱ
Cumulative hours of exposure, n (%)	-	116,8 (27.4)	195,7 (46)	7,4 (1.7)	15,7 (3.7)	90 (21.1)	425.6
Cumulative number of procedures, n (%)	-	259 (28.2)	241 (26.2)	59 (6.4)	129 (14.0)	232 (25.2)	920
Aerosol-producing procedures, n (%)	-	47 (15.6)	55 (18.2)	44 (14.6)	72 (23.8)	84 (27.8)	302
Medical visits, n (%)	-	90 (29.3)	83 (27)	5 (1.6)	47 (15.3)	82 (26.8)	307
Issues with PPE, n (%)	-	8 (47.1)	5 (29.4)	0	0	4 (23.5)	17
Issues with undressing procedures, n (%)	-	16 (69.5)	4 (17.5)	0	0	3 (13)	23
SARS-CoV-2 infection monitoring of 23 HCWs[§]							
HCW with SARS-CoV-2 symptoms, n (%)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
HCW positive to IgM rapid test (LIFA) ⁱⁱⁱ , n (%)	-	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
HCW positive to IgG rapid test (LIFA), n (%)	-	2 (8.6)	2 (8.6)	2 (8.6)	2 (8.6)	2 (8.6)	2
HCW positive to IgM serology (CLIA) ^{iv} , n (%)	0 (0)	-	0 (0)	-	-	0 (0)	0
HCW positive to IgG serology (CLIA), n (%)	1 (4.3)	-	2 (8.6)	-	-	2 (8.6)	2
HCW positive to RT-PCR on nasopharyngeal swab, n (%)	-	-	0 (0)	0 (0)	-	-	0

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Health-care associated SARS-CoV-2 infection, n (%)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
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Notes:

- i) The sum of single cells is higher/lower of the total as some patients and caregivers had hospitalization longer than one week;
- ii) Seven children aged < 2 years did not tolerate mask, § Percentage were calculated on the total of HCW monitored during the study;
- iii) LIFA manufacture label (Screen Test COVID –Screen Italia srl) declared sensitivity 85% (IgM) - 100% (IgG) and sensitivity and 96% (IgM) – 98% (IgG) specificity;
- iv) CLIA IgM (Snibe Diagnostics) sensitivity 79% and specificity 97.5, CLIA IgG (Abott) at 14 days of infection sensitivity 100% and specificity 99.6%

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