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Surfaces and equipment contamination by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in the emergency department at a university hospital

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ABSTRACT

Objectives: Environmental contamination by patients with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) through respiratory droplets suggests that surfaces and equipment could be a medium of transmission. We aimed to assess the surface and equipment contamination by SARS-COV-2 of an emergency department (ED) during the coronavirus infectious disease-2019 (COVID-19) outbreak.

Methods: We performed multiple samples from different sites in ED patients care and non-patient care areas with sterile premoistened swabs and used real-time reverse transcriptase polymerase chain reaction (RT-PCR) to detect the presence of SARS-CoV-2 ribonucleic acid (RNA). We also sampled the personal protective equipment (PPE) from health care workers (HCWs).

Results: Among the 192 total samples, 10 (5.2%) were positive. In patient care areas, 5/46 (10.9%) of the surfaces directly in contact with COVID-19 patients revealed the presence of SARS-CoV-2 RNA, and 4/56 (7.1%) of the surfaces that were not directly in contact with COVID-19 patients were positive. SARS-CoV-2 RNA was present only in the patients' examination and monitoring rooms. Before decontamination SARS-CoV-2 RNA was present on the saturation clip, the scuff for blood pressure measurement, the stretcher, the plastic screens between patients and the floor. After decontamination, SARS-CoV-2 RNA remained on the scuff, the stretcher and the trolleys. All samples from non-patient care areas or staff working rooms were negative. Only one sample from the PPE of the HCWs was positive.

Conclusions: Our findings suggest that surfaces and equipment contamination by SARS-CoV-2 RNA in an ED during the COVID-19 outbreak is low and concerns exclusively patients' examination and monitoring rooms, preserving non-patient care areas.

1. Introduction

During the novel coronavirus disease 2019 (COVID-19) outbreak, emergency departments (EDs) stood in the front line to face the significant increase of patients with suspected severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Direct transmission from an infected person to another remain the most common route of transmission of SARS-CoV-2 (Patel et al., 2020). Direct transmission is usually

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mediated by saliva droplets during coughing and speaking and needs close proximity (<1 m) or hand contact between two individuals to allow these droplets to reach the mucosa (Patel et al., 2020). Besides saliva droplet, other mediums of transmission such as fecal shedding or urinary excretion have been incriminated but with limited evidence. For instance, it is unclear if the virus is infective or has been inactivated in the intestinal lumen (Xiao et al., 2020; Zang et al., 2020). SARS-CoV-2 may also be indirectly transmitted without close contact between two individuals, through environmental contamination, including air, surfaces and equipment contamination. Airborne transmission is mediated by micro-droplets released during aerosolization that can remain in the air for longer periods and travel at higher distances (Patel et al., 2020; Morawska and Milton, 2020). Surfaces and equipment may also be contaminated through respiratory droplets or hand-contact by patients infected with SARS-CoV-2 and operate as a medium of contamination (Ong et al., 2020). Moreover, the virus has shown to remain viable and infectious in aerosols for hours and on surfaces up to days, depending on the inoculum shed and the nature of the surface (van Doremalen et al., 2020). Therefore, indirect transmission may be a threat for healthcare workers (HCWs) in departments attending COVID-19 patients. Some authors assessed the surface and equipment contamination rates by SARS-CoV-2 in several hospital departments showing a high contamination level in the departments dedicated to the COVID-19 patients care (Ye et al., 2020; Guo et al., 2020). A study reported 12.5% of positive samples in the ED without locating those samples according to the patient-care area (Ye et al., 2020). As EDs are generally characterized by overcrowding, high patient throughput and numerous coming and goings of HCWs, the risk of surfaces and equipment contamination could be high, exposing HCWs to nosocomial infection, despite decontamination procedures and HCWs personal protective equipment (PPE) use (Dexter et al., 2020; Kampf et al., 2020). Thus, HCWs may be concerned about the risk of contamination in the ED, particularly in non-patient care areas. In this study, we aimed to assess the surface and equipment contamination by SARS-CoV-2 of an ED during the COVID-19 outbreak depending on patient care and non-patient care areas.

2. Material and methods

This observational study was conducted from April 1 to April 8, 2020 in the ED of Saint-Louis university hospital, Paris, France. Prior to the outbreak, our department received on average, 115 patients per day and this number dropped to around 60 during the epidemic. Among these patients, 80% were suspected to have COVID-19 and, among those who were tested, approximately 60% were positive for SARS-CoV-2.

We performed multiple samples from different sites all-around the ED and the 7-beds Short Stay Unit (SSU) in patients care and non-patient care areas. Patient care area included patients' registration desk, triage room, waiting room for suspected COVID-19 patients, examination, monitoring and short stay hospitalization rooms (Fig. 1). In this patient care areas, we distinguished the surfaces that were directly in contact with patients such as stretchers, cuffs for arterial blood pressure measurement, pulse oximeter clips, stethoscopes, ECG or ultrasound (US) devices, with those that were more distant, that is to say not directly in contact with the patient, but still located in the same room, into an area of approximately 2 m of the patient, such as trolleys, monitor screens, benches, inside door handle, oxygen delivery manometer, plastic screen between two patients, and floor. Samples were obtained before and after decontamination.

In the non-patient care area, samples were obtained from the registration area (from the HCWs side), non-suspected COVID-19 patients waiting room, corridor with personal protective equipment (PPE) storage, staff working rooms, refreshment room, toilets, changing room, research office and medical equipment stockroom (Fig. 1). There, we focused our samples on the surfaces that were the most in contact with or manipulated by HCWs such as telephones, keyboards, handle doors, tables, desks, benches for medication preparation, buttons, plastic

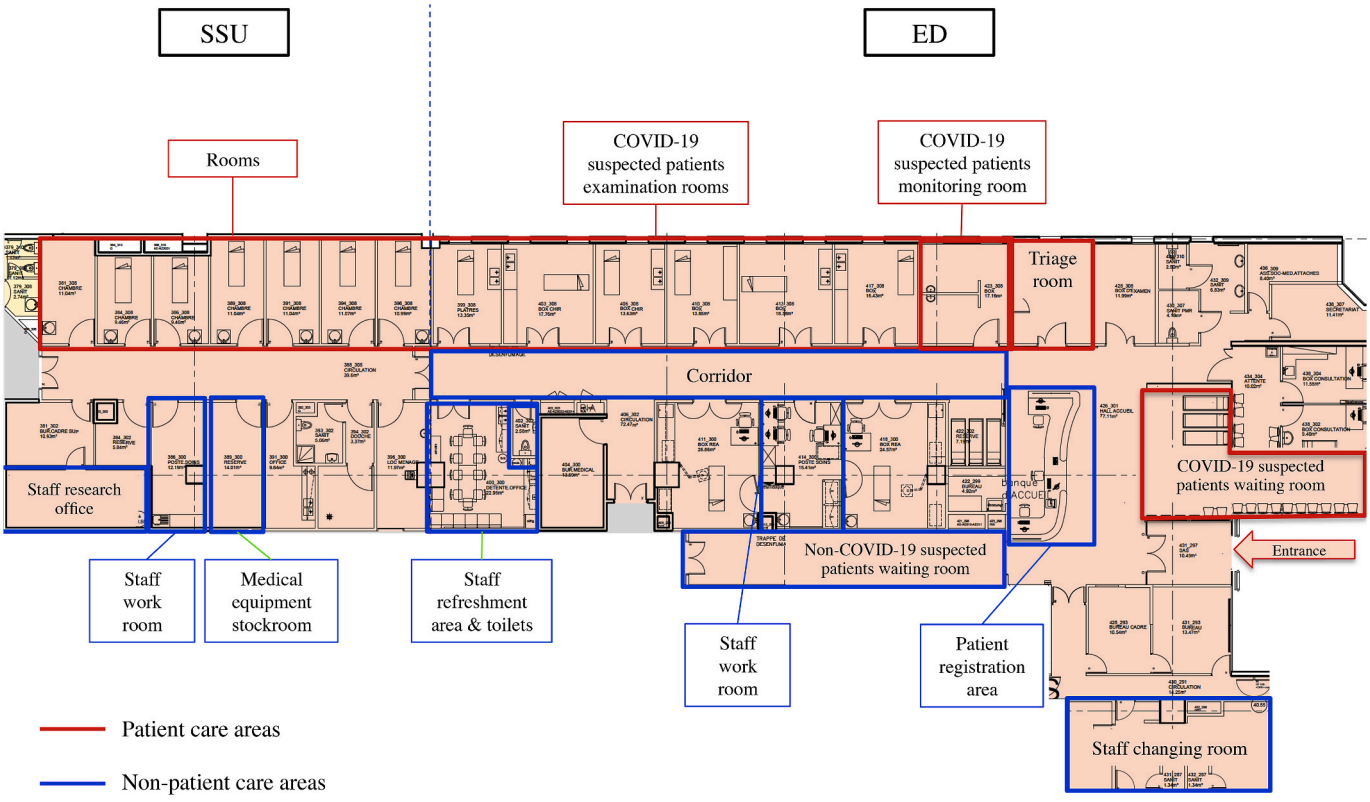

Fig. 1. Emergency Department and Short Stay Unit layout
COVID-19 coronavirus infectious disease 2019, *ED* Emergency Department, *SSU* Short Stay Unit.

jackets for medical files, food baskets, in order to assess the potential risk for indirect transmission. Basically, ED and SSU were adjacent and patient care areas were separated from non-patient care areas by a corridor (Fig. 1). The refreshment area, toilets, medical equipment stockroom and research office were close to the patients care area whereas the changing rooms were distant. ED examination and SSU rooms had a surface of approximately 12 m^2 and the monitoring room of 16 m^2. Thus, the distance between patient face and the swabbed surface varied between 1 m for closer surfaces such as trolleys, chairs, plastic screen, monitor screen and oxygen manometer to 2 m for more distant surfaces in the room such as door handle, bench, faucet or paper dispenser. It is important to underscore that these patients remained in their sketcher or bed during the whole stay in the room reducing the risk of contamination by hand contact. The air exchange rate in the different rooms where the samples were made ranged from 1 to 7 m^3/h and room sizes from 30 to 60 m^3, thus the entire air renewal duration of these rooms could range from 4 to more than 24 h. Patient care and non-patient care areas ventilation systems were connected. Generally, during the epidemic, patients with COVID-19 who needed hospitalization were promptly admitted in a COVID-19 ward in order to free up examination rooms for other patients. Usually, the length of stay of such patients did not exceed 4 h in examination or monitoring rooms. Then, after each patient suspect of COVID-19, examination rooms were cautiously decontaminated by HCWs before installing another patient. The decontamination procedure consisted in disinfecting the floors and all the surfaces of the rooms such as trolleys, sketchers, cuffs, door handles after each patient suspected of COVID-19 with Surfanios Premium (Anios®, France). Little objects such as stethoscopes were disinfected with Surfa'safe Premium (Anios®, France). After decontamination, the room had to remain empty for 30 min before installing another patient. Monitoring room and staff working rooms were regularly decontaminated every 2 or 3 h depending on the patients or HCWs throughput. In order to consider the difference in workload, samples were collected at 3 different days during the epidemic. We sampled three times the rooms that carried the highest HCWs or patient transit such as staff work, triage, examination and monitoring rooms. In the patient care area, samples were made as a priority when patients had a high clinical probability of COVID-19. Therefore, the seven patients that were in the examination rooms or in the monitoring rooms before sampling were tested positive for SARS-CoV-2 except one. All patients admitted in the ED wore a face mask. We also sampled the PPE from HCWs after they cared for patients with COVID-19. We made samples with sterile premoistened swabs according to the protocol proposed by the World Health Organization (https://apps.who.int/ir,) excepted for the surfaces of the swabbed area that were sometimes larger than the recommended 25 cm^2. In our study, the surface area that was swabbed depended on the size of the device or the equipment. We tried to maximize this size without exceeding 50 cm^2 and avoiding letting the swab dry completely. We used Universal Transport Medium for Viruses (UTM® 359C, Copan, Brescia, Italy). After sampling ED surfaces, samples were immediately sent to the Virology laboratory and were processed directly on the COBAS 6800 system after virus inactivation with the COBAS 6800 lysis buffer. We used real-time reverse transcriptase polymerase chain reaction (RT-PCR) (Cobas® SARS-CoV-2 Test, Roche, Meylan, France) to detect the presence of SARS-CoV-2 ribonucleic acid (RNA). RNA was extracted within the total nucleic acids isolation and purification in the sample processing module of the COBAS 6800 system. As determined by the manufacturer, the limit of detection was 0.009 and 0.003 50% Tissue Culture Infective Dose (TCID50)/mL for SARS-CoV-2 (Target 1) and pan-Sarbecovirus (Target 2), respectively. An independent study reported a sensitivity of 689.3 copies/mL (275.72 copies per reaction) (Pfefferle et al., 2020). The Cobas® SARS-CoV-2 test targets the non-structural ORF1a/b region specific of SARS-CoV-2 and the structural protein envelope E gene. In our study, a sample was considered positive if either both ORF1a/b and E genes were detected or ORF1a/b gene only or E gene only. The RT-PCR assay enables to detect the SARS-CoV-2 RNA genome but does not attest that infectious particles are still present. Samples with positive results are given with their cycle threshold (Ct) values, corresponding to the number of cycles when the fluorescence generated at each target amplification reaches a significant level. Ct values are inversely correlated to viral loads.

3. Results

We performed 192 samples during three days from different surfaces and PPE in the ED and the SSU. Among these samples, 10 (5.2%) were positive and revealed the presence of SARS-CoV-2 RNA. Given the Ct values ranging from 35.71 to 39.69 and indicating moderate to weak amounts of target nucleic acid, the assessment of virus viability by viral culture was not realized.

3.1. Patient care area

Table 1 shows the sample results in the patient care area. Concerning the surfaces directly in contact with patients with COVID-19, 5/46 (10.9%) revealed the presence of SARS-CoV-2 RNA. Among those surfaces, 3/5 (60%) samples were positive before decontamination and 2/41 (4.9%) after decontamination and concerned the cuff for arterial blood pressure and a stretcher. Concerning the surfaces that were not directly in contact with patients, only 4/56 (7.1%) were positive. Among those distant surfaces, 2/20 (10%) samples were positive before decontamination (plastic screen between two patients and floor) and 2/36 (5.6%) were positive (trolleys) after decontamination. Positive samples concerned patients' examination and monitoring rooms. The samples taken after decontamination in the triage room and those taken in a SSU room, where a patient with COVID-19 was hospitalized for 24 h, were negative.

Also, we did not detect any presence of SARS-CoV-2 RNA on the different surfaces of the patients' registration desk or COVID-19 patients' waiting room.

3.2. Non-patient care area

None of the samples taken in the non-patient care areas showed SARS-CoV-2 RNA (Table 2). More particularly, the samples taken from the phones and the keyboards from the ED and SSU staff working rooms that were located just in front of the examination or hospitalization rooms, were negative. Other sites located near the patient care areas such as the staff refreshment area, the HCWs toilets and the medical equipment stockroom did not show any presence of SARS-CoV-2 RNA. Other sites more distant from the patient care area but with a high throughput of HCWs such as the staff changing room or the staff research office were also negative.

3.3. Personal protective equipment

HCWs PPE (gown torso and arms, visor mask, face mask, shoes and head cover) were sampled three times (excepted for head cover that was sampled only one time) after they took care of patients with COVID-19. All samples were negative for SARS-CoV-2 except one on the front side of the gown (torso) with a Ct of 38.37.

4. Discussion

In our study, we showed that in an ED attended by patients with COVID-19 during the pandemic, only 5.2% of the surface samples were positive for SARS-CoV-2 RNA. SARS-CoV-2 RNA was present only in patients' examination and monitoring rooms but wasn't in either the non-patient care areas or in the staff working rooms.

These results suggest that the risk of ED HCW infection from surfaces and equipment is low if decontamination procedures are regularly applied. If these decontamination procedures seem to be efficient in non-

Table 1
Samples results for RT-PCR detection of SARS-CoV-2 RNA in the Emergency Department patient care area. Positives results are given with their cycle threshold values.

Sample site	Positive/ Total	Cycle threshold
Surfaces directly in contact with patients		
Before decontamination		
Patients' door bell (used only at night)	0/1	
Stretcher	1/1	38.96
Patient call bell	0/1	
Pulse oximeter (ear and finger clips)	1/1	36.98
Cuff for arterial blood pressure	1/1	36.84
After decontamination		
Patient registration front desk	0/1	
COVID-19 suspected patients waiting room, chairs	0/3	
COVID-19 suspected patients waiting room, stretcher	0/1	
Pulse oximeter (ear and finger clips)	0/9	
Cuff for arterial blood pressure	1/10	39.03
ECG wires from monitoring equipment	0/4	
Stethoscope	0/4	
Stretcher/bed	1/4	36.77
Wires from ECG device	0/3	
Pocket-size US device	0/2	
Surfaces not directly in contact with patients		
Before decontamination		
Door handles	0/2	
Bench	0/4	
Faucet	0/1	
Chair	0/1	
Plastic trolley	0/1	
Stainless steel trolley	0/2	
Light button	0/1	
Nurse call button	0/1	
Plastic screen (between 2 patients)	1/3	39.69
Oxygen outlet manometer	0/1	
Floor	1/1	35.71
Monitor screen	0/2	
After decontamination		
Door handles	0/7	
Bench	0/1	
Computer keyboard/mouse (in the triage room)	0/3	
Plastic jacket for medical file (in the triage room)	0/3	
Monitor screen	0/7	
Oxygen outlet manometer	0/5	
US gel bottle	0/1	
Plastic trolley	1/2	39.69
Stainless steel trolley	1/4	36.85
Light button	0/1	
Paper dispenser	0/1	
Plastic screen (between 2 patients)	0/1	

COVID-19 coronavirus infectious disease 2019, *ECG* electro-cardiogram, *ED* Emergency Department, *RT-PCR* real-time reverse transcriptase polymerase chain reaction, *SARS-CoV-2* severe acute respiratory syndrome coronavirus 2, *US* ultrasound.

Table 2
Samples results for RT-PCR detection of SARS-CoV-2 RNA in the in the Emergency Department non-patient care area.

Sample site	Positive/Total
Patient registration area (on HCWs' side)	
Desk	0/1
Phone	0/1
Computer keyboard/mouse	0/1
Drawers	0/1
Ink buffer	0/1
Health-card reader	0/1
Outside door opening button	0/1
Inside door opening button	0/1
Non-COVID-19 suspected patients waiting room, chairs	0/2
Corridor	
PPE storage	0/3
Trash can	0/1
Staff work room	
Desk	0/5
Phone	0/5
Computer keyboard/mouse	0/6
Plastic drawers/trolley	0/4
Plastic jacket for medical file	0/5
Bench (for treatment preparation)	0/3
Food basket	0/1
Inside door handle	0/1
Automated medication dispenser	0/1
Personal mobile phone from 2 HCWs	0/1
Staff refreshment area	
Outside handle door	0/2
Fridge door	0/2
Coffee maker	0/1
Food basket	0/2
Table	0/2
Staff toilets	
Outside door handle and digital code	0/3
Faucet	0/1
Medical equipment stockroom	
Computer keyboard/mouse	0/1
Rack 1	0/1
Rack 2	0/1
Rack 3	0/1
Staff changing room	
Outside door handle and digital code	0/1
Bag for used outfits	0/1
Bench	0/1
Toilets	0/1
Shower	0/1
Faucet	0/1
Staff research office	
Outside door handle and digital code	0/1
Table	0/1
Computer keyboard/mouse	0/1
HCW digital code to access ED	0/1
Door handle of corridor to staff changing rooms	0/1

COVID-19 coronavirus infectious disease 2019, *ECG* electro-cardiogram, *ED* Emergency Department, *HCW* health care workers, *PPE* personal protective equipment, *RT-PCR* real-time reverse transcriptase polymerase chain reaction, *SARS-CoV-2* severe acute respiratory syndrome coronavirus 2.

patient care areas, they need to be reinforced in examination and monitoring rooms which carry a high prevalence of patients with COVID-19. In particular, cuffs for arterial blood pressure measurement, finger or ear clips for oxygen saturation and plastic screens between patients need to be carefully disinfected. Other non-essential materials such as trolleys should be removed from these areas as suggested by van Doremalen et al. who showed that SARS-CoV-2 can remain viable up to 72 h on plastic and stainless-steel surfaces (van Doremalen et al., 2020). Our positivity rate was somewhat lower than that published by Ye et al. who found that 12.5% of the environmental samples were positives in the ED of the Zhongnan Medical Center in Wuhan, China (Ye et al., 2020). In this study, the positivity rates in the Intensive Care Unit (ICU), the Obstetric isolation ward and the general isolation ward for COVID-19 patients were 31.9%, 28.1% and 19.6% respectively (Ye et al., 2020). Medical equipment was contaminated in 12.5% of the cases and public facilities, such as elevator buttons, microwave ovens, faucets, handrails, and hair drier, in 8% (Ye et al., 2020). This high positivity rate may be explained by the highest proportion of samples that were made in patient care areas, medical equipment and PPE just after COVID-19 patient care. Whereas in our study the majority of samples were made after disinfection but also in non-patient care area. Guo et al. found that 23.7% of the surfaces tested were positive for SARS-CoV-2 in the ICU at Huoshenshan Hospital in Wuhan, China (Guo et al., 2020). Here again, the positivity rate was high but more surfaces were tested, and particularly the floors that carried a high contamination rate. On the other hand, the positivity rate of a general COVID-19 ward was closer to ours with 4.9% positive samples (Guo et al., 2020). In a multisite London, England hospital study, 5 surfaces samples out of 32 performed in the ED

were positive (16%). Among positives, 2 were located in the nurse station and 2 in the ambulatory waiting room (Zhou et al., 2020). Our results are more consistent with those found by Colaneri et al. who found that only 2 samples out of 26 performed in an Infectious Disease Emergency Unit were positive for SARS-CoV-2 (Colaneri et al., 2020). Those positive samples were taken from the plastic of the COVID-19 patients continuous positive airway pressure helmet. The authors explained that the timing of swabbing which was relatively close to the cleaning procedures may have contributed to the low rate of positivity. Therefore, this study emphasizes the effectiveness of those procedures when they are well conducted, even in a high throughput department such as the ED.

In line with Ong et al. who performed samples on the HCW PPE found that only one swab from the surface of a shoe was positive (Ong et al., 2020), we observed that among the 16 tested sites of PPE, only one swab on the front side of the gown (torso) was positive. These results also advocate for the relatively low risk of contamination carried by HCWs after COVID-19 patient care. In that study, surfaces were tested in three isolation rooms of a center dedicated to COVID-19 in Singapore. All positive swabs were observed before decontamination but were negative after decontamination. These results also suggest that current decontamination measures were sufficient, except that, contrary to our study, patients monitoring devices were not tested (Ong et al., 2020).

Another interesting finding of our study is that the surfaces from the patient care area that were not directly in contact with patients, such as door handles, benches or monitor screens, were mostly negative, even before decontamination. This observation is not supported by other studies that showed a high rate of contamination in the close environment of hospitalized COVID-19 patients in wards or in ICU (Ong et al., 2020; Guo et al., 2020). This could be explained because EDs carry a higher patient turnover than in wards or in ICU. Thus, reducing the length of stay of each patient in the examination and monitoring rooms and increasing the number of decontaminations after each visit could decrease the risk of contaminating the surrounding surfaces. Furthermore, these patients remained most of the time in their sketchers with a face mask and this also may contribute to lower the risk of contaminating more distant surfaces in the room. Also, ED HCWs became experienced and well trained to rigorous surfaces decontamination since the beginning of the epidemic.

In our study we did not assess air contamination. Whereas it has shown to be a potential medium of transmission (Morawska and Milton, 2020; Jones, 2020). Zhou et al. found that SARS-CoV-2 RNA was positive in only 2 and suspected in 12 out of 31 air samples collected in 7 clinical areas and 1 public area in a multi-site London hospital (Zhou et al., 2020). Positive and suspected results concerned the 8 areas tested and patient and non-patient care areas. Liu et al. also reported the presence of SARS-CoV-2 in aerosols from patient, medical staff and public areas of 2 hospitals in Wuhan (Liu et al., 2020). In this study, the concentrations of aiborne SARS-CoV-2 were very low and the higher concentrations were observed in patient toilets and in the protective-apparel removal rooms. Interestingly, the authors highlight the risk of virus resuspension from protective apparel of medical staff when equipment is being removed or from the floor surface (Liu et al., 2020).

4.1. Limitations

The detection of SARS-CoV-2 on a surface is limited to the area browsed by the swab and it is possible that we missed some droplets. To lower that risk we performed almost 200 samples in a wide range of surfaces and sometimes, several times. It is of importance to underscore that RNA detected by RT-PCR method does not mean the viable virus is present. Because of weak amounts of viral RNA in positive samples, we did not attempt to isolate viruses in cell culture to assess SARS-CoV-2 infectivity. Indeed previous works showed the inability to isolate viruses with such weak loads (Zhou et al., 2020). Previous studies showed that even SARS-CoV-2 nasopharyngeal loads up to 5 to 6 $\log_{10}$ copies/ml did not enable virus isolation in cell culture (Wölfel et al., 2020). Thus, it is possible that the risk of infection from these contaminated surfaces was very low or absent. Furthermore, some authors who reported the presence of SARS-CoV-2 RNA in the environment failed to demonstrate virus viability (Zhou et al., 2020; Colaneri et al., 2020). Some surfaces were sampled before decontamination but not after and *vice-versa*, thus, comparing the positive rate before and after decontamination in order to assess its efficacy is spurious. But, due to the high turnover of patients some days, we had to adapt our sampling to the workload.

In summary, our findings suggest that surface and equipment contamination by SARS-CoV-2 in an ED during the COVID-19 outbreak is low and concerns exclusively patients' examination and monitoring rooms, preserving non-patient care areas. If these results may decrease the fear of being infected by surfaces among HCWs when decontamination procedures are rigorously applied, it shouldn't reduce their alertness and efforts to lower this risk.

Authors contributions

Conception and design: OP, SE, JPF, MTLC, CD, JLG.
Surfaces sampling: OP, SE.
RT-PCR analysis: LF, NM, MS, AG, SMD, CD, JLG.
Manuscript writing: OP, JPF, MTLC, CD, JLG.
Final approval of manuscript: all authors.

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Ethical approval

Ethical approval was not necessary due to the absence of patient involvement in this study.

Declaration of competing interest

All authors declare no potential conflict of interest related to the study.

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