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Keep your distance! Measuring staff physical distancing during the Sars-Cov-2 pandemic using a real-time locating system

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ABSTRACT

Introduction: Staff-to-staff transmission of SARS-CoV-2 poses a significant risk to the Emergency Department (ED) workforce. We measured close (<6 ft), prolonged (>10 min) staff interactions in a busy pediatric Emergency Department in common work areas over time as the pandemic unfolded, measuring the effectiveness of interventions meant to discourage such close contact.
Methods: We used a Real-Time Locating System to measure staff groupings in crowded common work areas lasting ten or more minutes. We compared the number of these interactions pre-pandemic with those occurring early and then later in the pandemic, as distancing interventions were suggested and then formalized. Nearly all healthcare workers in the ED were included, and the duration of interactions over time were evaluated as well.
Results and conclusions: This study included a total of 12,386 pairs of staff-to-staff encounters over three time periods including just prior to the pandemic, early in the pandemic response, and later in the steady-state pandemic response. Pairs of staff averaged 0.89 high-risk interactions hourly prior to the pandemic, and this continued early in the pandemic with informal recommendations (0.80 high-risk pairs hourly). High-risk staff encounters fell significantly to 0.47 interactions per hour in the steady-state pandemic with formal distancing guidelines in place and decreased patient and staffing volumes. The duration of these encounters remained stable, near 16 min. Close contact between healthcare staff workers did significantly decrease with formal distancing guidelines, though some high-risk interactions remained, warranting additive protective measures such as universal masking.

1. Introduction

Mitigating staff-to-staff transmission of the SARS-CoV-2 virus is important to maintaining a healthy and productive healthcare workforce. Several studies demonstrate increased risk of transmission with close proximity and prolonged exposure time [1-3] and the CDC recommends maintaining six foot spacing between persons and limiting time together [4].

Increasing demand for emergency care over the last few decades have led to larger and more complex emergency departments (ED). However, in many high volume EDs, patient volume has outpaced the development of adequate physical space [5]. Without adding additional square footage in the ED by the use of temporary spaces like tents, most Emergency Departments are limited by a fixed space within to carry out clinical operations. Evolving in parallel, additional computer-based documentation demands can lead to staff and family crowding and high-risk encounters during a pandemic.

During the Sars-CoV-2 pandemic, environmental measures evolved over the course of the pandemic to encourage physical distancing between staff members. Retrospectively, three distinct time periods emerged during which our institutional response to the pandemic evolved: the baseline pre-pandemic state; the early, suggestive and reactionary early-pandemic response when data was still limited; and the more matured institutional response after early evidence was formalized and validated. At our institution, early in the pandemic (March 2020), emails and verbal outreach encouraged distancing of six feet and discouraged groupings of staff members. By April, we approached a steady pandemic state. By this time, we had implemented formal interventions, including posted signage, using tape to restrict use of specific workstations in close proximity with one another, and increasing

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the number of mobile work areas. Universal masking began on April 3, 2020, just prior to the steady-state pandemic phase. The purpose of this study was to evaluate the frequency of staff groupings over time as patient and staffing volumes fluctuated during the pandemic, and as informal and formal environmental interventions to discourage close contact were implemented, and measure their effectiveness at reducing the frequency of high-risk social gatherings. We used a real-time locating system (RTLS) to precisely and accurately measure prolonged (>10 min) groupings of staff members which violated the social distancing guidelines.

2. Methods

This was a retrospective, longitudinal, observational study of the physical groupings of healthcare workers in a large pediatric Emergency Department (ED) over the course of a hospital's pandemic response maturation. Data were generated by a radiofrequency identification-based RTLS system at the main campus of pediatric emergency department (ED) (60,000 visits annually, pre-pandemic). All ED staff wore personalized RFID badges before and during the pandemic, including all physicians, nurses, patient care associates, registration personnel, respiratory therapists, and mental health specialists. Staff badges were worn voluntarily prior to the pandemic as part of ongoing efforts to optimize clinical communication and locating. Child life personnel, pastoral services, and environmental service personnel were not included due to logistical challenges in badging. This study was approved by the Institutional Review Board.

Staff badge location histories from the RTLS were utilized for this analysis. This system documents the location and duration of staff members' movements within clinical areas in our ED. The accuracy of the movement data has been validated, with reliable data transfer and an accuracy to within a 3 s delay (range 1–9 s delay) and to within 1.5 f. in- or outside of each room or space threshold. We included interaction pairs occurring in common work areas between any two staff members in the ED. High-risk interactions lasted longer than 10 min in a crowded space. The system is unable to measure the direct distance between two badges, but is able to describe all the badges within a pre-defined space. Therefore, a crowded space was defined as occurring when the average of the number of people in a given space per minute exceeded the N_m, or the maximum number of people who can fit in the given space and maintain the 6′ distancing. Multiple high-risk interactions between the same two people were aggregated together within a 24 h period, as were multiple low-risk interactions between the same individuals. Common work areas including computer documentation stations, medication preparation spaces, hallways, greeter areas, as well as the staff lounge and locker rooms were included. All bathroom spaces were excluded, as all are single use bathrooms. Patient care rooms were not included because social distancing efforts may not be practical in direct patient care situations, and we presumed all staff were utilizing personal protective equipment appropriately in patient rooms. Additionally, studies show staff members spend considerably more time with each other in common work areas per shift than with patients in patient care rooms [6-8]. To account for unworn badges being left with personal belongings in common workspaces, potentially creating artificial interactions, we omitted data from badges that didn't change location for more than 6 h. This cutoff was chosen because some roles require staff to remain stationary for 4-h blocks of time (i.e. nursing or registration staff at the greeter desk), and it is reasonable that they would remain in the post throughout. All staff shifts are 8–12 h long. Thus, a 6-h cutoff allows for stationary duties within the normal scope of work, but will exclude data from badges not worn throughout a shift.

The frequency of interactions was measured hourly over 3 time periods: pre-pandemic (February 10–23, baseline), early-pandemic (March 13–26) and steady-state pandemic (April 6–20) phases. In the early pandemic phase, no formal environmental controls were in place and patient volumes fell from 67% to 49% of typical during this time, with a concurrent reduction in staffing. By April 6, staffing was reduced and formal environmental controls were in place, including signage and physical separation reminders, as well as universal masking. Average daily patient volumes remained near 40% of typical throughout. Staff badge compliance was assessed by comparing RTLS data to the employee timecard log (Kronos, © 2020 UKG, Inc).

3. Results

This study included 12,386 pairs of staff-to-staff encounters (3828 pre-pandemic, 4678 early-pandemic, and 3880 steady-state pandemic). Patient arrivals in February, prior to the pandemic, were consistent with our annual volumes, averaging 189 arrivals per day. From the beginning to the end of the early pandemic phase, arrivals fell from 123 to 89 daily visits (67.3% to 48.6% pre-pandemic). During the steady-state pandemic phase, patient arrivals stayed consistent at 69 per day (37.8% of pre-pandemic levels).

Just prior to the pandemic, staff averaged 0.89 prolonged, close interactions hourly, with the median encounter duration of 15.8 min. Early in the pandemic, the rate of high-risk staff encounters stayed stable (0.80 interactions/h, $p = 0.758$), with a significant decrease in the duration of these encounters (median duration 14.7 min early pandemic, $p = 0.027$). Staff were less likely to have prolonged, close groupings during the steady-state of the pandemic, falling to 0.47 high-risk interactions per hour, and this reached significance at the $p < 0.1$ level ($p = 0.073$). The close groupings that did occur returned to baseline duration (median 16.0 min, $p = 0.793$), Table 1.

Table 2 describes where and when high-risk staff encounters occurred. During the pre-pandemic time period, high-risk groupings occurred mostly in Team Work Area 2. By the steady-state pandemic

Table 1
Details of interaction pairs included in analysis. The number of Low-Risk encounters added to the number of High-Risk encounters may not equal the Total Interaction Pairs, as repeated interactions between the same two individuals were further stratified into Low- and High-risk categories and then the interactions summed together.

	# Total interaction Pairs	# Interactions occurring in patient rooms	# Interactions occurring common spaces	Mean hourly interaction rate in common spaces (mean # interactions/h)	Median duration interaction in common spaces (minutes)	Average daily count of staff badges
Pre-Pandemic Phase (February 10–23)	3828	401	3427	10.20	19.75	100
Low-Risk	3627	379	3248	9.67	19.66	99.2
High-Risk	321	23	298	0.89	15.77	13.4
Early-Pandemic Phase (March 13–26)	4678	658	4020	11.96	21.39	98.6
Low-Risk	4485	608	3877	11.54	21.38	97.9
High-Risk	322	54	268	0.80	14.67	15.9
Steady-State Pandemic Phase April(6–20)	3880	516	3364	9.34	22.88	87
Low-Risk	3753	500	3263	9.04	22.95	86.4
High-Risk	187	19	168	0.47	16.00	8.2

Table 2
Heat map depicting location and time of high-risk interactions by phase of the pandemic.

Room/month/shift[a,b]	Pre-pandemic phase			Early-pandemic phase			Late-pandemic phase		
	Day	Evening	Overnight	Day	Evening	Overnight	Day	Evening	Overnight
ED Greeter Area	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (0.7%)	5 (0.6%)	28 (3.4%)	88 (10.6%)	23 (2.8%)
ED Clinical Team Work Area 1	5 (0.6%)	41 (4.9%)	0 (0.0%)	23 (2.8%)	31 (3.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ED Clinical Team Work Area 2	69 (8.3%)	129 (15.5%)	34 (4.1%)	57 (6.9%)	67 (8.1%)	27 (3.3%)	7 (0.8%)	10 (1.2%)	9 (1.1%)
ED Clinical Team Work Area 3	8 (1.0%)	11 (1.3%)	1 (0.1%)	4 (0.5%)	44 (5.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
ED Staff Break Room	11 (1.3%)	0 (0.0%)	11 (1.3%)	26 (3.1%)	0 (0.0%)	14 (1.7%)	6 (0.7%)	7 (0.8%)	6 (0.7%)
Totals (% by phase)	93 (29.0%)	182 (56.7%)	46 (14.3%)	119 (37.0%)	153 (47.5%)	50 (15.5%)	43 (23.0%)	105 (56.2%)	39 (20.9%)

Color coding: White: 0%–0.9%, Light Gray: 1%–4.9%, Dark Gray: ≥5%.
[a] Day Shift: 8 am to 3:59 pm; Evening Shift: 4 pm to 11:59 pm; Overnight Shift: 12 am to 7:59 am.
[b] Rooms with a total count less than 10 were removed.

phase, high-risk encounters shifted toward, and increased in the Greeter area. The evening shift (4 pm to 11:59 pm) seems to have the highest portion of high-risk interactions across all time periods (ranging from 47.5%–56.7%).

The daily number of staff present and the arrival of patients during the study time periods changed over time as well. During the pre-pandemic time period, an average of 100 staff members were present daily. By the steady-state pandemic time period, staff levels had fallen to an average of 87 staff members daily (87%). To assess the impact of staff density in a fixed space on high-risk interactions, we stratified high-risk interactions by the number of staff members present across all study time periods and found no correlation between the average number of interactions and the number of staff members present. Staff levels are highest during the evening shift. Because patient volumes were distinct between each time period studied, we were unable to apply a similar control strategy for patient arrivals. The average number of daily high-risk encounters dropped directly with patient arrivals.

4. Discussion

Findings reveal that the frequency of high-risk staff interactions remained stable early in the pandemic, and significantly fell (at the $p = 0.1$ level) during the steady-state pandemic phase. Informal social distancing efforts during the early-pandemic phase did not reduce close interactions. While it is reasonable to expect an association between rates of high-risk social interactions and staffing numbers, analyses controlling for the staffing rates did not support this finding. Due to labile daily interaction counts as demonstrated in Fig. 1 and relatively small number of days studied, further study is warranted to further assess the impact of staffing levels. Data suggest, however, that formal environmental controls did reduce the number of high-risk staff gatherings, which are likely the highest risk event for person-to-person viral transmission in this setting. The duration of these interactions remained stable between pre- and steady-state pandemic phases.

Wide variability in daily high-risk staffing numbers were seen in all time periods studied. One explanation likely includes clustering of

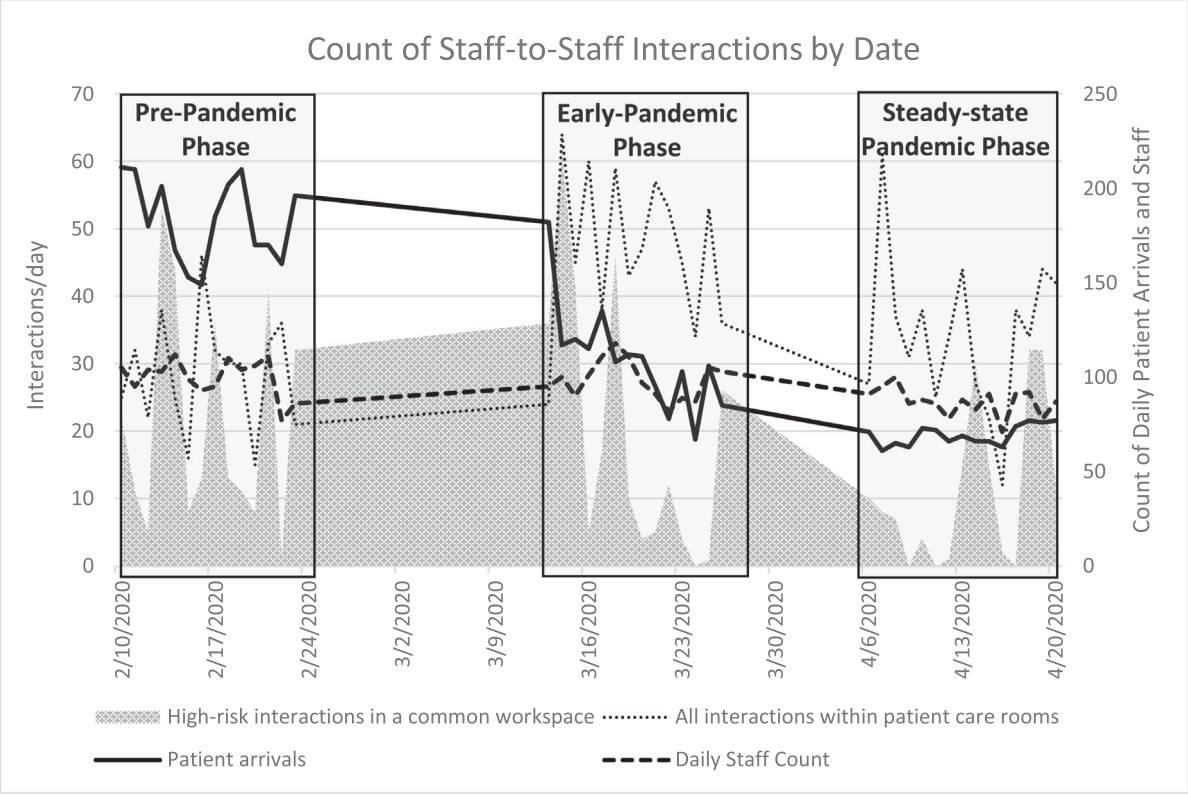

Fig. 1. Count of high-risk staff-to-staff interactions, all interactions within patient rooms, daily patient arrivals, and daily staff counts over time as the pandemic response matures.

groups of staff for prolonged time periods. The following illustrative example assumes all staff members stay present together for >10 min. Two staff members result in 1 high-risk encounter pair measurement. If 5 people clustered for the same duration of time, 10 pairs of interactions would result from the same time span. Grouping of staff for prolonged periods explains some of the measured variability and is likely a greater influence to high encounter days than the contributions of single staff members.

The frequency of the persistence of high-risk staff groupings is particularly notable. Even with the reduced staffing levels seen in the steady-state pandemic phase, 68 unique staff members had at least one high-risk encounter in common areas during this 15-day time period, or an average 4.5 staff members daily. In total, the 68 unique staff members made up 23.2% of the total staff members who reported during this time. Given imperfect badge wearing compliance, this measure is likely an underestimate.

This is the first study to measure the physical proximity of healthcare workers in a clinical environment during the Sars-CoV-2 pandemic. We utilized an innovative application of RTLS technology to precisely compare changes in healthcare worker interactions as the pandemic unfolded. The ability to precisely and accurately measure high-risk interactions of nearly every staff member at all times enhanced the rigor of our study. Additionally, our longitudinal design allowed us to measure changes in social distancing practices as patient arrivals and staffing patterns changed.

There are several limitations to this study. The percentage of all staff members wearing their badge during the study time ranged from 57% to 68%, suggesting some percentage of staff interactions were missed. Staff interactions occurring within patient rooms were also excluded because these events are a proportionally small percentage of time spent by staff, and it was assumed that appropriate personal protective equipment use was used throughout the pandemic during direct patient care. Additionally, staff movement is a fluid and flexible occurrence, and minute averages of staff groupings may miss some nuances of rapid fluctuations in grouping numbers. We attempted to address this through using an average count of groupings for each minute throughout the staff overlap. One of limitations of a RTLS is the inability to discern what staff were doing in each location. For instance, the system cannot tell us why certain trends occurred, such as increased gathering at the Greeter desk in the steady-state pandemic or increased interactions within patient rooms during the early-pandemic phase. Further investigation would be necessary to better understand these trends. Finally, we did not examine the frequency of actual Covid-19 infections which occurred in staff during this time to assess for actual transmission.

ED healthcare workers have higher rates of exposure to the virus, and ED healthcare workers are a medically sophisticated group, presumably up-to-date on transmission prevention guidelines. We demonstrated that high-risk staff interactions decreased with the implementation of formal distancing interventions and reducing staffing, yet staff continue to pose a significant risk to one another by continued grouping, despite the known risk of viral transmission. We suspect staff in our ED are not unlike staff in any other fixed-space environment, and that these findings are largely generalizable to other healthcare delivery settings. This study reinforces the need for established physical distancing interventions, as well as additive measures to control infection spread, such as universal masking, in clinical environments.

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Declaration of Competing Interest

None.

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