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Research Article

Protecting Healthcare Workers from SARS-CoV-2 Infection in the Pre-Vaccination Era: Effectiveness of Three Epidemiological Approaches

Michal Yakubovsky[1,2], Tanya Grossman[3], Nadav Ofshenko[1,2,4], Oryan Henig[1,2], Anna Medovy[1,2], Moran Biton[1,2,5], Suzy EstheMeijer[1,2], Ronen Ben-Ami[1,2], David Shasha[1,2], EugeneKatchman[1,2], Luba Tau[1,2], Oran Yakubovsky[4] and Yael Paran[1,2]

[1]*Department of Infectious Diseases and Infection Control, Israel*

[2]*Department of Medicine, Tel Aviv University, Israel*

[3]*Tel Aviv Sourasky Medical Center, Israel*

[4]*Departmentof Molecular Cell Biology, Weizmann Institute of Science, Israel*

[5]*Department of Health Sciences, Joyce & Irving Goldman Medical School, Ben Gurion University of the Negev, Israel*

Abstract

Introduction: Many Healthcare Workers (HCWs) were quarantined in the pre-vaccination era due to exposure to SARS-CoV-2. We examined a risk stratification model designed to reduce the number of quarantined HCWs, and investigated the efficacy and efficiency of three screening strategies for non-exposed and asymptomatic HCWs.

Methodology: This retrospective study involving 7500 HCWs took place at a tertiary medical center from July to December 2020. The SARS-CoV-2 post-exposure contact criteria of the Israeli Ministry of Health and the Center of Disease Control were eased, and "low-risk" contacts were not quarantined. We compared the ratio of quarantined HCWs to the number of positive Covid19 HCWs before and after changes in post-exposure contact criteria, and evaluated the risk of secondary transmissions from the non-quarantined HCWs. We also compared three screening strategies: self-referral, outbreak and periodic departmental, and evaluated the yield and efficiency of each strategy by comparing the number of tests and rates of positive results. All three consisted of point-of-care PCR sampling, at no additional cost for HCWs.

Results and discussion: The ratio between infected HCWs to quarantined HCWs was 7.3 from March to June 2020 and 0.84 during the study period with five HCWs being infected from non-quarantined contacts. Different complementary screening strategies for asymptomatic and non-exposed HCWs yielded different positivity rates which did not correlate with the absolute numbers of infected HCWs detected in each one (3.23% for self-referral, 1.74% for outbreak, and 0.28% for periodic departmental). The ratio of infected HCWs detected by each strategy (out of all positive HCWs) was 65.6%, 17.7%, and 9.3%, respectively.

Conclusions: Adding another category for low risk exposed HCWs combined with the use of other screening options can safely decrease the number of quarantined HCWs. Cost-free self-referral PCR tests for HCWs screening strategy efficiently detects SARS-C-V-2-infected HCW's and was superior to other screening strategies.

Keywords: Health care workers; SARS-CoV-2; Covid-19; Quarantine; Isolation; Epidemiology

Introduction

A contact-tracing strategy according to the Center of Disease Control (CDC) [1] - based Israeli Ministry of Health (MOH) [2], guidelines was commonly used during the early days of the SARS-CoV-2 pandemic in Israel. These strict guidelines had a low threshold for quarantining contacts during the infectious period, and thus resulted in many Healthcare Workers (HCWs) being quarantined for up to 14 days after exposure to SARS-CoV-2-infected patients, leading to a severe shortage of HCWs when they were most needed. Studies stratifying the HCWs' risk of infection following SARS-CoV-2 exposure, and publications on the efficacy and efficiency of various screening strategies of HCWs who are asymptomatic and without known exposures to SARS-CoV-2 are limited [3-12].

In this study, we examined the use of a simple risk stratification model specific to HCWs exposed to SARS-CoV-2, aiming reduction of the number of quarantined HCWs during a pandemic. In addition, we examined the efficacy and efficiency of three SARS-CoV-2 screening strategies for non-exposed and asymptomatic HCWs in terms of number of diagnostic tests and their yield.

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***Corresponding author:** Michal Yakubovsky, Department of Infectious Diseases and Infection Control, Tel Aviv Medical Center, 6 Weizmann Street, Tel-Aviv, 6423906 Israel, Tel: +972-52-4266138; E-mail: michalya@tlvmc.gov.il

Materials and Methods

Study site

This study was performed at the Tel Aviv Sourasky Medical Center (TASMC), a tertiary hospital with 1400 acute care beds staffed by approximately 7500 HCWs. The hospital serves a population of about one million people.

Study design

We compared two consecutive periods with different quarantine policies for SARS-CoV-2-exposed HCWs in TASMC. During Period A (March to June, 2020), a "permissive quarantine" policy was implemented, when quarantine was based upon every contact with an infectious individual. HCWs were exempt from quarantine only if they wore full PPE (See Table S1 for definitions of contacts and PPE). During Period B (July to December, 2020), a "quarantine sparing" policy plus the addition of complementary testing strategies was introduced, as we subcategorized the outcomes of an epidemiological investigation into high- and low-risk levels (See Table S1 for definitions of high and low risk contacts). The low-risk contact HCWs were not home quarantined but continued working in our medical center and were requested to undergo 2 screening tests for SARS-CoV-2 on days 3 and 8 after exposure. They were instructed to adhere to meticulous PPE and social distancing measures, both at work and at home. Only the high-risk contacts were home quarantined. The methods of classifying a contact as "high" or "low-risk" are detailed in Table S2. Three testing strategies were implemented in Period B: "self-referral" screening, "outbreak" screening, and "periodic departmental" screening. (See Table S1 for the definitions of the testing strategies in Period B). Other methods to reduce in-hospital SARS-Cov-2 transmission included designated COVID-19 wards and an intensive care unit, a designated "respiratory" emergency department, PPEs, strict rules regarding social distancing among HCWs, mandatory masks in all hospital spaces, in-hospital education and instructing activities, and more (Table S3).

Ethical approval

The study was approved by the TASMC Institutional Review Board (approval number TLV-1042-20). The Helsinki Committee waived written informed consent of the study participants.

Evaluated outcomes for each period

The four outcomes selected for evaluation were: (1) the ratio of SARS-CoV-2-positiveHCWs to quarantined HCWs, (2) the rate of risk of secondary transmission during Period B. (See Table S1 for the definition of secondary transmission rate), (3) the total number of tests that were performed and the total number of positive test results, and (4) the total number of tests that were performed and the rate of positivity for each of the three screening strategies (in the Period B only).

Data collection

Data collection was based on the computerized database of TASMC Services, including computerized data regarding HCWs epidemiological investigations. Included in the study were all TASMCHCWs between March to December 2020 and there were no exclusion criteria.

Statistical analysis

For Table 1, Fisher's exact test on contingency table was used to determine whether there was a significant association between non-quarantined HCWs in period A compare to non-quarantined HCWs in period B in relation to amount of quarantined HCWs in each period, respectively. There was a statistically significant decrease between those variables ($p<0.00001$).

For Table 2, a chi-square test of independence was performed to examine the difference between self-referral testing and periodic departmental testing. There was a statistically significant increase between self-referral strategy and periodic departmental screening strategy with p-value<0.00001. A chi-square test of independence was performed to examine the difference between outbreak strategy and self-referral strategy. There was a statistically significant decrease between outbreak strategy and self-referral with p-value<0.00001. A

Table S1: Terminology and definitions.

Term	Definition
Contact	Exposure to SARS-CoV-2 positive index during "infectious period" in proximity of up to 2 meters for 15 minutes or more
Infectious period	March 1 to March 10, 2020: 14 days prior to first positive PCR.
	March 11to Dec. 31, 2020: 4-7 days prior to first positive PCR, based upon index's symptoms.
PPE	Gloves, surgical or N-95 mask (if exposed to an aerosol-generating procedure), face shield and isolation gown
High-risk contacts	Contacts who clearly fulfilled the MOH/CDC criteria [1,2]
Low-risk contacts	Contacts for whom the criteria of time and distance (as defined by MOH/CDC [1,2]) were either inconclusive or borderline.
	Contacts who were wearing a mask (index and/or contact) (Table S2)
Self-referral screening	Cost-free unlimited PCR nasopharyngeal swab tests were offered to all HCWs in order to encourage those with or without symptoms to undergo testing
Outbreak screening	Screening of all HCWs from the same unit or ward conducted twice at 5-day intervals when more than two HCWs or patients in the same unit or ward were found to be positive for SARS-CoV-2 within a few days, without any clear epidemiologic contact between them.
Periodic departmental screening	A policy of routine screening for hospital ward HCWs. The frequency of screening was determined by risk stratification of possible exposure to COVID-19 patients. For example, HCWs were screened twice weekly in COVID-19-designated wards while HCWs in other wards were screened less frequently
Secondary transmission	Infection with SARS-CoV-2 due to exposure to another HCW known to have had exposure to SARS CoV-2, sub-categorized as a low-risk contact and quarantined

Table S2: Definitions for low-risk HCW contacts criteria. Quarantine exemption criteria for SARS-CoV-2-exposed HCWS. Exposure is defined as being in close proximity (less than 2 meters) for more than 15 minutes.

Index case contacts*	AGP	No-Mask	Surgical Mask	N95 Mask	N95 Mask+ Face Shield
No mask			1	1	2
Surgical mask		1	2		
N95 mask	1				
N95 mask+ face shield					

- quarantined

- Not quarantined

- (1). Not quarantined if up to 30 minutes of contact (2). Not quarantined if more than 30 minutes of contact.

Table S3: Methods to reduce in-hospital SARS-CoV-2 transmissions that were implemented during March 2020.

Period	Measure	Date of implementation
A	Covid 19-designated wards (with air suction system)	March 11, 2020
	Patient "triage" in the ER: Patients with suspected or known Covid 19 infection were isolated from the time of their entry to the ER throughout their hospitalization in a designated protected area or Covid 19 wards.	March 11, 2020
	Mandatory PPE protocols: gowns, gloves, N95 masks, face shields, long sleeved fluid resistant coverall and hat.	March 11, 2020
	Social limitations	March 11, 2020
	No eating in close proximity to others	
	No seating in the hospital cafeteria	
	Assigned number of people in staff rooms	
	Assigned number of participants in staff meetings according to room size, etc.	
	PPE guidance for HCWs	March 12, 2020
	Personal limitations: mandatory surgical masks for all patients, visitors, HCWs	March 18, 2020
	Mandatory surgical masks in hospital transportation for HCWs	March 31, 2020
	Body temperature measurement at medical center entrance	
	Mandatory morning declaration of health status for all HCWs	April 5, 2020
B	First "Outbreak" screening for entire ward	June 22, 2020
	First "Periodic departmental" screening	
	Screening for all admitted patients	June 25, 2020
	First "Self-referral" screening	June 28, 2020
	Implementation of "restrictive quarantine" policy	July 1, 2020
	Vapoterm/inhalation working protocols	July 2, 2020
	Screening of high-risk patients for elective procedures	July 6, 2020
	Dedicated ER for confirmed SARS-CoV-2 patients	July 16, 2020

Table 1: Reduction in the ratio of quarantined HCWs to infected HCWs in Period B.

Variable	Period A	Period B	
Total infected HCWs (% of all HCWs in our hospital)	57 (0.76)	408 (5.4)	
Quarantined contacts of the HCWs	417	346	P value<0.0001
Non-quarantined ("low-risk") HCWs	0	907	
Ratio of quarantined HCWs to infected HCWs	7.3	0.84	
Total infected HCWs out of quarantined HCWs	5 (1.2)	39 (3.1)	
Number of tests undergone by HCWs (total)	6950	36912	

multiple hypothesis correction was performed.

Results

A total of 863 epidemiological investigations on the HCWs were conducted in TASMC and 1670 secondary contacts were identified from March to December 2020. Data were collected on 462 (99.3%) of the 465 HCWs (6.1% of all HCWs in our center) who were infected with SARS-CoV-2 during the study period. Twenty of the infected HCW's were hospitalized, mostly with mild infection; none of them was ventilated or had lethal outcome. Altogether, 1431 COVID-19 non-HCW patients were hospitalized in the medical center for a collective total of 9809 days. During the whole study period (Period A and Period B combined), 44 of the1670 HCWs who were defined as secondary contacts with infected individuals were eventually found to be infected with SARS-CoV-2, yielding an infection rate of 2.63%.

During Period A, 57 (0.76%) HCWs were infected with SARS-CoV-2, leading to the quarantining of 417 HCW contacts, among whom only 5 (1.2%) became positive following the index exposure. During Period B, 408 (5.4%) HCWs were infected with SARS-CoV-2, leading to the quarantining of 346 HCW's. Only 12 (1.32%) HCWs among the "low-risk" (non-quarantined) contacts eventually tested positive for SARS-CoV-2 as the result of the known workplace exposure, leading to secondary transmissions to 5 other HCWs. To the best of our knowledge, these latter 5 HCWs did not infect additional hospital employees (Table 1). The ratio between quarantined to infected HCWs was 7.3 in Period A compared to 0.8 in Period B, representing an 8.7-fold decrease (Figure 1).

The yield and efficiency of the three screening strategies

A total of 408 HCWs were infected with SARS-CoV-2 during Period B, of whom 39 (9.6%) were detected by epidemiological investigations and 369 (90.4%) by complementary screening methods for non-exposed HCWs (Table 2). The efficacy (defined as the ratio between the number of HCWs found positive for SARS-CoV-2 to the number of tests had to been performed) of each of the three screening strategies was 3.23% for self-referral, 1.74% for outbreak, and 0.28% for periodic departmental (Figure 2).

Discussion

The first surge of the pandemic in Israel took place between March and June 2020, and the numbers of patients infected with SARS-CoV-2 nationwide as well as in our hospital were the lowest of the total five "surges" [13]. A disproportionally high number of HCWs and patients were defined as “contacts” and were quarantined during this early period. Although a permissive quarantine policy is

Table 2: Significantly higher efficacy of self-referral screening strategy when compared to Periodic departmental and when compared to Outbreak strategy, separately. (During Period B).

Screening Strategy	Number HCWs Detected by the Strategy	Number of Tests	Efficacy: Positive HCWs/ Tests (%)	P Value	Rate of Total Infected HCWs Detected by Each Strategy (%)
Self-referral	266	8218	3.23	P<0.001	65.6
Periodic departmental	72	25064	0.28		17.7
Outbreak	38	2179	1.74		9.3
Total	376*	35461	1.06		92.6

*Each HCW could be tested by each screening method more than once, and eight HCWs tested positive by two different screening strategies.

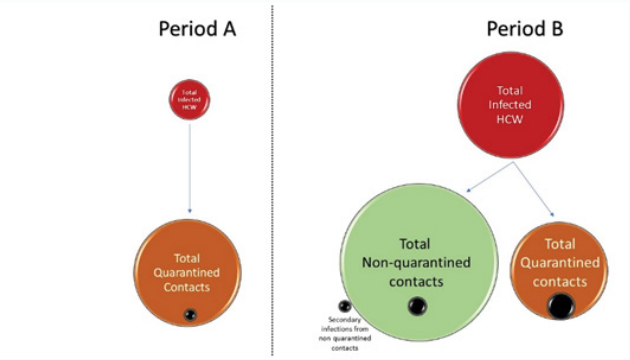

Figure 1: Infected HCWs and their exposed contacts.
- Circle size is proportional to actual number of HCWs
- Black circles represent SARS-CoV-2-infected HCWs detected in each group

The "quarantine-sparing" policy in Period B spared up to 10 days of quarantine for 895 healthy HCWs, as detailed in Table 1.

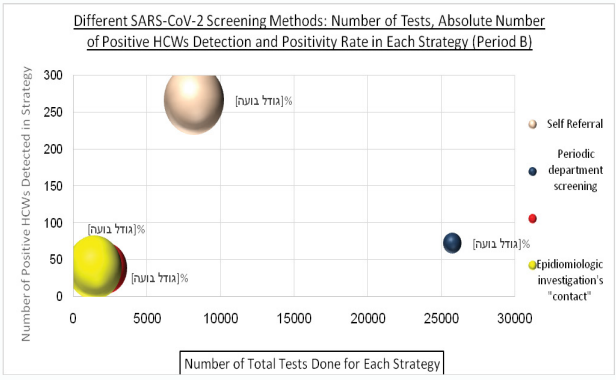

Figure 2: Three SARS-CoV-2 Screening Methods: Number of Tests, Absolute Number of Positive HCWs Detected and Positivity Rate in Each Strategy during Period B.

Circle size represents efficacy (positivity rate of each strategy). For example, the largest circle (in red color), " Self-Referral" screening, represents a positivity rate of 3.23% of tests (266 positive HCWs and a total of 8211 tests performed with this strategy). Data are shown for Period B (between July 1, 2020 to December 31, 2020).

an effective method for breaking chains of transmissions, it caused a severe shortage of HCWs. Therefore, during "Period B", a "quarantine-sparing policy" was implemented that aimed to avoid unnecessary days under quarantine for HCWs without a further risk of infection transmission.

Since the risk of infection for a HCW defined as a 'contact' of another HCW, was relatively low before implementation of the "quarantine-sparing policy" (1.2% in Period A), we assumed that the basic MOH/CDC contact definitions [1,2], were too broad when applied to HCWs, among whom most exposures occurred when either the index case or the contact or both wore surgical masks. "Low-risk contacts" were defined after a thorough epidemiological investigation, during which contacts were classified according to CDC definitions [1]. In practice, many infected HCWs and their contacts could not recall precise exposure event details, such as full adherence to mask wearing throughout interactions with contacts or the duration of the interactions. These incomplete data together with the imprecise information provided by some infected HCWs and their contacts complicated decision making about the need for quarantine. The main difficulty was with choosing not to quarantine a HCW with a minimal exposure to SARS-CoV-2 but with missing or unreliable data. We believe that the option of permitting the HCWs to continue working following strict protocol of post-exposure PCR screenings had provided the epidemiological investigators team psychological safety net as well when deciding not to quarantine a colleague, thus reducing many unnecessary HCWs quarantines. Indeed, after the screening intervention was implemented, the proportion of quarantined HCWs lowered dramatically, with an almost 9-fold reduction in the ratio between the quarantined HCWs and the infected HCWs. This policy had spared 901 HCWs defined as "low-risk contacts" from being quarantined for an average of 10 days.

The epidemiologic cost of a quarantine-sparing policy was relatively low: 12 HCWs out of 901 HCWs who had not been quarantined became infected, while all of them were detected early after exposure. This effective screening policy had led to secondary infections of only 5 additional HCWs. None of the 465 infected HCWs developed a severe clinical COVID-19 infection even in the pre-vaccination era (March to December 2020), probably mainly due to their relatively young age. To conclude, the quarantine sparing policy's epidemiological and health costs for HCWs were minor. The actual cost embodied only in tests numbers, with 5.3-fold increase in the RT-PCR tests for SARS-CoV-2 during period B.

In addition to the focusing on contacts tracing while trying to break the virus transmission chains (a highly time-consuming method), we tried to add other easy and pro-active techniques in order to detect positive HCWs and isolate them as early as possible. During Period B the implementation of complementary screening strategies for HCWs who did not have any documented exposure to SARS-CoV-2 or relevant symptoms, turned out to be more effective than an epidemiological investigation of the HCWs who had a known exposure to SARS-CoV-2, with the detection of more than 90% of all infected HCWs throughout that period. The "self-referral" screening strategy emerged as being the most effective of the three tactics we investigated in terms of the highest absolute detection numbers and the highest positivity rates. We observed that a large segment of the HCWs who were tested positive under the "self-referral" screening strategy had some symptoms or known exposure to SARS-CoV-2 but would not have been tested otherwise. Of note, during both Periods A and B, SARS-CoV-2 PCR tests were less available in community centers and while the mean number of PCR tests for each citizen in Tel-Aviv area during the second half of 2020 was 0.82 tests per person [13], the mean number of PCR tests for each HCW in our medical center was almost 5 times higher (4.05 tests for each HCW). These figures can explain the high positivity rate yielded by the "self-referral" screening strategy. Also interesting is the finding that even though many efforts were made to encourage HCWs with symptoms to avoid attending work and to have themselves tested, we found that more than one-half of the symptomatic HCWs were actually identified as infected by screening methods that were originally aimed to identify asymptomatic HCWs.

Study limitations

Not all of the reductions in quarantine rates after July 1, 2020 can be attributed to implementation of the "quarantine-sparing policy". The quarantine rates among our HCWs were also disproportionately high during the first surge of the pandemic due to changes in the MOH's definitions of an "infective window", which was shortened in mid-

March from 14 days to 4-7 days preceding a positive PCR test result, based upon symptoms. Other factors that might have led investigators to follow a more permissive approach to quarantine were the absence of data on infectivity (for example, fear of transmission through fomites) and overall concern about an unfamiliar emerging virus. Finally, most of this study was conducted during the predominance of the wild-type SARS-CoV-2 variant and before the appearance of other variants, such as "delta" and "omicron", which are known to be more transmissible [4,5].

Conclusion

Screening protocols are capable of safely reducing unnecessary quarantining of HCWs with minimal epidemiological cost. In addition, a complementary testing strategy for HCWs can detect as many as 90% of actually infected HCWs, making Sisyphean traditional epidemiologic investigation essentially unnecessary. A cost-free self-referral PCR test for HCWs screening strategy efficiently detects SARS-C-V-2-infected HCWs and was superior to other screening strategies.

This held true for the beginning of the SARS-CoV-2 pandemic when vaccinations and rapid lateral flow antigens were not in routine use, and can be relevant to a new pandemic with similar transmission routes.

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