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Original Article

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# Universal COVID-19 screening of 4040 health care workers in a resource-limited setting: an Egyptian pilot model in a university with 12 public hospitals and medical centers

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## Abstract

**Background:** The scale of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection among health care workers (HCWs), particularly in resource-limited settings, remains unclear. To address this concern, universal (non-symptom-based) screening of HCWs was piloted to determine the proportion of SARS-CoV-2 infection and the associated epidemiological and clinical risk factors at a large public health care facility in Egypt.
**Methods:** Baseline voluntary screening of 4040 HCWs took place between 22 April and 14 May 2020 at 12 hospitals and medical centres in Cairo. Epidemiological and clinical data were collected using an online survey. All participants were tested for SARS-CoV-2 using reverse transcription polymerase chain reaction (RT-PCR) and rapid IgM and IgG serological tests.

**Results:** Of the 4040 HCWs screened, 170 [4.2%; 95% confidence interval (CI): 3.6-4.9] tested positive for SARS-CoV-2 by either of the three tests (i.e. infected); 125/170 (73.5%) tested PCR-positive. Most infected HCWs were nurses (97/170, 57.5%). Median age of infected HCWs was 31.5 [interquartile range (IQR): 27.0–41.3] years. Of infected HCWs, 78 (45.9%) reported contact with a suspected case and 47 (27.6%) reported face-to-face contact within 2 m with a confirmed case. The proportion of infection among symptomatic HCWs ($n = 54/616$) was 8.8% (95% CI: 6.7-11.3); 6/54 (11.1%) had fever $\geq 38^{\circ}$C and 7/54 (13.0%) reported severe symptoms. Most infected HCWs were asymptomatic (116/170, 68.2%). The proportion of infection among asymptomatic HCWs ($n = 116/3424$) was 3.4% (95% CI: 2.8-4.0).

**Conclusions:** The high rate of asymptomatic infections among HCWs reinforces the need for expanding universal regular testing. The infection rate among symptomatic HCWs in this study is comparable with the national rate detected through symptom-based testing. This suggests that infections among HCWs may reflect community rather than nosocomial transmission during the early phase of the COVID-19 epidemic in Egypt.

**Key words:** COVID-19, SARS-CoV-2, health care workers, asymptomatic, screening, epidemiology, RT-PCR, serology, resource-limited setting, Egypt

**Key Messages**

- The available evidence of the magnitude and risk factors for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection among health care workers (HCWs) is from screening programmes in high-and upper-middle-income countries.
- We present key findings from one of the first large universal screening programmes of asymptomatic and symptomatic HCWs in resource-limited settings. We report the baseline screening results and the associated epidemiological and clinical risk factors among 4040 HCWs between 22 April and 14 May 2020 in 12 public hospitals and medical centres at Ain Shams University, Cairo, Egypt.
- The overall proportion of SARS-CoV-2 infection among HCWs was 4.2% (170/4040) (8.8% versus 3.4% among symptomatic and asymptomatic HCWs, respectively). More than two-thirds of the infected HCWs (116/170, 68.2%) were asymptomatic at the time of screening. More than a half of the infected HCWs did not report any contact with a suspected or confirmed case. Working as a nurse, in the operation room, and having the following symptoms: fever, dry cough, change/loss of smell, were independently associated with infection.
- The infection rate among symptomatic HCWs in this study is comparable with the national rate of infections detected through symptom-based testing. This suggests that infections among HCWs may reflect community rather than nosocomial transmission during the early phase of the COVID-19 epidemic in Egypt.
- The high rate of asymptomatic infections among HCWs reinforces the need for expanding universal regular testing to reduce the risk of nosocomial transmission among HCWs and unprotected patients. This screening approach is particularly important as countries are lifting their lockdown measures. Given the various success factors required for sustained implementation and regular testing, further evaluation of the feasibility and effectiveness of implementing such programmes is required in different resource-limited settings.

## Introduction

More than 8.8 million cases and 46 5000 deaths related to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection have been reported globally.[1] Health care workers (HCWs) represented 3.8%–18.8% of the total coronavirus disease 2019 (COVID-19) cases in some reports[2–5] and many lost their lives.[6] Health care systems, not only in resource-limited but also in developed countries, are struggling to accommodate the growing burden of COVID-19.[7]

Uncertainty in the proportion of asymptomatic SARS-CoV-2 carriage missed in symptom-based screening may

augment ongoing transmission, challenge the already strained health care systems and hinder the mitigation measures.[8] Asymptomatic infections varied in different settings, representing 17.9–87.9% of non-HCW cases.[9,10] Among asymptomatic HCWs in the UK, 7.1% (1.1% at week 5 follow-up) tested positive for SARS-CoV-2.[11] Asymptomatic cases can shed the virus for up to 26 days,[12] symptoms develop after 2 weeks in some cases[13] and transmission can occur during the pre-symptomatic phase.[14] Also, HCWs short of personal protective equipment (PPE) may reuse or use them extendedly.[15] These factors may amplify nosocomial transmission, especially in resource-limited settings.

In Egypt, the first COVID-19 case was reported on 14 February 2020.[16] The doubling rate in the early phase of the epidemic was slow; by mid-March, there were 126 casesand the government took several containment measures(Figure 1).[16,17] The Ministry of Health and Population (MoHP) adopted a symptom-based testing approach (using polymerase chain reaction) and active contact tracing. Reports on increasing COVID-19 cases among HCWs urged the MoHP to start testing HCWs in quarantine hospitals (19 April).[18] However, testing of HCWs in non-quarantine hospitals is still lacking.

Universal screening of HCWs can minimize unnecessary isolation and staff shortages, reduce nosocomial transmission from asymptomatic or pauci-symptomatic cases, and protect HCWs and vulnerable patients.[8] However, the extent of SARS-CoV-2 infection in HCWs and the associated risk factors, specifically in resource-limited settings, are unknown. To address this, we set up a prospective investigation consisting of baseline and follow-up screening and risk assessment of HCWs (SARAH: NCT04348214). In this article, we describe the baseline screening procedures in Ain Shams University (ASU) medical campus, including 12 university hospitals and medical centres in Cairo, Egypt. We present the proportion of SARS-CoV-2 infection among HCWs—symptomatic and asymptomatic—using rapid serological tests and reverse transcription polymerase chain reaction (RT-PCR), and the associated epidemiological and clinical risk factors.

## Methods

### Study design, setting and participants

Baseline screening at ASU hospitals was piloted between 22 April and 14 May 2020. It consisted of a cross-sectional study that included an online survey to identify HCWs' epidemiological and clinical characteristics, plus laboratory sampling and testing to assess HCWs' SARS-CoV-2 infection status.

ASU hospitals are part of a large governmental public health care facility in Cairo, Egypt, receiving approximately 50 000 outpatients, 15 000 emergencies and 2000 inpatients per month. ASU serves patients through 10 hospitals (Geriatrics, Surgery, Internal Medicine, Cardiovascular Surgery, Paediatrics, Obstetrics and Gynaecology, Emergency,

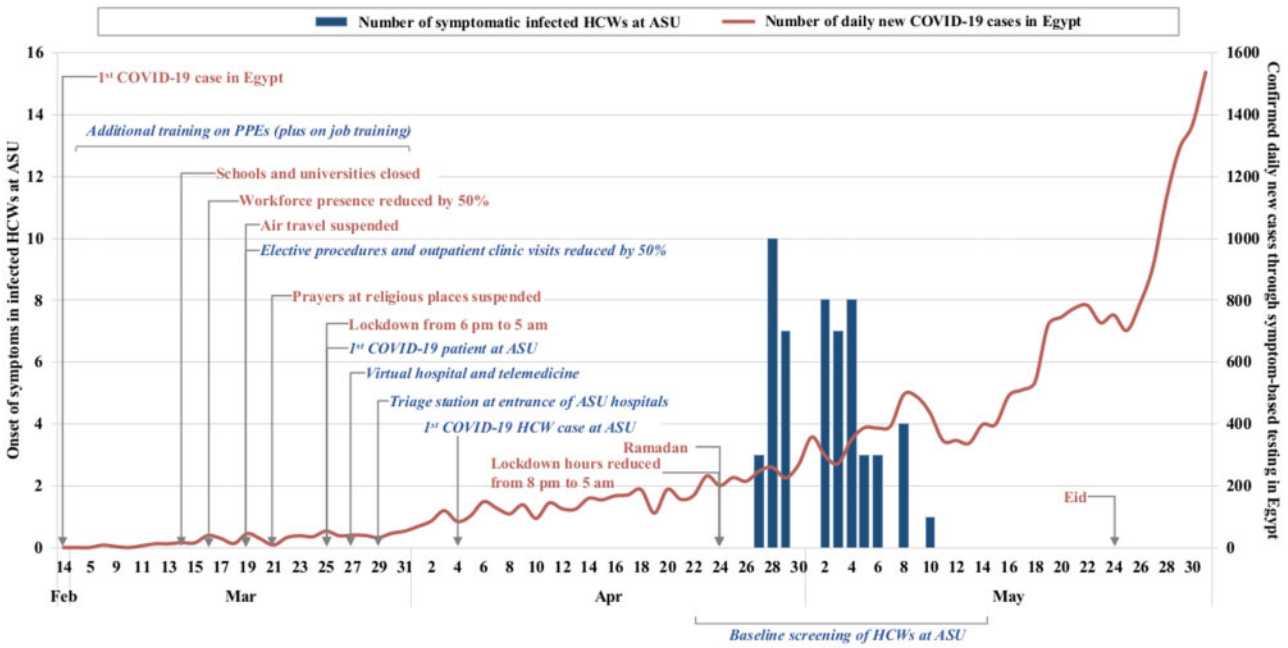


**Figure 1** Number of infected health care workers (HCWs) in Ain Shams University (ASU) hospitals or medical centres by date of onset of symptoms (bar chart, left y-axis) and daily confirmed COVID-19 cases detected through symptom-based testing in Egypt (line graph, right y-axis). The mitigation measures and remarkable events are shown at the national level (non-italic) and at ASU level (italic)

Student, Specialized and El-Obour); the latter three hospitals are located outside the main ASU medical campus. Each hospital has several outpatient clinics, except Internal Medicine and Surgery hospitals, which have one separate large outpatient clinics building. ASU also includes four medical centres (Oncology, Psychiatry, Toxicology and Endoscopy). Till 14 May, none of the ASU hospitals were dedicated for quarantine and treatment of confirmed COVID-19 patients, except for the El-Obour hospital. In addition, due to replacement of on-site university teaching activities with distant online learning, the student hostel was adapted for isolation of mild confirmed COVID-19 HCWs or patients, whose house conditions were not suitable for proper home isolation. The Faculty of Medicine Research Institute and the accredited Central Laboratories are centrally located within ASU hospitals.

Workstations were set up within hospitals or medical centres where it was logistically possible to conduct screening procedures without interrupting the workflow and where spaces allowed adequate social distancing precautions.

There were no exclusion criteria, i.e. screening targeted all hospital staff on the job (approximately 6000), who provided clinical or non-clinical care to patients—including asymptomatic HCWs—and in all hospital areas (no units/wards were prioritized for screening). This study was approved by the Ethics Review Committee, Faculty of Medicine, ASU (FMASUP18b/2020).

## Data collection

Participation was voluntary and all HCWs on the job were informed and scheduled for screening through formal announcements by their hospital administration. At each hospital or centre, three workstations were set up for HCWs' screening, and dedicated teams consisting of the hospital management, infection control focal points, nurses, technicians and administrative staff coordinated the screening activities. Participants had to go through the three workstations on the same day.

### Workstation 1: recruitment and consent

The screening purpose and procedures were explained. HCWs were assured about data confidentiality and anonymity, and freedom to withdraw without affecting the needed health care. HCWs who agreed to participate in the study were assigned study identification numbers (ID) and they provided a written informed consent before proceeding to the next workstation.

### Workstation 2: online survey

HCWs completed the survey through available personal computers (PCs) with internet connection or their cellphones, to reduce the screening time and unnecessary contact with shared surfaces. Staff were available to interview HCWs who needed assistance in filling the survey. Data were entered using the assigned study ID to facilitate anonymous linkage with laboratory results.

### Workstation 3: laboratory sampling

At the same setting from each HCW: (i) combined nasal and oropharyngeal swabs were collected in a single tube containing viral transport medium for the detection of viral RNA by RT-PCR,[19] swabs being transported to the laboratory in an ice box at 4 °C; and (ii) a 5-ml venous blood sample was collected by venepuncture into a plain vacutainer for the qualitative detection of SARS-CoV-2 IgM and IgG antibodies.

## Study tools

### Baseline online survey

Questions were adapted from relevant World Health Organization protocols and interim guidance.[20,21] The questionnaire was originally developed in English, then translated into Arabic and back-translated for validation. It was pre-tested to ensure clarity of the questions and the answer categories. The survey was created on a secured online platform of the Faculty of Medicine via a dedicated e-mail that is available only to the research staff. The survey consisted of five main sections: demographic characteristics; symptoms; pre-existing medical conditions; community and nosocomial exposure to a suspected or confirmed COVID-19 case; and adherence to infection prevention and control (IPC) measures. Measures included in this analysis are described in the Supplementary material, available as Supplementary data at *IJE* online.

### Laboratory tests

Detection of viral RNA was done using the *CerTest* Viasure® SARS-CoV-2 Real Time PCR Detection Kit (CerTest, Biotec, Spain) according to manufacturer's instructions. The detection was done in one step real-time reverse-transcription format where the reverse transcription and the subsequent amplification of specific target sequence occur in the same reaction well. The isolated RNA target was transcribed generating complementary DNA by reverse transcriptase, which was then followed by the amplification of a conserved region of the ORF1 ab and N genes for SARS-CoV-2 using specific primers and a fluorescent-labelled probe. The assay has 97.5% sensitivity and >99.9% specificity. The average estimated limit of detection for SARS-CoV-2 was 18 copies/ml.[22] Detection of SARS-CoV-2 IgM and IgG antibodies was done using the

lateral flow immunochromatographic assay Artron® One Step COVID-19 IgM/IgG Antibody Test (Artron Laboratories Inc., Canada). The assay has 83.3% sensitivity and 100% specificity.[23]

#### Case definition

For the purpose of this analysis, the HCW was considered 'recently or previously infected' with SARS-CoV-2 if either the PCR or IgM (indicating recent infection) or IgG (indicating past infection) tests results were positive. Stratification of different conditions and combinations of test results are detailed in the Supplementary material. The detailed testing algorithm, its clinical implication, subsequent management and HCWs' protocol for isolation and return to work are described in the Supplementary material.

### Statistical analysis

For the descriptive analysis, we report measures of central tendency and distribution for continuous variables or counts and proportions for categorical variables. We tested for associations between exposure, clinical and demographic characteristics and the HCWs' infection status, using bivariate logistic regression analysis. Multivariable logistic regression analysis was conducted to identify independent factors associated with HCWs' infection status. Unadjusted and adjusted odds ratios and 95% confidence intervals (CI) are reported. Effect estimates with confidence intervals and exact *P*-values are provided. SPSS version 25 was used for all analyses.

## Results

### Study participants

Between 22 April 22 and 14 May, 4040 HCWs participated in the baseline screening. Of those, 170 (4.2%; 95% CI 3.6-4.9) were infected with SARS-CoV-2 (Table 1). Overall, 1598 (39.6%) HCWs were nurses, 1577 (39.0%) were physicians and 865 (21.4%) were involved in non-clinical care. Most HCW participants were females ($n = 2486$, 61.5%). More than half of the infected HCWs were nurses (97/170, 57.1%). Infected HCWs' median age was 31.5 [interquartile range (IQR) 27.0–41.3]. The proportion of infection was highest in the outpatient clinics building (7.4; 95% CI 3.0-14.6) and the Obstetrics and Gynaecology hospital (7.1; 95% CI 5.2-9.5) (Table 2). In the bivariate analysis, working in the delivery or operation rooms or the radiology unit was associated with higher odds of infection than working in other hospital units (Supplementary Table S1, available as Supplementary data at *IJE* online). A total of 33 (19.4%) infected HCWs self-reported having one or more pre-existing medical conditions (Table 1); the most common were hypertension ($n = 14$, 8.2%), diabetes ($n = 5$, 2.9%) and obesity ($n = 5$, 2.9%) (Supplementary Table S2, available as Supplementary data at *IJE* online).

### Positive tests

Of the 170 infected HCWs, 117 (68.8%) tested positive only for PCR, 34 (20.0%) tested positive only for IgM and 11 (6.5%) tested positive only for IgG. Four (2.4%) tested positive for both PCR and IgM, three (1.8%) tested positive for both PCR and IgG, one (0.6%) had all three tests positive and none of the infected HCWs tested PCR-negative, IgM- and IgG-positive (Table 3). Overall, approximately three-quarters of the 170 infected HCWs tested positive for PCR ($n = 125$, 73.5%).

### Contact with a COVID-19 case

In all, 68 (40.0%) infected HCWs reported contact with a confirmed case vs 1030 (26.6%) non-infected HCWs (Table 4). Infected HCWs reported more frequent face-to-face interaction within 2 m with a confirmed case compared with non-infected HCWs [47 (27.6%) of 170 vs 725 (18.7%) of 3870]. Among those, the duration of contact was longer than 15 min in 28/47 (59.6%) infected HCWs vs 332/725 (45.8%) non-infected HCWs. The median time since last contact with a confirmed case to screening date was 5.5 days (IQR 3.0–10.0) in infected HCWs and 7.0 days (IQR 3.0–10.0) in non-infected HCWs.

### Adherence to PPE use

Overall, adherence of HCWs to PPE use was more frequent for medical masks [2241 (64.1%) out of 3496 in need] and gloves [1854 (59.3%) out of 2300 in need] and least for the use of respirators [579 (25.4%) out of 2319 in need] (Supplementary Table S3, available as Supplementary data at *IJE* online). In the bivariate analysis, non-infected HCWs were not more likely to be adherent to PPE use than infected HCWs.

### Symptoms

Most infected HCWs were asymptomatic ($n = 116$, 68.2%) (Table 4). Asymptomatic infection varied by hospital (Table 2). The proportion of infection was 3.4 (95% CI 2.8-4.0) among asymptomatic HCWs (116/3424) and 8.8 (95% CI 6.7–11.3) among symptomatic HCWs (54/616) (Table 4). Among infected symptomatic HCWs, only

**Table 1** Demographic and background characteristics of enrolled health care workers in the baseline screening ($n = 4040$)

| | Total $n = 4040$ $n$ (column %) | Infected n = 170 $n$ (column %) | *P*-value[a] | Unadjusted odds ratio[b] (95% CI) | Proportion of infection Overall = 4.2 (3.6-4.9) row % (95% CI) |
|---|---|---|---|---|---|
| Age | | | | | |
| 18-24 | 603 (14.9) | 21 (12.4) | | Ref | 3.5 (2.2-5.3) |
| 25-29 | 1279 (31.7) | 48 (28.2) | 0.7709 | 1.08 (0.64-1.82) | 3.8 (3.2-5.6) |
| 30-39 | 1057 (26.2) | 48 (28.2) | 0.3001 | 1.32 (0.78-2.22) | 4.5 (3.4-6.1) |
| 40-49 | 700 (17.3) | 39 (22.9) | 0.0754 | 1.64 (0.95-2.81) | 5.6 (4.0-7.5) |
| ≥50 | 401 (9.9) | 14 (8.2) | 0.9941 | 1.00 (0.50-2.00) | 3.5 (1.9-5.8) |
| Gender | | | | | |
| Male | 1554 (38.5) | 62 (36.5) | 0.5850 | Ref | 4.0 (3.1-5.1) |
| Female | 2486 (61.5) | 108 (63.5) | | 1.09 (0.79-1.50) | 4.3 (3.6-5.2) |
| Governorate of residence | | | | | |
| Outside Cairo | 978 (24.2) | 43 (25.3) | 0.7355 | Ref | 4.1 (3.5-4.9) |
| Cairo | 3062 (75.8) | 127 (74.7) | | 0.94 (0.66-1.34) | 4.4 (3.2-5.9) |
| Urban/rural residence | | | | | |
| Urban | 3543 (87.7) | 148 (87.1) | 0.7955 | Ref | 4.2 (3.5-4.9) |
| Rural | 497 (12.3) | 22 (12.9) | | 1.06 (0.67-1.68) | 4.4 (2.8-6.6) |
| Marital status | | | | | |
| Not married | 1865 (46.2) | 65 (38.2) | 0.0349 | Ref | 3.5 (2.7-4.4) |
| Married | 2175 (53.8) | 105 (61.8) | | 1.40 (1.02-1.93) | 4.8 (4.0-5.8) |
| Education | | | | | |
| University or higher | 2122 (52.5) | 64 (37.6) | | Ref | 2.3 (0.5-6.6) |
| Secondary | 1551 (38.4) | 91 (53.5) | <0.0001 | 2.00 (1.45-2.78) | 5.0 (2.6-8.6) |
| Primary or preparatory | 238 (5.9) | 12 (7.1) | 0.0969 | 1.71 (0.91-3.21) | 5.9 (4.7-7.2) |
| Less than primary | 129 (3.2) | 3 (1.8) | 0.6551 | 0.77 (0.24-2.47) | 3.0 (2.3-3.8) |
| Occupation | | | | | |
| Physician | 1577 (39.0) | 45 (26.5) | | Ref | 2.9 (2.1-3.8) |
| Nurse | 1598 (39.6) | 97 (57.1) | <0.0001 | 2.20 (1.53-3.16) | 6.1 (4.9-7.4) |
| Non-clinical care | 865 (21.4) | 28 (16.5) | 0.5948 | 1.14 (0.71-1.84) | 3.2 (2.2-4.6) |
| Tobacco use, yes | | | | | |
| Current | 479 (11.9) | 15 (8.8) | 0.214 | 0.71 (0.41-1.22) | 3.1 (1.8-5.1) |
| Past | 79 (1.9) | 3 (1.9) | 0.8069 | 0.86 (0.27-2.77) | 3.8 (0.8-10.7) |
| Self-reported pre-existing medical condition | | | | | |
| No | 3339 (82.6) | 137(80.6) | | Ref | 4.1 (3.5-4.8) |
| Yes | 701 (17.4) | 33 (19.4) | 0.4689 | 1.15 (0.78-1.70) | 4.7 (3.3-6.5) |

[a]*P*-values indicate differences between infected and non-infected health care workers.
[b]Odds ratio (95% CI) were calculated using binary logistic regression.

six (11.1%) had fever ≥38°C and only seven (13.0%) had severe symptoms. Infected HCWs were more likely to report fever, dry cough, loss of appetite and change/loss of taste or smell than non-infected HCWs (Supplementary Table S4, available as Supplementary data at *IJE* online). The onset of symptoms ranged between 1 and 31 days, with a median of 4.0 days, after contact with a suspected (IQR 3.0–8.0) or confirmed (IQR 3.0–7.0) case (Figure 2). In some symptomatic HCWs, the onset of symptoms was on the same day or before their last contact with a case.

In the multivariable analysis, being a nurse was independently associated with infection [adjusted odds ratio (OR) 4.67; 95% CI 1.95-11.18]. Also, being 30–39 years old (4.28; 1.06–17.28), working in the operating theatre (3.24; 1.32–7.97), having: a fever <38°C (2.54; 1.10–5.88); fever ≥38°C (4.03; 1.23–13.16); dry cough (2.18; 1.05–4.52); and change/loss of smell (26.24; 2.09–329.73) were associated with increased odds of infection (Table 5).

## Discussion

Among 4040 HCWs screened at baseline, 170 (4.2%) tested positive for SARS-CoV-2 (3.4% in asymptomatic and 8.8% in symptomatic HCWs) by PCR, IgM or IgG, indicating recent or past infection. Throughout March, ASU adopted many proactive mitigation measures aiming to reduce nosocomial transmission risk (Figure 1). Early in April, a few suspected cases among patients and HCWs

**Table 2** Hospital or medical centre, proportion of total infections and asymptomatic infections among enrolled health care workers in the baseline screening ($n = 4040$)

| | Total $n = 4040$ $n$ (column %) | Infected $n = 170$ $n$ (column %) | $P$-value[a] | Unadjusted odds ratio[b] (95% CI) | Proportion of infection Overall = 4.2 (3.6-4.9) row % (95% CI) | Proportion of asymptomatic infection among infectedOverall = 68.2 (60.7-75.2)% (95% CI) |
|---|---|---|---|---|---|---|
| Hospital or medical centre | | | | | | |
| Cardiovascular surgery | 202 (5.0) | 2 (1.2) | | 1 (Reference) | 1.0 (0.1-3.5) | 100.0 (15.8-100.0) |
| Geriatrics | 232 (5.7) | 3 (1.8) | 0.7686 | 1.31 (0.22-7.92) | 1.3 (0.3-3.7) | 100.0 (29.2-100.0) |
| Surgery | 922 (22.8) | 42 (24.7) | 0.0318 | 4.77 (1.15-19.88) | 4.6 (3.3-6.1) | 66.7 (50.5-80.4) |
| Internal medicine | 870 (21.5) | 36 (21.2) | 0.0454 | 4.32 (1.03-18.08) | 4.1 (2.9-5.7) | 72.2 (54.8-85.8) |
| Paediatrics | 656 (16.2) | 24 (14.1) | 0.0715 | 3.80 (0.89-16.21) | 3.7 (2.4-5.4) | 91.7 (73.0-99.0) |
| Obstetrics and gynaecology | 617 (15.3) | 44 (25.9) | 0.0051 | 7.68 (1.84-31.96) | 7.1 (5.2-9.5) | 40.9 (26.3-56.8) |
| Emergency | 141 (3.5) | 2 (1.2) | 0.7176 | 1.44 (0.20-10.34) | 1.4 (0.2-5.0) | 50.0 (1.3-98.7) |
| Oncology | 151 (3.7) | 4 (2.4) | 0.2514 | 2.72 (0.49-15.06) | 2.6 (0.7-6.6) | 100.0 (39.8-100.0) |
| Psychiatry | 32 (0.8) | 1 (0.6) | 0.3449 | 3.23 (0.28-36.64) | 2.4 (0.1-12.9) | 100.0 (2.5-100.0) |
| Toxicology | 41 (1.0) | 1 (0.6) | 0.4588 | 2.50 (0.22-28.24) | 3.1 (0.1-16.2) | 100.0 (2.5-100.0) |
| Endoscopy | 81 (2.0) | 4 (2.4) | 0.0601 | 5.19 (0.93-28.94) | 4.9 (1.4-12.2) | 100.0 (39.8-100.0) |
| Clinic buildings | 95 (2.4) | 7 (4.1) | 0.0106 | 7.95 (1.62-39.06) | 7.4 (3.0-14.6) | 85.7 (42.1-99.6) |

[a]*P*-values indicate differences between infected and non-infected health care workers.
[b]Odds ratio (95% CI) were calculated using binary logistic regression.

**Table 3** Positive cases by type of test among infected health care workers ($n = 170$)

| Test | | | $n = 170$ | |
|---|---|---|---|---|
| **PCR**[a] | IgM | IgG | $n$ | % |
| Positive | Negative | Negative | 117 | 68.8 |
| Negative | Positive | Negative | 34 | 20.0 |
| Negative | Negative | Positive | 11 | 6.5 |
| Positive | Positive | Negative | 4 | 2.4 |
| Positive | Negative | Positive | 3 | 1.8 |
| Positive | Positive | Positive | 1 | 0.6 |
| Negative | Positive | Positive | 0 | 0.0 |

[a]Polymerase chain reaction.

initiated localized SARS-CoV-2 PCR screening for their close contacts. This prompted universal screening of all HCWs for early detection and isolation of COVID-19 cases. The baseline screening took place in the early phase of the COVID-19 epidemic; there were 3659 total cases in Egypt at screening launch (22 April). By the end of baseline screening (14 May), the cumulative infections through the nationally adopted symptom-based screening were 10 829 cases/135 000 PCR tests[24] (8.0%; 95% CI 7.9-8.2), comparable to the proportion of infection among symptomatic HCWs in the current study (8.8%). The onset of symptoms in infected ASU-HCWs during baseline screening follows the epidemic curve in the community, suggesting that infections may have been acquired through community rather than nosocomial transmission. This finding is consistent with observations in high- and upper-middle-income settings, such as the UK,[25] The Netherlands[5] and China.[2]

In the early epidemic phase, 6% (86/1353) in two Dutch hospitals[5] and 5% (2/38) in the UK[25] tested positive for SARS-CoV-2 among symptomatic HCWs, compared with 8.8% in this study. In the UK study, the infection rate increased to 20% at a later epidemic stage.[25] Evidence of asymptomatic carriage in HCWs was documented; two studies reported infection rates close to the 3.4% in this study: 3.9% of 2872 and 2.9% of 1032 asymptomatic HCWs tested positive for SARS-CoV-2 in the USA[26] and the UK,[27] respectively. Another UK study reported an initial rate of 7.1% (28/396) falling after 5 weeks to 1.1 (3/269).[11] More than two-thirds of the infected HCWs (116/170, 68.2%) in this study were asymptomatic at the time of screening. Others also documented asymptomatic carriage in HCWs (57%)[27] and non-HCWs (51.7%–87.9%).[9,10,28] This finding underscores the importance of relaxing the strategy of testing individuals, particularly HCWs, based on a strict clinical case definition, to accommodate asymptomatic or pauci-symptomatic individuals.

Our findings suggest that adopting a symptom-based-only self-isolation approach may result in unnecessary isolation of approximately nine out of 10 HCWs. Implementing universal screening, however, is cost-saving and keeps the much-needed workforce active. The negotiated volume purchase price of SARS-CoV-2 RT-PCR and rapid serological tests used in this study was 50 USD per

**Table 4** Exposure and clinical characteristics of enrolled health care workers in the baseline screening ($n = 4040$)

| | Total $n = 4040$ $n$ (column %) | Infected $n = 170$ $n$ (column %) | *P*-value[a] | Unadjusted odds ratio (95% CI)[b] | Proportion of infection Overall = 4.2 (3.6-4.9) row % (95% CI) |
|---|---|---|---|---|---|
| Contact with a suspected case, yes | 1496 (37.0) | 78 (45.9) | 0.0151 | 1.47 (1.08-2.00) | 5.2 (4.1-6.5) |
| Contact with a confirmed case, yes | 1098 (27.2) | 68 (40.0) | 0.0002 | 1.84 (1.34-2.52) | 6.2 (4.8-7.8) |
| Direct care for a confirmed case in ASU hospital/centre, yes | 459 (11.4) | 22 (12.9) | 0.5076 | 1.17 (0.74-1.85) | 4.8 (3.0-7.2) |
| Face-to-face interaction within 2 m with a confirmed case in ASU hospital/centre, yes | 772 (19.1) | 47 (27.6) | 0.0042 | 1.66 (1.17-2.34) | 6.1 (4.5-8.0) |
| Duration of contact with a confirmed case in ASU hospital/centre | $n = 772$ | $n = 47$ | | | |
| Less than 5 min | 183 (23.7) | 10 (21.3) | | Ref | 5.5 (2.7 -9.8) |
| 5-15 min | 229 (29.7) | 9 (19.1) | 0.4626 | 0.71 (0.28-1.78) | 3.9 (1.8-7.3) |
| More than 15 min | 360 (46.6) | 28 (59.6) | 0.3203 | 1.46 (0.69-3.07) | 7.8 (5.2-11.0) |
| Symptoms during the past 14 days | | | | | |
| No | 3424 (84.8) | 116 (68.2) | <0.0001 | Ref | 3.4 (2.8-4.0) |
| Yes | 616 (15.2) | 54 (31.8) | | 2.74 (1.96-3.83) | 8.8 (6.7-11.3) |
| Symptoms severity | $n = 616$ | $n = 54$ | | | |
| Mild | 408 (66.2) | 21 (38.9) | | Ref | 3.4 (2.8-4.0) |
| Moderate | 180 (29.2) | 26 (48.1) | 0.0002 | 3.11 (1.70-5.70) | 5.1 (3.2-7.8) |
| Severe | 28 (4.5) | 7 (13.0) | 0.0002 | 6.14 (2.35-16.07) | 14.4 (9.7-20.4) |

[a]*P*-values indicate differences between infected and non-infected HCWs.
[b]Odds ratio (95% CI) were calculated using binary logistic regression.

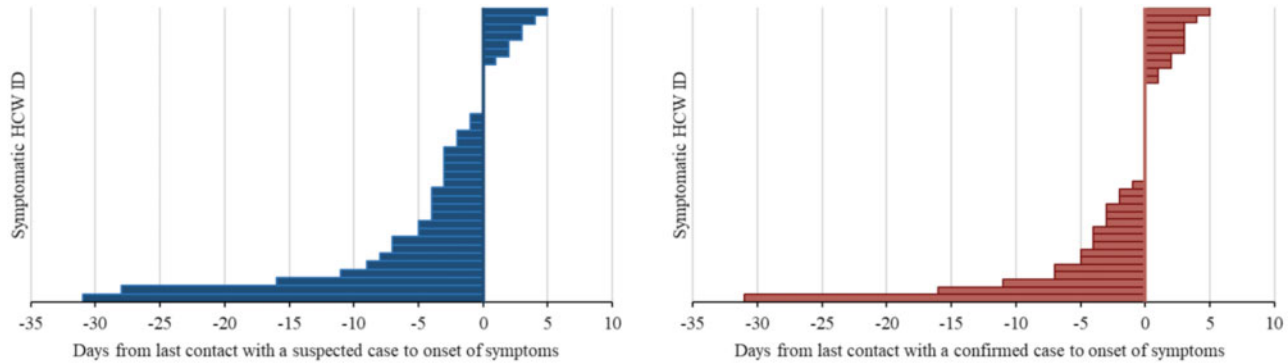


**Figure 2** Time between last contact with a suspected or confirmed case to onset of symptoms in infected health care workers (HCWs) who reported relevant dates ($n = 39/54$ symptomatic infected HCWs). 0 indicates onset of symptoms on the same day of contact with the case. Negative indicates contact before onset of symptoms

person. The cost saves managing the consequences of infection in vulnerable patients, who may need prolonged hospital stay, intensive care unit (ICU) admission or mechanical ventilation—all of which are scarce assets in resource-limited health care systems.

Despite the relatively high (97.5%) sensitivity of RT-PCR,[22] it can yield high false-negative results.[29] Therefore, a risk stratification protocol for HCWs who tested negative with scheduled re-testing is recommended.[30] Serological tests were performed in this study to evaluate baseline seroprevalence and identify seroconversion at follow-up—not as a confirmatory test of HCWs' infection at baseline. Only 11/4040 (0.3%) HCWs in this study tested IgG-positive, indicating that infection was not yet widespread in ASU-HCWs in this early epidemic phase.

The first identified COVID-19 HCW case was in the Obstetrics and Gynaecology hospital (4 April) only complaining of general malaise, and may have resulted in a cluster of infection among other HCWs, being paucisymptomatic. This might explain why the proportion of infection was higher in this hospital (7.1%) compared with

**Table 5** Multivariable logistic regression analysis of factors associated with health care workers' infection status

| | $\beta$ | SE | *P*-value | Adjusted odds ratio (95% CI) |
|---|---|---|---|---|
| Age | | | | |
| 18-24 | | | | Ref |
| 25-29 | 1.3674 | 0.7198 | 0.0575 | 3.93 (0.96-16.09) |
| 30-39 | 1.4551 | 0.7116 | 0.0409 | 4.28 (1.06-17.28) |
| 40-49 | 1.0429 | 0.7718 | 0.1766 | 2.84 (0.63-12.88) |
| ≥50 | 1.4404 | 0.8223 | 0.0798 | 4.22 (0.84-21.16) |
| Gender | | | | |
| Male | | | | Ref |
| Female | 0.0344 | 0.3990 | 0.9313 | 1.04 (0.47-2.26) |
| Occupation | | | | |
| Physician | | | | Ref |
| Nurse | 0.1988 | 0.6199 | 0.0005 | 4.67 (1.95-11.18) |
| Non-clinical care | 1.5414 | 0.4453 | 0.7484 | 1.22 (0.36-4.11) |
| Immunological disorder, yes | 1.2736 | 0.8994 | 0.1568 | 3.57 (0.61-20.83) |
| Contact with a suspected case, yes | −0.2305 | 0.4054 | 0.5696 | 0.79 (0.36-1.76) |
| Contact with a confirmed case, yes | 0.3130 | 0.4598 | 0.4961 | 1.37 (0.56-3.37) |
| Face-to-face interaction within 2 m with a confirmed case, yes | 0.0773 | 0.4146 | 0.8520 | 1.08 (0.48-2.44) |
| Place of work at hospital | | | | |
| Delivery room | 0.3123 | 0.6141 | 0.6111 | 1.37 (0.41-4.55) |
| Radiology unit | 0.6251 | 0.8205 | 0.4461 | 1.87 (0.37-9.33) |
| Operation room | 1.1763 | 0.4590 | 0.0104 | 3.24 (1.32-7.97) |
| Symptoms | | | | |
| Fever <38°C, yes | 0.9320 | 0.4284 | 0.0269 | 2.54 (1.10-5.88) |
| Fever ≥38°C, yes | 1.3933 | 0.6042 | 0.0211 | 4.03 (1.23-13.16) |
| Dry cough, yes | 0.7798 | 0.3715 | 0.0358 | 2.18 (1.05-4.52) |
| Loss of appetite, yes | 0.0016 | 0.8585 | 0.9985 | 1.00 (0.19-5.39) |
| Change/loss of taste, yes | 1.1100 | 1.1599 | 0.3386 | 3.03 (0.31-29.47) |
| Change/loss of smell, yes | 3.2674 | 1.2913 | 0.0114 | 26.24 (2.09-329.73) |
| Constant | −5.1850 | 0.8231 | <0.0001 | 0.01 |

SE, standard error.

others. The variability of infection rates among participating sites requires further investigation of the behavioural, personal and social characteristics associated with asymptomatic infection. HCWs occasionally work in multiple hospitals within ASU premises, and a few COVID-19 infected HCWs (6.5%) reported working in other hospitals. Tracking the trajectories of infected HCWs and tracing the viral genetic sequence may help determine the occurrence of cross-infection between health care facilities.

Working in the operating theatre was independently associated with infection in this study. Close contact with colleagues and patients, emergency operations performed for life-saving conditions before excluding patient's infection, and procedures entailing aerosol generation and spilling of patients' body fluids, are among factors increasing the risk of infection, in addition to accidental damage of PPE during work and inappropriate sequence of donning and doffing.

HCWs who were adherent to gown use in this study were more likely to be infected than those who were non-adherent. Occasional breaching of infection prevention and control (IPC) procedures and relaxed HCWs' attitudes towards the prohibited social gathering cannot be dismissed. Consistent use of PPEs can reduce the risk of infection among HCWs.[31] However, adequate PPE availability did not completely eliminate that risk in HCWs who were adherent to PPE use in the UK and the USA[32]; adherence to proper use should be investigated. More mistakes were detected among nurses during donning or doffing PPEs in a Chinese hospital.[33]

In this study, working as a nurse compared with a physician was independently associated with infection, which

is consistent with previous findings.[34] Nurses are in contact with many colleagues and patients' relatives at the nurses' stations. Also, in ASU hospitals, many tasks still involve paperwork, mainly handled by nurses and exposing them to a higher possibility of infection.

The time between infected HCWs' last contact with a confirmed case to the onset of symptoms ranged between 1 and 31 days, conforming with recent work estimating 5% of cases may take 2 weeks or more to develop symptoms.[13] HCWs' direct face-to-face interaction within 2 m with a confirmed COVID-19 case, but not the duration, was associated with a greater proportion of infection only in the bivariate analysis. Interestingly, more than half the infected HCWs did not report any contact with a COVID-19 case either in the workplace or at home, a proportion double that reported in previous studies.[5] Moreover, some infected HCWs reported contact with cases after several days from the onset of their symptoms, suggesting exposure to an asymptomatic or pre-symptomatic case, as infectivity peaks in the pre-symptomatic stage.[14] Several factors support that in-hospital transmission at this early epidemic stage was unlikely. Infection that could not be traced to a specific exposure may signal the stage of community transmission.[35]

We found that SARS-CoV-2 infection among HCWs was independently associated with fever, dry cough and change/loss of smell. Another study reported these symptoms as predictors of a positive COVID-19 test with high specificity.[32] In this study, loss of smell was reported by only five HCWs, four of whom were infected. Also, six reported fever $\geq$38°C (11.1%) and most symptomatic cases showed only mild to moderate symptoms, a finding consistent with previous reports.[5,28] Klutymans *et al*. suggested modifying the case definition for suspected HCWs by including fever as a possible—not as a required—symptom.[5]

Pre-existing medical conditions among HCWs in this study were not associated with an increased risk of SARS-CoV-2 infection. Approximately three-quarters of enrolled HCWs were younger than 40 years of age. Also, the data may have not have revealed independent associations, due to the small number of infected HCWs with comorbidities. A recent UK study reported that, apart from chronic kidney disease and obesity, none of the chronic conditions among 587 primary care patients were associated with positive SARS-CoV-2 tests.[36] Infected participants' relatively young age (median 31.5 years) may have also contributed to the high proportion of asymptomatic infections in the current study. Recent modelling work suggests an age-dependent effect in COVID-19 transmission[37]; asymptomatic infections occur mostly in younger ages, which might partly explain why clinically apparent cases are lower in countries with predominantly young population structures, such as Egypt.

Implementing similar universal COVID-19 screening in other resource-limited settings may be challenging. The centrally located accredited laboratories in ASU expedited transfer of samples with a testing capacity of 500 samples per day. There were also dedicated trained teams responsible for screening. Notably, screening of HCWs should be periodic for early detection of infections—especially asymptomatic infections—and to assist decision makers in prompt management of the health care workforce. The preparations for baseline screening, including capacity building and training of hospital teams, may positively reflect on future hospital policies for communicable diseases and the preparedness for other epidemics. Costs, availability of tests, testing capacity and suitable laboratory facilities with skilled personnel are among many barriers to universal screening of HCWs in resource-limited settings. Therefore, developing accurate affordable rapid point-of-care diagnostic tests is vital to the success and sustainability of this approach. Moreover, universal screening should be coupled with vigilant IPC measures to protect HCWs and hospitalized patients. Conversely, there is a unique opportunity in universal screening of HCWs; discovering asymptomatic infections will be critical in flattening the curve and preventing second waves which could result in staff shortages and the overwhelming of health care facilities, particularly in countries experiencing COVID-19 epidemic exponential growth.

## Limitations and challenges

As testing of HCWs was voluntary there was a possibility of self-selection bias. HCWs who thought they were at a higher risk of COVID-19 were more likely to participate for reassurance. The association between infected and symptomatic/asymptomatic status would most likely not be biased, though; if biased, the direction of bias would be underestimation of asymptomatic infections. Second, symptoms may have been over-reported, but the recall period was short and HCWs filled the online survey first and did not know the results of the tests, except later on. Third, comparison of HCWs' demographic and clinical characteristics with the nationwide confirmed cases was not possible because MoHP data were not publicly available. Since Egypt is currently experiencing exponential growth in the epidemic, changes in the proportion of infection among HCWs is expected to occur rapidly and this will be examined in the follow-up phase of this study. Fourth, the cross-sectional nature of the baseline screening does not allow drawing causal inferences. We were unable to validate whether asymptomatic HCWs were truly

asymptomatic or were in the pre-symptomatic phase. This could be further investigated in longitudinal study designs. Also, evaluation of impact of the many interventions ASU adopted to mitigate nosocomial transmission of COVID-19 was not possible. Fifth, the online survey collected several data within the HCWs' limited time; the collection of behavioural risk factors and elaborate evaluation of IPCs was not feasible. Investigating temporal and spatial nosocomial transmission dynamics for SARS-CoV-2 infection, particularly in hospitals with a higher proportion of infections, was not possible. Sixth, the test sensitivity for lateral flow immunochromatographic antibody assay was poor (83%); therefore, the frequency of recovery from infection may have been under-reported. We faced some logistical challenges during implementation. Internet disruption caused delay in completing the online survey for 1 day, but this was overcome by using cellphone internet packages. There was HCW and consequently sample overflow into baseline screening on 2 days, exceeding the capacity of both the local screening and the laboratory teams, which was overcome by assigning additional shifts, teams and workstations.

## Conclusions

The overall proportion of infection among 4040 HCWs assessed in the baseline screening in the early phase of the epidemic in Egypt was 4.2%. The majority were asymptomatic, and nurses were more likely to be infected. The rate of symptomatic infection in this study is comparable with the national rate in the early epidemic phase in Egypt, suggesting community-acquired rather than nosocomial infection. Universal screening—including symptomatic and asymptomatic HCWs—informed ASU policies for evidence-based management and updated local guidance for HCWs. Given the various success factors required for sustained implementation and regular testing, further evaluation of the feasibility and effectiveness of implementing such programmes is required in different resource-limited settings.

All data are available in the article and its online Supplementary material.

## Supplementary Data

Supplementary data are available at *IJE* online.

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## Author Contributions

A.Mostafa conceptualized and visualized the study, planned and designed the study, performed literature search, developed the study tools, planned the study workflow, supervised the study, coordinated and monitored implementation, led data management, conducted statistical data analysis, prepared the tables and figures, interpreted the data, wrote the first draft of the manuscript, and critically reviewed the manuscript. S.K. participated in the study design, performed literature search, advised on the study tools, participated in writing the second draft of the manuscript, and critically reviewed the manuscript. M.H.E-S. supervised the study planning and conduct and critically reviewed the manuscript. Supervision and logistics: M.E-M. and A.S. Supervision: A.O. Coordination of implementation: O.M. and S.G. Laboratory analysis of samples: H.H., S.S., H.E., M.R. F.S.E.E. participated in monitoring implementation. M.Y. adapted the study tool for online data collection and participated in data management. Implementation of screening: I.A., F.H., S.E., A.R., D.F., A.Mahmoud, A.Mansour, M.S., P.H.

## Conflict of Interest

None declared.

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