Association Between Implementation of a Universal Face Mask Policy for Healthcare Workers in a Health Care System and SARS-CoV-2 Positivity Testing Rate in Healthcare Workers

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Objective: Examine the effect of a universal facemask policy for healthcare workers (HCW) and incidence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) positivity. **Methods:** Daily number of symptomatic HCW tested, SARS-CoV-2 positivity rates, and HCW job-descriptions were collected pre and post Universal HCW facemask policy (March 26, 2020). Multiple change point regression was used to model positive-test-rate data. SARS-CoV-2 testing and positivity rates were compared for pre-intervention, transition, post-intervention, and follow-up periods. **Results:** Between March 12 and August 10, 2020, 19.2% of HCW were symptomatic for COVID-19 and underwent SARS-CoV-2 testing. A single change point was identified ~March 28–30 (95% probability). Before the change point, the odds of a tested HCW having a positive result doubled every 4.5 to 7.5 days. Post-change-point, the odds of a tested HCW having a positive result halved every 10.5 to 13.5 days. **Conclusions:** Universal facemasks were associated with reducing HCW's risk of acquiring COVID-19.

Keywords: COVID, healthcare workers, nurses, personal protection equipment, universal facemask

Learning Objectives

- Discuss the timeline of implementation of a universal face mask policy for healthcare workers (HCWs) in the study health system.
- Summarize the new findings on how the face mask policy affected SARS-CoV-2 positivity through the pre- and post-implementation period.
- Identify groups of HCWs with higher and lower rates of SARS-CoV-2 positivity.

During the 1918 Spanish Flu pandemic, hospitals were paralyzed by lack of healthcare workers (HCW) due to hospital acquired infections.[1] One control measure found useful then was use of cloth facemasks.[2,3] A century later, similar to the 1918 flu pandemic, healthcare workers serving the frontline in the coronavirus pandemic remain most exposed and vulnerable to infection.

HCW have a threefold increased risk of reporting testing positive for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus that causes coronavirus disease 2019 (COVID-19) compared with the general population.[4] Early reports between January and March, 2020, in the pandemic from China and Italy found up to 30% of HCW developed COVID-19.[5,6] As of December 21, 2020, the CDC reported 287,010 HCW have been infected with SARS-CoV-2 with 953 (0.33%) HCW COVID-19 related deaths.[7] However, the number of HCWs infected with SARS-CoV-2 and deaths from COVID-19 is under-reported and infection rates among HCWs based on occupation type are limited.[7,8] Both mainstream and social media outlets have reported controversies surrounding universal facemask policies as there are limited data available reflective of potential associations between facemask policies, type of facemasks to be used, and SARS-CoV-2 infection amongst HCW in high-prevalence areas of infection.[9–11]

Between March and April 2020, the State of Michigan ranked 3rd amongst all States in the United States for confirmed COVID-19 cases.[12] Within the span of this 1 month, more than 2000 HCW across multiple southeast Michigan health systems were confirmed or suspected to have COVID-19.[13] Metro-Detroit was identified as Michigan's COVID-19 epicenter. As a result of the rapid COVID-19 outbreak among HCW, Henry Ford Health System (HFHS), a large tertiary medical center serving the metro-Detroit and Southeast Michigan population, consisting of six hospitals and over 33,500 HCW, implemented a universal facemask policy for HCW on March 26, 2020. The policy included providing surgical/procedural masks to team members while working in the hospital facilities or community on behalf of the health system and securing personal protection equipment (ie, N95masks, gowns, goggles/faceshields) for all staff who were directly caring for COVID-19 suspected or positive patients.[14] This project evaluated the association of a facemask policy with SARS-CoV-2 infection in HCW in a COVID-19 hotspot.

METHODS

The Henry Ford Health System Institutional Review Board reviewed and approved this quality improvement project and informed consent was waved. All HCW entering HFHS facilities underwent daily health screening questionnaire for symptoms of COVID-19 in accordance with HFHS infection control implemented Employee COVID Entrance Screening Policy. HCWs exhibiting symptoms consistent with COVID-19 infection were referred for SARS-CoV-2 testing via reverse-transcriptase polymerase chain reaction (PCR) testing of upper respiratory nasopharyngeal specimens. HCWs who tested positive between March 12 and August 10

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Clinical significance: This study supports the use of universal facemasks as part of a multi-tiered health system approach to reduce healthcare workers' risk of acquiring COVID-19. This data supports the CDC's policy of wearing facemasks to reduce the spread of SARS-CoV-2. This data also identifies Nurses at highest occupation risk of COVID-19.

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were included in the study. The daily number of HCW tested across HFHS, the number of positive SARS-CoV-2 tests, and HCW job descriptions were collected via an internal hospital quality metric reporting analytics database (COVID-19 Analytics Database) that was not associated with the electronic medical records. All test results were verified by HFHS Employee Health and Infection Control prior to inclusion in the COVID-19 Analytics Database. No personal identifying information is accessible, nor linked to HCW test results in this database. No attempts were made to identify HCW. Data are presented as daily summarized de-identified numbers. The daily number of COVID-19 related hospitalizations within the health system were collected. The daily number of confirmed COVID-19 cases in the state of Michigan were tabulated from publicly available reporting by the Michigan Department of Health and Human Services.[15,16] State of Michigan Coronavirus Executive Orders and Directives and HFHS Infection Control implemented interventions were documented within this time period[14,17] (Appendix 1, Appendix 1.2, http://links.lww.com/JOM/A882).

Data Summarization

Daily testing counts capture the HCWs who were sampled for a SARS-CoV-2 test on that day. Positive tests are attributed to the date in which the sample was collected. Positivity rate was defined as the first positive test result for all HCWs in the numerator and total number of HCWs who were tested that day in the denominator. In HCWs who were tested multiple times during the study period, only the initial positive test was included. Daily testing data were collected from March 12 through August 10, 2020. Four phases were identified for analysis: a pre-intervention phase; a transition period, allowing for passage of a 14-day incubation period from time of universal HCW facemask policy implementation; a post-intervention period; and a follow-up period. Since the State of Michigan lifted its Stay-at-Home order on June 1, 2020, SARS-COV2 PCR test results from March 12 (day 0) through June 1 were used for modeling analysis and testing data from June 2 through August 10 were considered for follow-up.

Statistical Analysis

Multiple change point regression was used to model the positive test rate data (R v 4.0.4, mcp package v 0.3.0[18,19]). Unweighted linear, logistic, and probit regression models were considered with one or two change points, both with and without continuity at those change points. Default priors were used with a burn-in of 5000 iterations. The Gelman-Rubin convergence diagnostic (Rhat) was considered for each of the model parameters.[20] Comparison of the expected log pointwise predictive density (ELPD) between models, estimated by leave-one-out cross validation,[21] was used to assess parsimony. The presence of outlying Pareto k estimates ($k > 0.7$), was considered as evidence of potential model misspecification. The logistic regression model with one change point and no discontinuity was selected as the best fit to these data. This model was parsimonious with four parameters, had robust convergence (Rhat = 1.0 for all parameters), and no evidence of misspecification (Pareto $k < 0.5$). Figure 1 depicts the modeled curve for the expected positivity rates, drawn from the median posterior predicted values of the multiple change point model (red-dashed line), with observed positivity proportions overlaid. From the identified change point we created windows of potential intervention (up to 2 days prior; pre-intervention), transition/incubation period (14 days), post-intervention, and follow-up. A Chi-square test of independence was used to assess association between studied time intervals and job class. Comparisons of proportions of patterns and positive testing were conducted between each studied time interval and within job category using Chi-square tests. Differences in proportions are given along with their 95% confidence intervals. Of interest were changes between pre- and post-intervention, and between post-intervention and follow-up periods.

RESULTS

Change Point Estimation and Associated Time Periods in Relation to State of Michigan Stay at Home Executive Order

Between March 12, 2020 (day 0) and June 1, 2020, the number of tests performed per day ranged from 2 to 176, with 0% to 53.8% of the tests returning as positive. In Fig. 1, the proportion of HCW positive tests per day is indicated with varying sized circles, for which the diameter relates to the number of tests conducted that day. The red-dash line depicts the two modeled logistic curves for

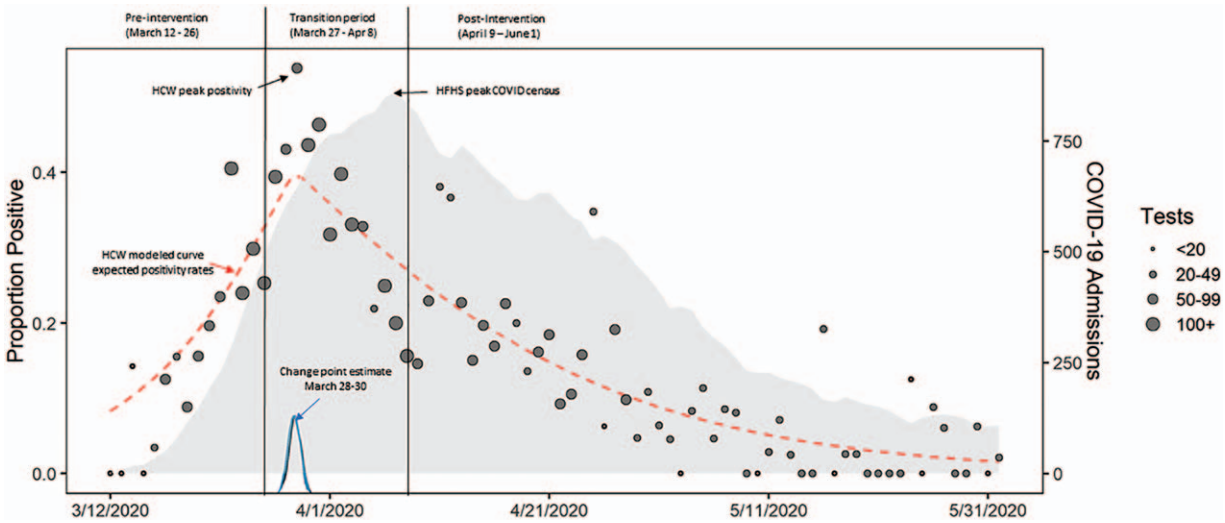

FIGURE 1. Model of positive test results among healthcare workers. Daily proportion of positive tests (circles; diameter relative to number of tests) is modeled by two curves (red dashed line) with a change point estimated between March 28 and 30 (blue density curve). The Henry Ford Health System daily COVID19 inpatient census is shaded in grey in the background for reference. HCW, healthcare worker; HFHS, Henry Ford Health System.

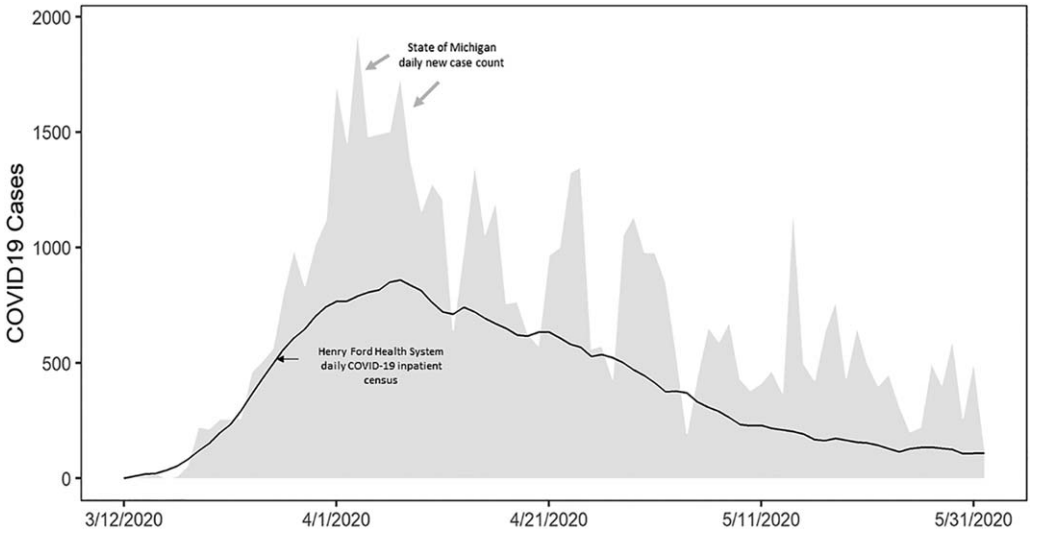

FIGURE 2. COVID19 case load during study period. The Henry Ford Health System daily COVID-19 inpatient census (black line) is overlaid on the daily new case count for the entire State of Michigan (grey shadow).

the expected positivity rates. Using a change-point analysis, a single change point was identified and estimated to be between March 28 and March 30, with 95% probability as shown by the blue density curve at the bottom of Fig. 1 (mean: 16.7 days from 3/12, 95% credible interval: (15.6 days, 17.9 days); consistent with the initial policy implementation date of March 26, 2020.

On Fig. 1, before the change point, the rising curve estimated the odds of a tested HCW having a positive result doubling every 4.5 to 7.5 days (logit per day, 95% credible interval: 0.091, 0.155). On Fig. 1, after the change point, the descending curve showed the odds of a tested HCW employee getting a positive result halving every 10.5 to 13.5 days (logit per day, 95% credible interval: −0.065, −0.051). For reference, the inpatient COVID-19 daily census for Henry Ford hospital is depicted by the grey shaded region in the background of Fig. 1. While the temporal trend of the Henry Ford Hospital COVID-19 daily census continued to increase in the pre-intervention period through majority of the transition period, the change point occurred earlier in the transition period (Fig. 1). The Henry Ford hospital (Henry Ford hospital system [HFHS]) COVID-19 census was at its maximum on April 7, 2020 with 861 admissions. The State of Michigan saw its maximum daily COVID-19 case increase on April 3, 2020, with 1953 new cases reported (Fig. 2).

With identification of the change point period by change-point analysis, four phases were then identified for in-depth evaluation: a pre-intervention phase from March 12 to March 26, 2020; a transition period from March 27 to April 8, 2020, allowing for passage of a 14-day incubation period for any pre-exposed HCW who had not yet developed symptoms; a post-intervention period from April 9 to June 1, 2020; and a follow-up period from June 2, 2020 to August 10, 2020. The incubation period (defined as period of exposure to manifestation of symptoms) ranges from 2 to 14 days.[22] We thereby propose that policies implemented by March 26 were influential for the March 28−30 change point.

Cumulative HCW Testing Pattern by HCW Job Function During the Study Period

A total of 6429 (19.2%) of 33,538 HCW were tested during the study period. Overall SARS-CoV-2 testing by HCW job function

TABLE 1. Comparison of Healthcare Worker Roles Among Those Receiving SARS-CoV-2 Testing

Job Category	Total HCW Tested (March 12−Aug 10)	Pre-Intervention (March 12−26)*	Transition (March 27−April 8)*	Post-Intervention (April 9−June 1)*	Follow-Up Interval (June 2−Aug 10)*
Nursing	35.4% (2278/6429)	33.2% (276/832)	43.9% (625/1423)	39.5% (725/1834)	27.9% (652/2340)
Allied Health Professional[a]	13.3% (853/6429)	10.8% (90/832)	13.4% (190/1423)	12.9% (237/1834)	14.4% (336/2340)
Administrative support	8.4% (541/6429)	8.5% (71/832)	7.9% (112/1423)	7.4% (135/1834)	9.5% (223/2340)
Senior Physicians	5.6% (362/6429)	9.7% (81/832)	3.2% (46/1423)	4.0% (74/1834)	6.9% (161/2340)
Resident physicians	3.3% (209/6429)	6.1% (51/832)	2.8% (40/1423)	3.2% (60/1834)	2.5% (58/2340)
All other healthcare workers	34.2% (2199/6429)	31.6% (263/832)	28.8% (410/1423)	32.9% (603/1834)	38.9% (910/2340)

[a]Radiology, Pharmacy, Pathology, Rehabilitation, Advanced Practitioners, Dialysis Technicians, Surgical Techs, Social Work, Case Management, Ophthalmology.
*Chi-square test of independence, $P < 0.0001$.

TABLE 2. SARS-CoV-2 Testing Results by Healthcare Worker Job Category at Henry Ford Health System (March 10 Through August 10, 2020)

Job Category	Employees Tested	Employees Positive	% Positive
Nursing	2278	474	20.8%
Allied health[a]	853	120	14.1%
Administrative support (non-clinical)	541	97	17.9%
Clinical support[b]	519	78	15.0%
Facility/Security/Support services[c]	399	77	19.3%
Physicians	571	52	9.1%
Leadership/Management	257	38	14.8%
Business (non-clinical)	273	29	10.6%
Behavioral health	83	17	20.5%
All other HCW	655	34	5.2%
Total symptomatic employees	6429	1016	15.8%

[a]Allied Health includes Radiology, Pharmacy, Pathology, Rehabilitation, Advanced Practitioners, Dialysis Technicians, Surgical Techs, Social Work, Case Management, Ophthalmology.
[b]Clinical support includes Medical Support, Population Health, Dietary, Clerical teams for Surgical Departments, Quality/Utilization Reviewers, Pastoral Care, Perfusion, Home Health, and Transplant Coordinators.
[c]Facilities/Support/Dietary/Nutrition, Environmental Services, Security, Facilities Engineers, Materials Management, and Transportation.

included 2278 (35.4%) Nurses, 853 (13.3%) Allied Health Professionals, 541 (8.4%) Administrative Support non-clinical roles, 519 (8.1%) Clinical Support, 399 (6.2%) Facilities/Security/Support, 571 Physicians (8.9%), 257 (4.0%) Leadership/Management, 273 (6.4%) Business non-clinical, 83 (1.3%) Behavioral Health, and 655 (10.2%) Other. Testing rates across the four periods are shown for clinical job categories in Table 1. The proportion of testing was greater among Physicians and Administrative Support personnel in the pre-intervention interval than the transition or post-intervention intervals. Conversely, the proportion of testing was greater among Nursing and Allied Health Professionals in the transition and post-intervention intervals (Table 1).

General Observations of Testing Results

A total 6429 (19.2%) of 33,538 employees were tested, of whom 1016 (15.8%) tested positive. The number of infected workers represents approximately 3.0% of the workforce. Positivity rates varied based on HCW job category. Cumulatively, Nursing positivity rate was 20.8% (474/2278), Allied Health Professional's positivity rate was 14.07% (120/853), and Administrative Support's (nonclinical) positivity rate was 17.93% (97/541). Physicians had a positivity rate of 9.11% (52/571); of these, 22 of 52 (42.3%) were identified as Trainees (Table 2).

SARS-CoV-2 testing results amongst non-Physician and non-Nursing HCW were additionally evaluated (Table 3). Cumulatively, these patient-centered HCW job functions also had elevated positivity rates. Notably, the top three job categories were Patient Advocate HCW with the highest positivity rate at 26.58%, followed by Dietary HCW at 21.28%, and Environmental Services HCW at 19.47% (Table 3).

HCW Positivity Rate Pre- and Post-Intervention by Associated Time Periods

A comparison of positivity rates between the pre-universal facemask policy for HCW intervention interval and the post-intervention interval showed a decrease of 7.8% in positivity for Nursing (95% CI: 1.9 to 13.7; Chi-square $P = 0.0059$), a decrease of 12.0% for Allied Health Professionals (95% CI: 3.09 to 20.9; Chi-square $P = 0.0022$), and a decrease of 34.1% for Administrative Support (95% CI: 21.4 to 46.6; Chi-square $P < 0.0001$). Among Physicians, a comparison of positivity rates between the pre-intervention and the post-intervention interval showed an increase of 6.0% among Senior Staff Physicians (95% CI: −3.1 to 15.1; Chi-square $P = 0.1938$) and an increase of 9.4% for Resident Physicians (95% CI: −2.5 to 21.3; Chi-square $P = 0.0844$). Among all HCW tested, we observed an 11.1% decrease in SARS-CoV-2 positivity between the pre- and post-intervention intervals (95% CI: 7.8 to 14.4; Chi-square $P < 0.0001$) (Table 4).

HCW Positivity Rate Pre- Versus Post-Intervention Period and Evaluation for Sustainability in Follow-Up Period

Pre- and post-intervention HCW positivity rates were additionally analyzed for a follow-up period of 2 months (June 2 to August 10) after the State of Michigan's stay at home order was

TABLE 3. SARS-CoV-2 Testing Results of Non-Physician/Nurse Patient-Centered Healthcare Workers (March 10 Through August 10, 2020)

Job Category	Employees Tested	Employees Positive	% Positive
Patient advocate	79	21	26.58%
Dietary	94	20	21.28%
Environmental services	190	37	19.47%
Security	67	12	17.91%
Dialysis	74	13	17.57%
Administrative clerical	414	66	15.94%
Rehabilitation/therapy	159	23	14.47%
Transportation	111	14	12.61%
Pharmacy	156	18	11.54%

TABLE 4. Comparison of SARS-CoV-2 Positivity Rate for All Healthcare Workers Across Study Intervals and by Selected Job Classes

Positivity Rates	Pre-Intervention (March 12–26)	Transition (March 27–April 8)	Post-Intervention (April 9–June 1)	Follow-Up Interval (June 2–Aug 10)	Chi-square *P*-Value Pre vs Post*	Chi-square *P*-Value Post vs Follow-Up**
All healthcare workers	23.8% (198/832)	35.6% (506/1423)	12.7% (233/1834)	3.4% (79/2340)	$P < 0.0001$	$P < 0.0001$
Nursing	25.7% (71/276)	39.4% (246/625)	17.9% (130/725)	4.1% (27/652)	$P = 0.0059$	$P < 0.0001$
Allied health professional	20.0% (18/90)	37.4% (71/190)	8.0% (19/237)	3.6% (12/336)	$P = 0.0022$	$P = 0.0205$
Administrative support	43.7% (31/71)	40.2% (45/112)	9.6% (13/135)	3.6% (8/223)	$P < 0.0001$	$P = 0.0184$
Senior staff physician	6.2% (5/81)	23.9% (11/46)	12.2% (9/74)	3.1% (5/161)	$P = 0.1938$	$P = 0.0064$
Resident physician	3.9% (2/51)	27.5% (11/40)	13.3% (8/60)	1.7% (1/58)	$P = 0.0844$	$P = 0.0175$

*Chi-square tests of proportions between pre- and post-intervention intervals.
**Chi-square tests of proportions between post- and follow-up intervals.

lifted to see if any observed effects were sustained (Table 4). Four HCW job categories were identified as having high risk of direct-patient exposure; Nursing, Allied Health Professional, Administrative-Support, and Physicians. Subgroup analysis was performed to evaluate rate of HCW positivity from post-intervention to follow-up according to these job categories (Table 4). There was an additional statistically significant decline in HCW SARS-CoV-2 positivity rate between the post-intervention, and follow-up period among Nursing, Allied Health Professionals, and Administrative Support HCW. There was no statistically significant change among Senior and Resident Physician HCW between the pre- and post-universal facemask policy intervention period (Chi-square $P = 0.1938$ and $P = 0.0844$, respectively), but demonstration of statistically significant change between the post-intervention and follow-up period (senior physician $P = 0.0064$, Resident Physician $P = 0.0175$).

DISCUSSION

This study describes the rate of SARS-CoV-2 infections among HCWs based on job category and impact of universal face masking in a multicenter academic institution during the COVID-19 epidemic in Southeast Michigan.

During the COVID epidemic, nearly one-fourth of the HFHS workforce was symptomatic and tested for SARS-CoV-2 infection. The number of HCW tested largely correlated with the disease burden in the health system. The positivity rate among our HCWs is similar to rates reported by the CDC in their morbidity and mortality publication.[23] Per the CDC, positivity rates were higher among nursing HCW, accounting for ~30% of infections among 5913 HCWs with available occupation data.[23] The higher rate of infection among Nurses and Support Staff, including Medical or Nursing Assistants, is attributed to the frequent, close contact with patients increasing their exposure risk to SARS-CoV-2.

Of note, within the HFHS, there were high rates of positivity among non-clinical staff who were tested. Non-clinical staff may have had exposure to coworkers, household members, or other persons in the community.[24,25] Additionally, the surge in volume of COVID-19 patients required significant measures to ramp up HFHS's hospital bed capacity. This involved reassigning and deploying HCW employees into new roles to respond to the surge crisis. The associated HCW job function and location reassignment may have increased the frequency and duration of non-clinical staff's face-to-face contact with patients (Table 3). Overall, Physicians had lower volume of testing and rate of infection compared with Nursing and Allied Health.

The early implementation of a universal HCW facemask policy at HFHS was associated with a significant decline in SARS-CoV-2 positivity rate among HCWs. The facemask policy occurred within 2 days of the State of Michigan's executive stay-at-home-order (March 24) and more than 2 weeks after closure of the Big-3 automotive factories (March 18th) and all indoor bar and restaurant businesses (March 16) (Appendix 1, http://links.lww.com/JOM/A882). Despite these external measures, the COVID-19-related inpatient hospitalizations continued increasing in the transition period, not declining until the post-intervention period. The model developed on the HCW testing data at HFHS retrospectively suggests an effective intervention for infection control in HCWs was initiated by March 26; effectively flattening the HCW's epidemic curve as demonstrated by other institutions with similar policy implementation.[26] The model indicates that positivity rate for SARS-CoV-2 in HCW was increasing rapidly in March, with a doubling time of 4.5 to 7.5 days. This increasing trend peaked at about March 29, approximately 3 days after HFHS communicated a universal facemask policy among HCW. After allowing a 14-day transition period, we observed a steady decline of positivity rate among HCW. It is notable that while the HFHS daily COVID-19 inpatient census follows the pattern of new case detection in the state, the HCW positivity rate reached a maximum approximately 9 days ahead of the hospital's peak census (April 7, 2020). This would suggest that other factors were at play beyond those affecting the general population.

The greatest declines on HCW positivity rates were noted to be amongst Nursing, Allied Health Professionals, and Administrative (non-clinical support) HCW. Amongst Physicians, there was an absence of statistical significance in change in SARS-CoV-2 positivity between the pre- and post-intervention period. Multiple factors may account for this aberrancy among Physicians. First year Interns and Medical Students were not allowed to care for patients with COVID-19 during the COVID surge. Additionally, the number of HCWs managing COVID-19 patients, including non-essential staff and Physicians, was restricted to minimize exposure and conserve personal protection equipment (PPE) due to a nationwide shortage, which remains a challenge for many health systems.[27,28] Consulting Physicians managed patients virtually, thus limiting frequent, close contact with patients. Lastly, Physicians are not commonly the first point of contact for patients seeking medical care. This clinical workflow algorithm of patients first registering at hospitals, proceeding through nursing triage, likely identified and placed patients with suspected COVID-19 in isolation prior to the first Physician contact.

LIMITATIONS

With this retrospective data we can see association, or correlation, but cannot imply causation. Limitations to this study include the inability to separate the impact of masks from the many hospital implemented infection control measures such as creation of single patient rooms, reduction in elective procedures, conversion to virtual clinic visits, and overall HCW accumulated experience with COVID-19 management and use of personal protection equipment. Changes in testing procedures and availability of testing over time are also unable to be accounted for in this retrospective analysis (however there was a decline in number of cases despite increased testing). The impact of utilization of drive-through testing for SARS-CoV-2 and triaging suspected COVID-19 patients in make-shift tent facilities outside the emergency room are additionally unable to be assessed, as both may have led to a significant decrease in exposure in our facilities. Lastly, breakdown of HCW occupational data is limited to human resources labeled job description and may not account for HCW reassignment during the COVID-19 surge to other healthcare responsibilities/locations. However, we saw a significant decline between the odds of a HCW having a positive SARS-CoV-2 positive result before and after the change point period which is unlikely to be completely biased, and has been noted in other health systems with similar universal facemask policies for HCW.[26]

CONCLUSION

In an already stressed healthcare system, it is unlikely a randomized clinical trial will be performed evaluating efficacy of universal facemask policies for healthcare workers in this pandemic. Given the ongoing COVID-19 epidemic, healthcare workers remain at risk of acquiring SARS-CoV-2 infection. This study supports the use of universal facemasks as part of a multi-tiered health system approach to reduce healthcare workers risk of acquiring COVID-19. This data adds support to the CDC's policy of wearing facemasks to reduce the spread of SARS-CoV-2.[29]

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