Original Article

Analysis of the Effects of COVID-19 Mask Mandates on Hospital Resource Consumption and Mortality at the County Level

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Objectives: Coronavirus disease 2019 (COVID-19) threatens vulnerable patient populations, resulting in immense pressures at the local, regional, national, and international levels to contain the virus. Laboratory-based studies demonstrate that masks may offer benefit in reducing the spread of droplet-based illnesses, but few data are available to assess mask effects via executive order on a population basis. We assess the effects of a county-wide mask order on per-population mortality, intensive care unit (ICU) utilization, and ventilator utilization in Bexar County, Texas.

Methods: We used publicly reported county-level data to perform a mixed-methods before-and-after analysis along with other sources of public data for analyses of covariance. We used a least-squares regression analysis to adjust for confounders. A Texas state-level mask order was issued on July 3, 2020, followed by a Bexar County–level order on July 15, 2020. We defined the control period as June 2 to July 2 and the postmask order period as July 8, 2020–August 12, 2020, with a 5-day gap to account for the median incubation period for cases; longer periods of 7 and 10 days were used for hospitalization and ICU admission/death, respectively. Data are reported on a per-100,000 population basis using respective US Census Bureau–reported populations.

Results: From June 2, 2020 through August 12, 2020, there were 40,771 reported cases of COVID-19 within Bexar County, with 470 total deaths. The average number of new cases per day within the county was 565.4 (95% confidence interval [CI] 394.6–736.2). The average number of positive hospitalized patients was 754.1 (95% CI 657.2–851.0), in the ICU was 273.1 (95% CI 238.2–308.0), and on a ventilator was 170.5 (95% CI 146.4–194.6). The average deaths per day was 6.5 (95% CI 4.4–8.6). All of the measured outcomes were higher on average in the postmask period as were covariables included in the adjusted model. When adjusting for traffic activity, total statewide caseload, public health complaints, and mean temperature, the daily caseload, hospital bed occupancy, ICU bed occupancy, ventilator occupancy, and daily mortality remained higher in the postmask period.

Conclusions: There was no reduction in per-population daily mortality, hospital bed, ICU bed, or ventilator occupancy of COVID-19-positive patients attributable to the implementation of a mask-wearing mandate.

Key Words: Bexar County, Texas, coronavirus, county, COVID-19, mask

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The first reports of coronavirus disease 2019 (COVID-19) caused by the severe acute respiratory syndrome coronavirus 2 were a cluster of pneumonia-like illnesses in Wuhan, China on December 31, 2019.[1] Only 100 days later, reports totaled 1.35 million confirmed cases of COVID-19 and 79,235 deaths among 211 countries and territories around the globe.[2] The rapidity of the spread of COVID-19 prompted governments to enact several countermeasures to slow its progression, including but not limited to border closures, school and nonessential business closings, quarantine restrictions, stay-at-home orders, social distancing directives, and the public use of face masks requirements.[3]

The public use of face masks or coverings to reduce the spread of COVID-19 infection is a contentious topic, primarily because there is a lack of strong evidence substantiating its effectiveness in real-world use. Initially, multiple systematic reviews of the existing literature concluded that there is insufficient evidence to demonstrate medical and cloth masks (not N95 and FFP2

Key Points

- On visual examination, cases continued to climb, despite implementing mask orders.
- We found no reduction in case burden because of the mask order, despite adjustments for measurable confounders.

[filtering facepiece] respirators) prevent infection.[4–10] Some of these studies, however, noted mechanistic evidence that medical and cloth masks may be effective for source control. This aspect of public mask wear is important because contagious individuals are asymptomatic or subclinical during the initial incubation period, and published reports demonstrate 50% to 78% of people infected with COVID-19 were found to be asymptomatic.[6,9–12] Subsequent simulation models found that mask wear is beneficial and survey studies suggested public acceptance of this nonpharmaceutical intervention.[13–16] The consensus among medical experts appears to support public mask wear because the potential benefits of source control outweigh the risks, despite the lack of strong evidence.[11,12,17–22]

To date, limited published data evaluating the effects of public mask wear on COVID-19 incidence demonstrate a significant, beneficial effect.[23–25] These studies, however, restricted their analysis to publicly reported COVID-19 infection rates without an evaluation of corresponding hospital resource utilization. Furthermore, the single study conducted in the United States excluded 35 states (among them Texas) because they did not have a statewide mandate for public mask wear during the study period.[23] Although the impetus behind the mandates and recommendations since the emergence of COVID-19 has been to "flatten the curve," meaning to prevent hospital capacity from being overwhelmed, studies have generally centered on cases, with the tacet assumption being that the cases theoretically prevented would be a representative sample including those who would ultimately become sickest.[26] This is not without basis in fact; a study examining cases versus case fatality proportion found them positively correlated, suggesting inversely that reducing cases could lead to a lower mortality.[27] Even so, explicitly examining hospital burden has, to our knowledge, not been done.

We performed a mixed-methods before-and-after analysis to assess whether implementation of a statewide mask mandate with further measures implemented at the county level had a measurable effect on hospital bed occupancy, ICU bed occupancy, ventilator occupancy, and/or mortality.

Methods

Ethics

Protocol H-20-032 was reviewed by the US Army Institute of Surgical Research regulatory office and determined exempt from institutional review board oversight because it used only publicly available, nonidentifiable data.

Subjects and Settings

This study examined Bexar County, Texas, which encompasses San Antonio along with several other surrounding cities. Texas has an estimated population of 28,995,881. The county has an estimated population of 2,003,554, with San Antonio estimated to be 1,547,253 (77.2% of the county) as of 2019. We used publicly available data for this analysis collected by the county and published online (http://covid19.sanantonio.gov; Table 1). This Web site publishes public health data with a focus on testing capacity, testing results, contact tracing, hospital trends (including admissions, ventilator use), deaths, and positivity, and uses these data to provide a public measure of hospital stress ranging from safe to moderate, steady, severe, and critical.

Table 1. Public data sources

Bexar County case data	http://covid19.sanantontio.gov
Texas state-wide case data	https://infection2020.com/
Traffic data	https://www.sanantonio.gov/SAPD/Calls
Weather data	https://www.wunderground.com
Census data	https://www.census.gov
Public health complaints	https://covid19.sanantonio.gov/About-COVID-19/Case-Numbers-Table-Data

Timeline of Events

The first case of COVID-19 in the United States was found on January 20, 2020 in the state of Washington.[28] Cases increased and spread throughout the country subsequently. In response to this, Texas Governor Greg Abbott issued an executive order declaring a state of emergency on March 13, 2020. Subsequent executive orders restricted the use of retail services (GA-18), hospital capacity utilization in preparation for an influx in COVID-19–infected patients (GA-19), and travelers coming into the state from certain high volume areas (GA-20). Per executive order GA-26, Texas entered phase 3 of the reopening on June 3, 2020 and has remained so as of September 5, 2020. Physical distancing measures were already in place before the mask order along with other capacity-limiting requirements. On July 2, 2020, Abbott released executive order GA-29, which put into effect a statewide mask mandate as of July 3, 2020, with a fine of up to $250 for noncompliance. In response to an increasing caseload within the county, Bexar County Judge Nelson Wolff issued executive order NW-13, effective July 15, 2020, which further restricted gatherings both indoors and outdoors, reinforced the penalty associated with noncompliance to the mask order, and additionally placed a fine of $1000 on businesses not enforcing the mask order. NW-13 expired on August 12, 2020.

Data Analysis

We performed the statistical analysis using Microsoft Excel version 10 (Microsoft, Redmond, WA) and JMP Statistical Discovery from SAS version 13 (SAS Institute, Cary, NC). We reported categorical variables as numbers with percentages, ordinal variables as medians with interquartile ranges, and continuous variables as means with confidence intervals. Data were analyzed on a per-100,000 population basis for the state, county, and city based on the data location. We performed least-squares regression modeling with adjustments as described. Significance was set at $P = 0.05$ and 95% confidence intervals (CIs) were used.

Table 2. Unadjusted comparison of the before and after mask order groups on a per-100,000 population basis

Variable	Before, mean (95% CI)	After, mean (95% CI)	P[a]
New cases	16.1 (11.2–21.0)	38.3 (22.4–54.3)	0.009
Hospital bed occupancy	18.8 (13.0–24.7)	50.5 (47.2–53.7)	<0.001
ICU bed occupancy	6.1 (4.4–7.8)	19.2 (18.4–20.1)	<0.001
Ventilator occupancy	3.1 (2.2–4.1)	13.0 (12.5–13.5)	<0.001
New deaths	0.06 (0.03–0.09)	0.58 (0.37–0.78)	<0.001

Caseload: June 2, 2020–July 2, 2020 and July 8, 2020–August 12, 2020. Hospital bed occupancy: June 2, 2020–July 2, 2020 and July 10, 2020–August 12, 2020. ICU/ventilatory occupancy/deaths: June 2, 2020–July 2, 2020 and July 13, 2020–August 12, 2020. CI, confidence interval; ICU, intensive care unit.

[a]*t test.*

We performed a series of mixed-methods before-and-after analyses related to these two mask orders assessing county-level hospital resource consumption. For this analysis, we defined the before period as 30 days before the implementation of the statewide order, from June 2, 2020 to July 2, 2020. We used a 5-day incubation period for overall caseload analysis (July 8, 2020–August 12, 2020).[29] We used a 7-day timeframe from implementation for the total hospitalization analysis (July 10, 2020–August 12, 2020). We used a 10-day incubation period for ICU bed occupancy and ventilator requirement (July 13, 2020–August 12, 2020).[29] Of note, physical distancing and service industry reduced capacity orders (reduced from 75% to 50%) were already in place before the mask order went into effect, based on executive order GA-28, issued on June 29, 2020 by Governor Abbott. The order also required that bars (<51% of sales from food) close.

Model Development

We used publicly reported data from the San Antonio Police Department (SAPD) for traffic calls as a surrogate for overall activity within the city, because changes in activity will likely lead to changes in overall exposure opportunity within the city. In addition, we used specific data reported daily from SAPD for calls relative to complaints of mask wear, physical distancing, and capacity violations as an indicator for overall policy adherence. Since San Antonio within Bexar County serves as a regional receiving center for more advanced care (eg, extracorporeal membrane oxygenation) and overflow from smaller hospitals, we used the total caseload within the remainder of the Southwest Texas Regional Advisory Council (STRAC; https://www.strac.org), which manages transfers throughout the region (eg, ventilator shortages in rural areas). The STRAC data were used as single variable with caseload modeled on a per-100,000 population basis using the county-level populations (Supplemental Digital Content Table 1, http://links.lww.com/SMJ/A237). Weather is reported to have an impact on COVID-19 as related to outdoor activity and heat.[30] As such, we used the daily mean temperature to control for this potential confounder.

Results

From June 2, 2020 through August 12, 2020 (71 days), there were 40,771 reported cases of COVID-19 within Bexar County, with 470 total deaths. At the state level during this period, there were 463,266 new cases reported. SAPD reported a total of 48,206 traffic calls and 5,404 public health violation calls. The average temperature was 84.5 °F/29.1 °C. The average number of new cases per day within the county was 565.4 (95% CI 394.6–736.2). The average number of positive hospitalized patients was 754.1 (95% CI 657.2–851.0), the number of patients in the ICU was 273.1 (95% CI 238.2–308.0), and number of patients on a ventilator was 170.5 (95% CI 146.4–194.6). The average deaths per day were 6.5 (95% CI 4.4–8.6). The volumes for new cases, hospital bed occupancy, ICU bed occupancy, and ventilator occupancy were generally upward trending, without any visually apparent effect from the mask orders (Supplemental Digital Content Figures 1–5, http://links.lww.com/SMJ/A236). All of the measured outcomes were higher on average in the postmask period, as were most covariables included in the adjusted model

Table 3. Comparison of covariance data before and after mask order periods on a per-100,000 population basis (based on respective populations)

Variable	Before, mean (95% CI)	After, mean (95% CI)	P[a]
STRAC-wide new cases less Bexar	9.6 (6.0–13.2)	29.4 (21.0–37.8)	<0.001
SAPD traffic calls	47.6 (43.8–51.4)	38.6 (35.6–41.5)	<0.001
SAPD public health complaints	3.3 (2.1–4.5)	6.1 (5.3–6.8)	<0.001
Mean temperature	82.3 (81.4–83.3)	85.8 (85.1–86.6)	<0.001

Timeframe: 02 June 2, 2020–July 2, 2020 and July 8, 2020–August 12, 2020. CI, confidence interval; SAPD, San Antonio Police Department; STRAC, Southwest Texas Regional Advisory Council.

[a]*t test.*

(Tables 2 and 3). When adjusting for traffic activity, total regional caseload (excluding Bexar County), public health complaints, and mean temperature, the daily caseload, hospital bed occupancy, ICU bed occupancy, ventilator occupancy, and daily mortality remained higher in the postmask period (Table 4).

Discussion

We performed a before-and-after analysis of a countywide mandate for public mask use on rates of COVID-19 infection, mortality, ICU utilization, and ventilator utilization. We found that in both unadjusted and adjusted assessments, the caseload for all of the measured outcomes increased after the mask orders went into place. On visual assessment (Supplemental Digital Content Figures 1–5) there appeared to be no readily apparent effect in reducing the resource consumption after implementation of the mask order. Our findings suggest that mask orders alone cannot be expected to mitigate the spread of COVID-19.

To date, there are limited data on the effectiveness of public mask wear regarding COVID-19 infection rates.[23,24] Lyu et al compared public data for COVID-19 infection rates pre- and poststatewide mandates for public use of masks in the United States; among 15 states and the District of Columbia issuing governmental requirements for public mask wear from April 8 to May 15, 2020, they found a significant reduction in county-level COVID-19 infection rates of 0.9% to 2.0% ($P < 0.05$ for all).[23] They also evaluated the same outcome among 20 states that issued directives for mask use among business employees, but not among the public. This analysis revealed no benefit to mask utilization.[23] The state of Texas was not included in either analysis because it had not issued a statewide mandate for mask use in public or among business employees. We found no effect at the county level. Early in the course of the COVID-19 pandemic, there were concerns about a sudden influx of patients overwhelming hospital resources resulting in a situation in which limited resources such as ventilators must be rationed.[31–33] Unlike their

Table 4. Comparison of before and after on least squares regression with model adjustment for statewide caseload, SAPD traffic call volume, SAPD public health complaints, and mean daily temperature

Outcome	Before, LSM (SE)	After, LSM (SE)	P^a	Effect test[b]
Daily case load	23.48 (7.92)	32.05 (7.16)	0.033	0.492
Temperature				0.609
Traffic calls				0.615
Public health calls				0.093
STRAC volume				0.414
Hospital occupancy	23.66 (2.14)	46.14 (2.01)	<0.001	<0.001
Temperature				0.008
Traffic calls				0.020
Public health calls				<0.001
STRAC volume				0.724
ICU bed occupancy	7.41 (0.60)	18.02 (0.60)	<0.001	<0.001
Temperature				0.036
Traffic calls				0.045
Public health calls				<0.001
STRAC volume				0.815
Ventilator occupancy	3.72 (0.35)	12.46 (0.35)	<0.001	<0.001
Temperature				0.142
Traffic calls				0.023
Public health calls				<0.001
STRAC volume				0.965
Daily mortality	0.19 (0.08)	0.45 (0.08)	<0.001	0.066
Temperature				0.079
Traffic calls				0.011
Public health calls				0.540
STRAC volume				0.465

Caseload: June 2, 2020–July 2, 2020 and July 8, 2020–August 12, 2020. Hospital bed occupancy: June 2, 2020–July 2, 2020 and July 10, 2020–August 12, 2020. ICU/ventilatory occupancy/deaths: June 2, 2020–July 2, 2020 and July 13, 2020–August 12, 2020. ICU, intensive care unit; LSM, least square mean; SAPD, San Antonio Police Department; SE, standard error; STRAC, Southwest Texas Regional Advisory Council.

[a] *Based on analysis of variance.*

[b] *Probability, first line is mask order group.*

analysis, which focused on overall caseload, we used county-level data with more granularity, including resources such as ventilator and ICU bed use.[2] We did not detect a decrease in hospital resource consumption, which was the primary reason for implementing measures targeted at limiting the rapid influx (ie, methods sought to flatten the influx curve).

Cheng et al compared COVID-19 infection rates within Hong Kong with other areas of the world from day 1 (December 31, 2019) to day 100 (April 8, 2020) of the outbreak.[24] They reported a significantly lower incidence of COVID-19 in Hong Kong than 8 other countries, including the United States ($P < 0.001$).[24] They attributed this finding to public mask wear within Hong Kong, which they reported to be 95.7% to 97.2% as directly measured by 67 hospital staff over a period of 3 days.[24] They suspect the Hong Kong public's compliance with universal mask wear (although not dictated by the Hong Kong government) was the result of the city's experience with the 2003 severe acute respiratory syndrome outbreak and the assumption that COVID-19 was as lethal.[24] It should be noted that Hong Kong is 570 miles from Wuhan, China, has a population of 7.45 million, has a population density of 6700 individuals per square kilometer, and experiences an average of 170,000 travelers entering and departing the city daily.[24] The size, location, and population are far different from Bexar County, thus limiting the ability to extrapolate their findings to Texas. We were unable to compare our county findings to other counties that were exempt from the mask order by virtue of the low incidence within those counties. Such an analysis would add further to this limited body of literature.

Our analysis, like the previously discussed studies, is a natural difference-in-differences experiment, which may be considered a lower level of evidence within evidence-based medicine.[34] Natural experiments, however, are both necessary and useful as the availability of both control and experimental study groups for an intervention such as public mask wear with public health–oriented outcome measures would be difficult to create and, as a result, likely suffer from a lack of external validity.[35] Consequently, findings of natural experiment studies should be considered by policy makers when deciding which nonpharmaceutical public health measures are appropriate in the setting of infectious disease pandemics. Bexar County represents a unique opportunity for attempting to identify a discrete effect of a mask order, because most other established means of control (eg, social distancing recommendations, availability of testing) had already been in place for months and did not meaningfully change during the study period.

We have several limitations to our study that we must acknowledge. First, we are only assessing the effect of the mask order itself. In other words, we are not able to assess the actual mask use because we do not have data on adherence to the mask order. Although we adjusted our model for public health complaint calls, we do not have a direct measure of wear. Second, we performed model adjustment based on local caseload to account for local caseload changes. Because many San Antonio hospitals serve as regional receiving centers for the offloading of cases from smaller hospitals along with regional support for extracorporeal membrane oxygenation capabilities, we have no way to determine what volume of the ICU and ventilator use was attributable to transfers.[36] Although obesity has been identified as a risk factor for COVID mortality and cannot be adjusted for in our study, the overweight and obese proportion in Bexar County (71%) is similar to that of national proportions (66%).[25,37,38] It also is possible that the mask order had a hypothetical effect in slowing the rate of increase of the various burden metrics; if this were the case, then implementing an order earlier may have a greater impact on the hospital burden in terms of the daily increase in caseload without affecting the total caseload. Conversely, the mask order may be extraneous, and the disease may follow a typical progression in spite of it (eg, application of Farr's law).[39] It also is possible that the order did not meaningfully alter mask utilization patterns because mask use was not novel in San Antonio or Bexar County. Lastly, given that we used only publicly available data and did not have patient-level data including transfer status or comorbidities, it is not possible to perform substratified analysis regarding any demographic or medical specifics to determine whether the mask order had meaningful effects on one or more subgroups.

Conclusions

We were unable to detect a reduction in per-population daily mortality, hospital bed, ICU bed, or ventilator occupancy attributable to the implementation of a mask order.

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