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INCLUSIVITY IN PEOPLE, METHODS, AND OUTCOMES

RESEARCH ARTICLE

## The COVID-19 Pandemic's Effect on Preventive Imaging



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**Introduction:** This study assessed the effect of the COVID-19 pandemic on preventive care imaging and potential disparities because preventive care may be perceived as nonurgent. The objective was to identify the associations between the COVID-19 pandemic and changes in preventive imaging volumes for patients in general and as affected by race and ethnicities.

**Methods:** The authors performed a retrospective observational study by extracting the weekly volumes of all imaging studies between January 7, 2019 and May 1, 2022 from a radiology data warehouse at a tertiary care medical center ( $n=92,105$  preventive imaging studies and 3,493,063 total radiology imaging studies) and compared preshutdown with postshutdown periods using a 2-sample *t*-test. Additional comparisons stratified by race and ethnicity were performed for mammograms and bone density examinations using interrupted time series models with negative binomial error distribution to assess the immediate level change and trends over time of preventive imaging volumes after shutdown.

**Results:** The authors found a significant decrease in bilateral mammograms, bone density examinations, and aortic ultrasound examinations in the postshutdown period compared with those in the preshutdown period ( $p<0.001$ ,  $p=0.003$ , and  $p=0.001$ , respectively). There were no significant changes in low-dose computed tomography chest examinations ( $p=0.46$ ). The shutdown was associated with a significant immediate decrease in mammograms in the Hispanic and Latino group to approximately three quarters of its preshutdown level ( $p=0.04$ ). For bone density examinations, postshutdown weekly volumes tripled compared with the preshutdown volumes for Hispanic or Latino patients and doubled for non-Hispanic Black patients ( $p<0.0001$  for both). In comparison, a significant decrease was seen for Other patients (reduced to nearly a fifth of preshutdown volume) ( $p<0.0001$ ).

**Conclusions:** There was a significant decrease in overall volume of bilateral mammograms, bone density examinations, and aortic ultrasound examinations after pandemic shutdown. For mammograms, some of this decreasing trend was already seen before shutdown (such as for patients with Other race), so the shutdown was only specifically associated with an immediate decrease in

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mammogram levels in the Hispanic and Latino group. For bone density examinations, the shut-down was unexpectedly associated with an increase in volumes for Hispanic or Latino patients and non-Hispanic Black patients, which was countered by a significant steep decrease in volumes only for patients of Other race. Health systems should carefully explore their preventive screening examination volumes to determine which patients should be actively engaged to assure catch up on recommended care.

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## INTRODUCTION

In 2020 in the U.S., federal, state, and local governments enacted public health measures in response to the precipitous spread of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) virus that strained the resources, medical supplies, and staff of healthcare organizations, medical offices, and nursing homes.<sup>1</sup> The pandemic's effect extended beyond the morbidity and mortality from coronavirus disease 2019 (COVID-19) to employment, commerce, and the economy.<sup>2</sup> The expressed goal of public health measures, such as closures of schools and businesses not deemed essential, was to reduce or slow down further transmissions.<sup>3,4</sup>

Concurrently, healthcare systems responded to the COVID-19 pandemic with rapid expansion of telemedicine services.<sup>5-7</sup> Although telemedicine provided essential services to patients during the pandemic, it further aggravated existing discrepancies in healthcare access.<sup>8</sup> Because minority groups such as older, rural, Asian, Black/African American, and Hispanic/Latino patients and patients with a lower socioeconomic status use telemedicine less, existing discrepancies in access to care were further exacerbated during the pandemic.<sup>9</sup> Telemedicine also reduced diagnostic testing because it requires the physical presence of a patient in a healthcare setting such as a radiology or phlebotomy suite.

The pandemic negatively affected radiology and laboratory services through clinical practice disruptions, a perceived workload increase due to an increase of patients with COVID-19, and the need to adhere to infection protocols.<sup>10</sup> Increased burnout among radiographers was another reported effect of the pandemic.<sup>11</sup> The pandemic caused a global decrease in imaging volumes such as cardiac imaging,<sup>12</sup> cancer imaging,<sup>13</sup> emergency department imaging,<sup>14</sup> and nuclear medicine imaging.<sup>15</sup> Furthermore, the U.S. saw substantial reductions in procedures used to diagnose cancer because of the COVID-19 pandemic.<sup>16</sup>

Preventive or screening imaging services are services with a high or moderate net benefit for patients that the U.S. Preventive Services Task Force recommends most

highly for implementation in preventive care.<sup>17</sup> Preventive studies include screening mammograms for breast cancer, aortic ultrasounds screening for aneurysm, low-dose chest computed tomography (CT) for lung cancer screening, and bone density testing for osteoporosis screening.

Modeling predicted an excess of 10,000 deaths related to breast and colorectal cancer in the U.S. over the next 10 years owing to pandemic-related reduction in therapy and screening.<sup>18</sup> Another study predicted an increase of cancer-related deaths by 7.9%–9.6% for breast cancer and 4.8%–5.3% for lung cancer in the United Kingdom over 5 years.<sup>19</sup> The authors hypothesized that the COVID-19 pandemic restrictions resulted in a greater reduction of preventive imaging in the healthcare system than of other imaging studies. Because patients eligible for screening examinations are often asymptomatic, providers might perceive these screening tests as nonurgent and eligible for delays during a public health crisis. The authors performed an inferential statistical analysis to identify the preventive screening trends associated with the pandemic to determine the effect on the healthcare system and to identify potential opportunities to mitigate reduction in preventive imaging and the resulting preventable morbidity and mortality.

## METHODS

### Study Sample

For this retrospective observational study, the authors used weekly imaging volumes for a tertiary care medical center in Texas for 3 periods: (1) January 7, 2019 to March 15, 2020 (434 days) as the preshutdown period; (2) March 16, 2020 to May 9, 2020 (55 days) as the shutdown period; and (3) May 10, 2020 to May 1, 2022 (722 days) as the postshutdown period. These dates were selected on the basis of events during the pandemic in Texas: on March 13, 2020, the Texas governor declared a statewide public health disaster, and on March 19, 2020, the governor issued an executive order that limited social gatherings to 10 people, prohibited eating and drinking at restaurants and bars, closed gyms, and

temporarily closed schools.<sup>20,21</sup> Reopening occurred gradually starting from May 1, 2020, when Texas restaurants, retail outlets, and movie theaters were allowed to reopen at 25% capacity. On May 5, 2020, the Texas governor announced that hair salons and public pools would reopen on May 8 and fitness centers on May 18.<sup>20</sup>

### Measures

The authors defined preventive imaging studies to include all screening bilateral mammograms, bone density examinations, low-dose CT chest examinations, and aortic ultrasounds. The authors excluded unilateral mammograms to avoid the risk of biasing the study with nonscreening modalities because they were commonly utilized for surveillance or follow-up for breast cancer or other abnormal findings. The breakdown of the study population is illustrated in [Appendix Table 1](#) (available online). This study was approved by an IRB (IRB Number STU-2021-0444).

### Statistical Analysis

For all study periods, the authors extracted the weekly volume for (1) all preventive imaging studies included in the study and (2) all imaging performed in the tertiary care medical center from the radiology data warehouse. The sum of all weekly volumes across all 3 study periods amounted to 92,105 preventive imaging studies and 3,493,063 total radiology imaging studies in the analysis. The authors normalized the weekly volumes for each preventive imaging study to the weekly volumes of total radiology imaging by simple division. The authors compared the preshutdown with the postshutdown weekly volumes using a 2-tailed, unequal variance *t*-test using Excel, Version 16.74 (Microsoft, Redmond, WA). Data preprocessing and graphical visualization were accomplished using Python, Version 3.9.12 (Python Software Foundation, Wilmington, DE). The locally weighted scatterplot smoothing method was used to create smoothed curves for graphs.

For the demographics-based analyses, patients were grouped by race and ethnicity from electronic health record data into Hispanic or Latino, non-Hispanic Black, non-Hispanic White, and Other. Patients were categorized as Hispanic or Latino if their ethnicity was documented as Hispanic or Latino, with any combination of race. Patients were categorized as non-Hispanic Black or non-Hispanic White if their ethnicity was documented as neither Hispanic nor Latino and they had documentation of only a single race (Black or White, respectively). All other patients were categorized as Other. Race data from more recent imaging examinations were used to backfill race data (if unknown) for a patient's prior study. Interrupted time series models

(with negative binomial error distribution) were used to test the immediate level change and slope change of preventive imaging volumes. Time (months since January 2019) was used as a continuous variable. Two-way interactions between the COVID-19 period and race–ethnicity and 3-way interactions between the COVID-19 period, race–ethnicity, and time were used to estimate race–ethnicity-specific intercepts and slopes as well as the corresponding level change and slope change. Owing to the log link function in negative binomial regression, all changes are ratios of the estimates. Additional covariates, to adjust for potential confounders, included the weekly number of positive COVID-19 tests (0 for preshutdown period and log transformed for postshutdown period) during the week of the imaging examination and 1 and 2 weeks after the examination.

The authors counted weekly imaging volumes from Monday through Sunday and weekly positive COVID-19 tests from Sunday through Saturday. The same model was applied to bone density and mammogram data, respectively. All analyses were done in SAS 9.4 (SAS Institute, inc., Cary, NC).

## RESULTS

In the preshutdown period, the weekly average volume (and SD) for bilateral mammograms, bone density examinations, low-dose CT chest examinations, and aortic ultrasound examinations were 408.0 (77.3), 166.8 (44.2), 9.3 (3.5), and 13.1 (3.7) examinations per week, respectively. In the postshutdown period, the weekly average examination volumes (and SD) for bilateral mammograms, bone density examinations, low-dose CT chest examinations, and aortic ultrasound examinations were 347.7 (116.9), 155.8 (44.2), 9.9 (6.0), and 11.3 (4.7), respectively. The resulting percentage change in weekly average volumes for the preventive screens mentioned earlier between pre- and postshutdown periods were therefore –14.8%, –6.6%, +6.1%, and –13.8%, respectively. In comparison, the weekly average volumes (and SD) for total radiology imaging studies were 20,628.0 (1198.9) before shutdown and 20,600.1 (2896.7) after shutdown, demonstrating a –0.1% percent change ([Table 1](#)). The authors present smoothed curves to visualize the weekly change in volume in the preventive screening examinations and total radiology examinations over time in [Figure 1](#).

Normalized average weekly preventive screen volumes to total weekly radiology studies demonstrated a significant decrease in bilateral mammograms, bone density examinations, and aortic ultrasound examinations in the postshutdown period compared with those in the preshutdown period ( $p < 0.001$ ,  $p = 0.003$ , and  $p = 0.001$ ,

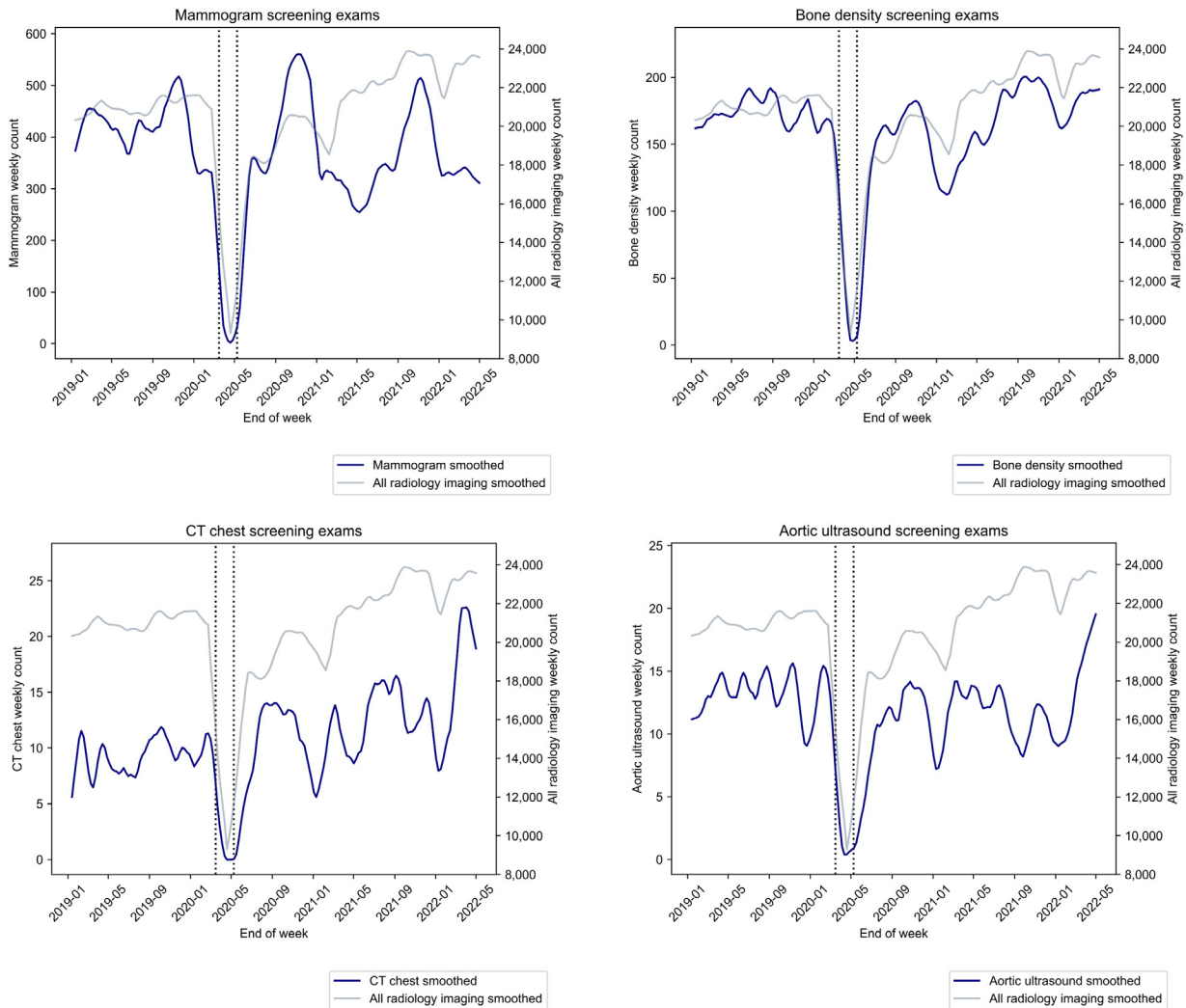
**Table 1.** Weekly Volumes of Preventive Imaging and All Radiology Studies During Preshutdown and Postshutdown Periods

Type of imaging study	Preshutdown		Postshutdown		Percentage change	p-value
	Average	SD	Average	SD		
Preventive imaging studies						
Bilateral mammogram	408.0	77.3	347.7	116.9	-14.8%	<b>&lt;0.001</b>
Bone density	166.8	44.2	155.8	44.2	-6.6%	<b>0.003</b>
CT chest	9.3	3.5	9.9	6.0	6.1%	0.463
Aortic ultrasound	13.1	3.7	11.3	4.7	-13.8%	<b>0.001</b>
All radiology studies	20,628.0	1,198.9	20,600.1	2,896.7	-0.1%	

Note: Boldface indicates statistical significance ( $p < 0.05$ ).

respectively). There were no significant changes in low-dose CT chest examinations between pre- and postshutdown periods ( $p=0.46$ ) (Table 1).

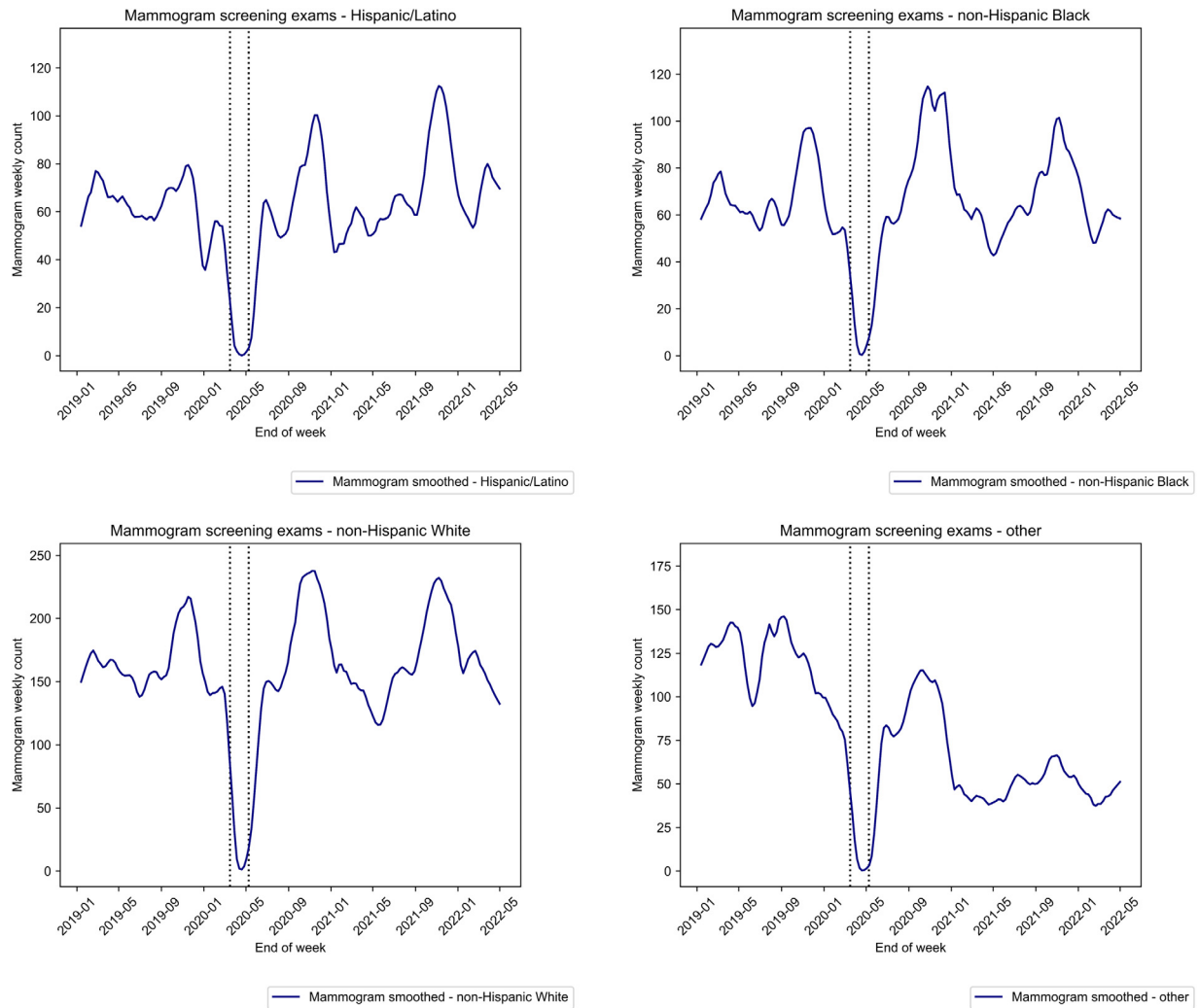
For mammograms and bone density examinations, the authors analyzed race and ethnicity categories to assess whether the pandemic-related shutdown was



**Figure 1.** Smoothed curves of weekly volumes of preventive imaging and all radiology studies during before and after shutdown periods.

The dotted bars in the graphs divide preshutdown (before March 16, 2020) from postshutdown (after May 9, 2020) periods.

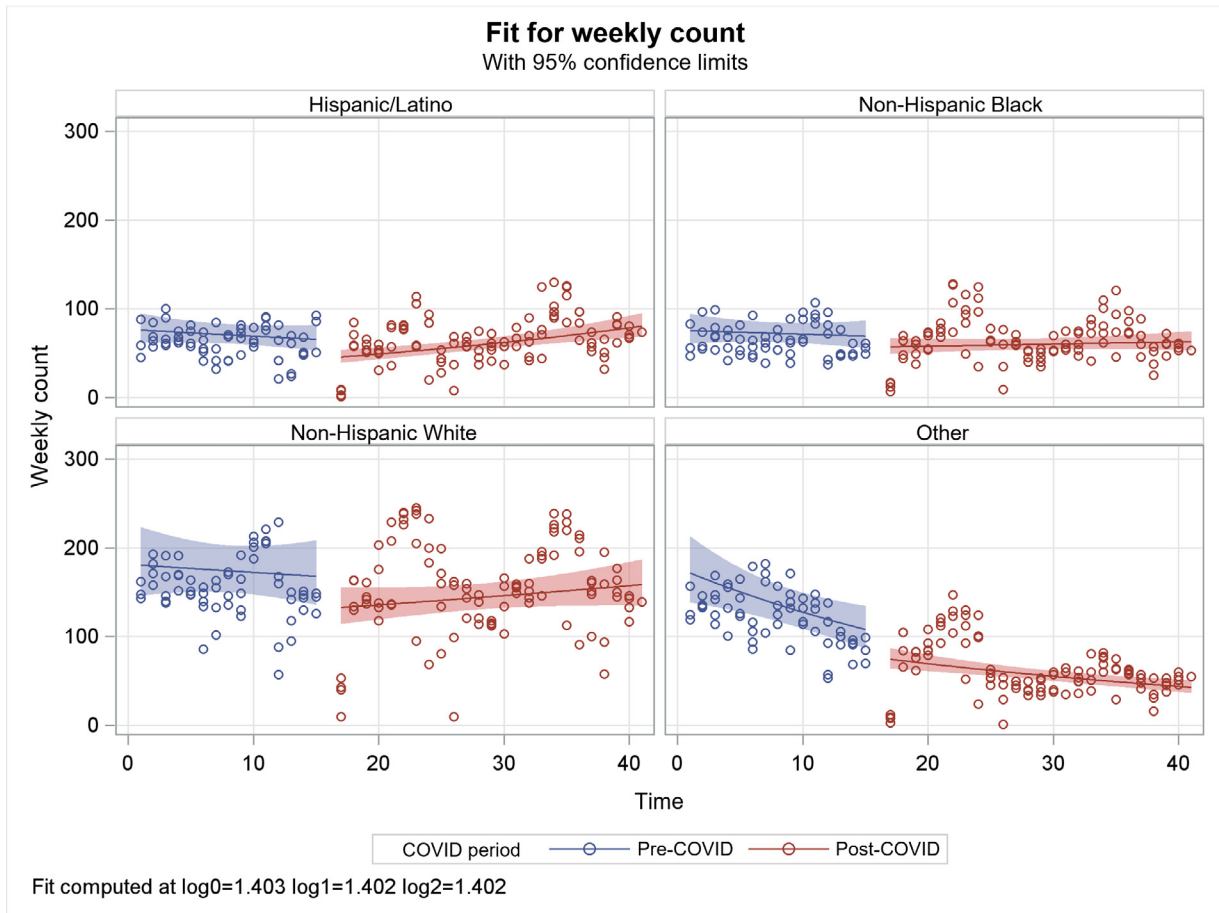
CT, computed tomography.



**Figure 2.** Smoothed curves of weekly volumes of mammograms by race and ethnicity status for pre- and postshutdown periods. The dotted bars in each graph divide preshutdown (before March 16, 2020) from postshutdown (after May 9, 2020) periods.

associated with differences in preventive imaging studies for these groups. The authors present smoothed curves of the weekly change in mammogram volumes in Figure 2. Level and slope changes in weekly volume of preventive imaging studies were assessed using interrupted time series models with negative binomial error distribution (Figure 3). The number of positive COVID-19 tests adjusted by 0, +1, or +2 weeks were included as covariates to account for potential confounding effects. For mammograms, immediate postshutdown volumes were comparable with preshutdown volumes for non-Hispanic Black and non-Hispanic White patients ( $p=0.28$  and  $p=0.17$ , respectively). There was a trend toward decreased postshutdown volumes for patients with Other race, which did not quite reach statistical significance ( $p=0.06$ ). However, for Hispanic or Latino patients, there was an immediate decrease in volume levels after the shutdown to approximately three

quarters of its preshutdown level and an increasing trend over time after shutdown ( $p=0.04$  and  $0.006$ , respectively) (Figures 2 and 3 and Table 2). For bone density examinations, the authors present smoothed curves of the weekly change in volumes in Figure 4 and interrupted time series models in Figure 5. Weekly volumes tripled after the shutdown for Hispanic and Latino patients and doubled for non-Hispanic Black patients ( $p<0.0001$  for both), whereas patients categorized as Other race show a significant, steep decrease in screening levels after shutdown to approximately a fifth of preshutdown volumes ( $p<0.0001$ ) (Figures 4 and 5 and Table 3). Hispanic and Latino patients and patients categorized as Other race showed a statistically significant increase in volume trend over time after shutdown ( $p=0.02$  and  $0.001$ , respectively) (Figures 4 and 5 and Table 3). Of those with Other race, those with a race of null comprised most of these cases



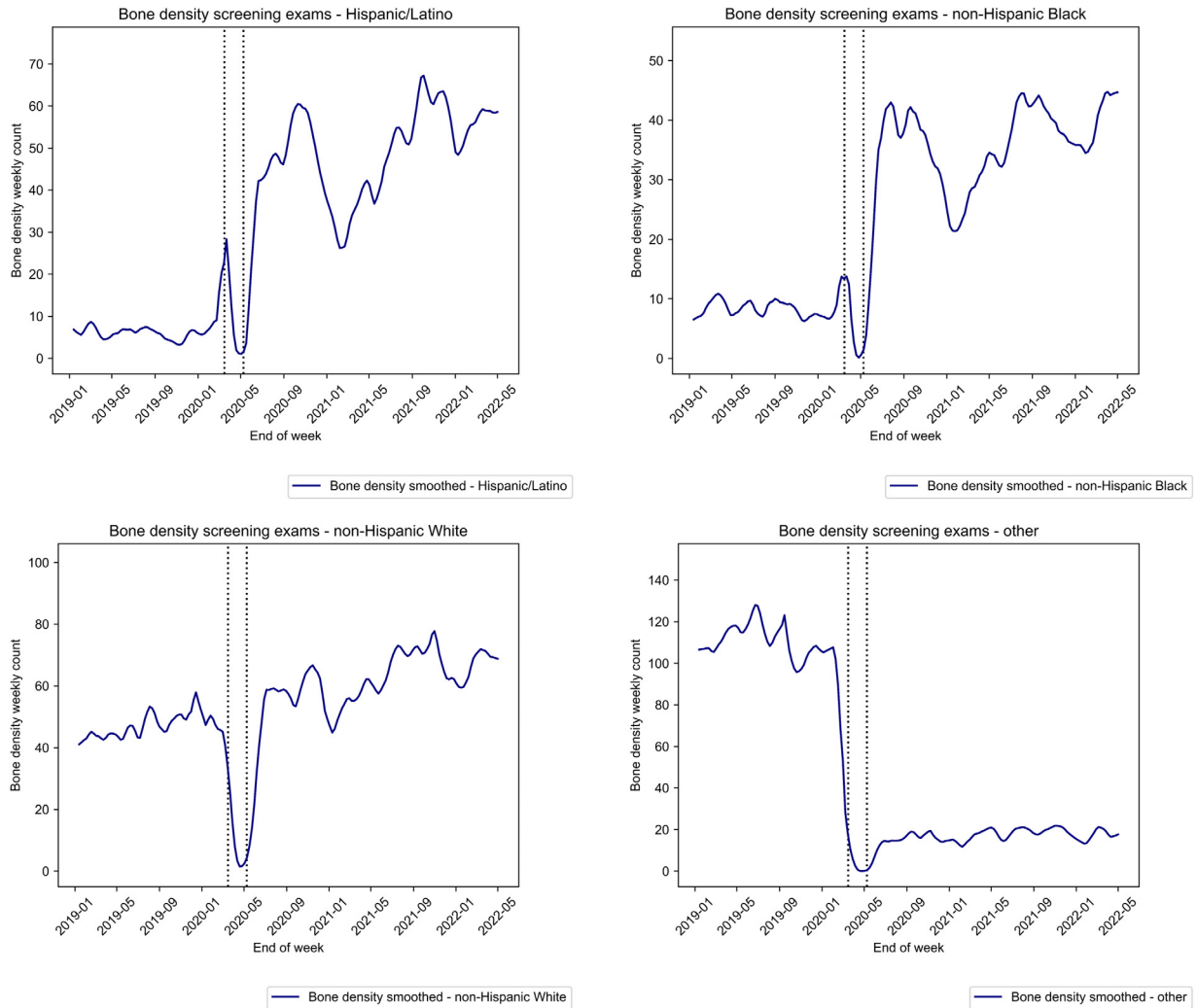
**Figure 3.** Interrupted time series analysis for weekly volumes of mammograms by race and ethnicity.

The Hispanic or Latino group showed an immediate decrease in volume after shutdown to approximately three quarters of its preshutdown volume, with an increasing volume trend over time. There was also a trend toward decreased volume for patients categorized as Other race after shutdown, which did not quite reach statistical significance. The gap in each graph separates preshutdown (before March 16, 2020) from postshutdown (after May 9, 2020) periods.

**Table 2.** Ratio of Means and Confidence Limits Associated With Interrupted Time Series Analysis of Weekly Volumes of Mammograms by Race and Ethnicity

Race and ethnicity	Ratio of means	95% confidence limits		p-value
Level change				
Hispanic or Latino	0.71	0.52	0.99	<b>0.04</b>
Non-Hispanic Black	0.84	0.6	1.16	0.28
Non-Hispanic White	0.8	0.58	1.1	0.17
Other	0.74	0.53	1.02	0.06
Slope change				
Hispanic or Latino	1.03	1.01	1.06	<b>0.006</b>
Non-Hispanic Black	1.01	0.99	1.04	0.42
Non-Hispanic White	1.01	0.99	1.04	0.30
Other	1.01	0.99	1.04	0.42

Note: Boldface indicates statistical significance ( $p < 0.05$ ).



**Figure 4.** Smoothed curves of weekly volumes of bone density scans by race and ethnicity status for before and after shutdown periods.

The dotted bars in each graph divide preshutdown (before March 16, 2020) from postshutdown (after May 9, 2020) periods.

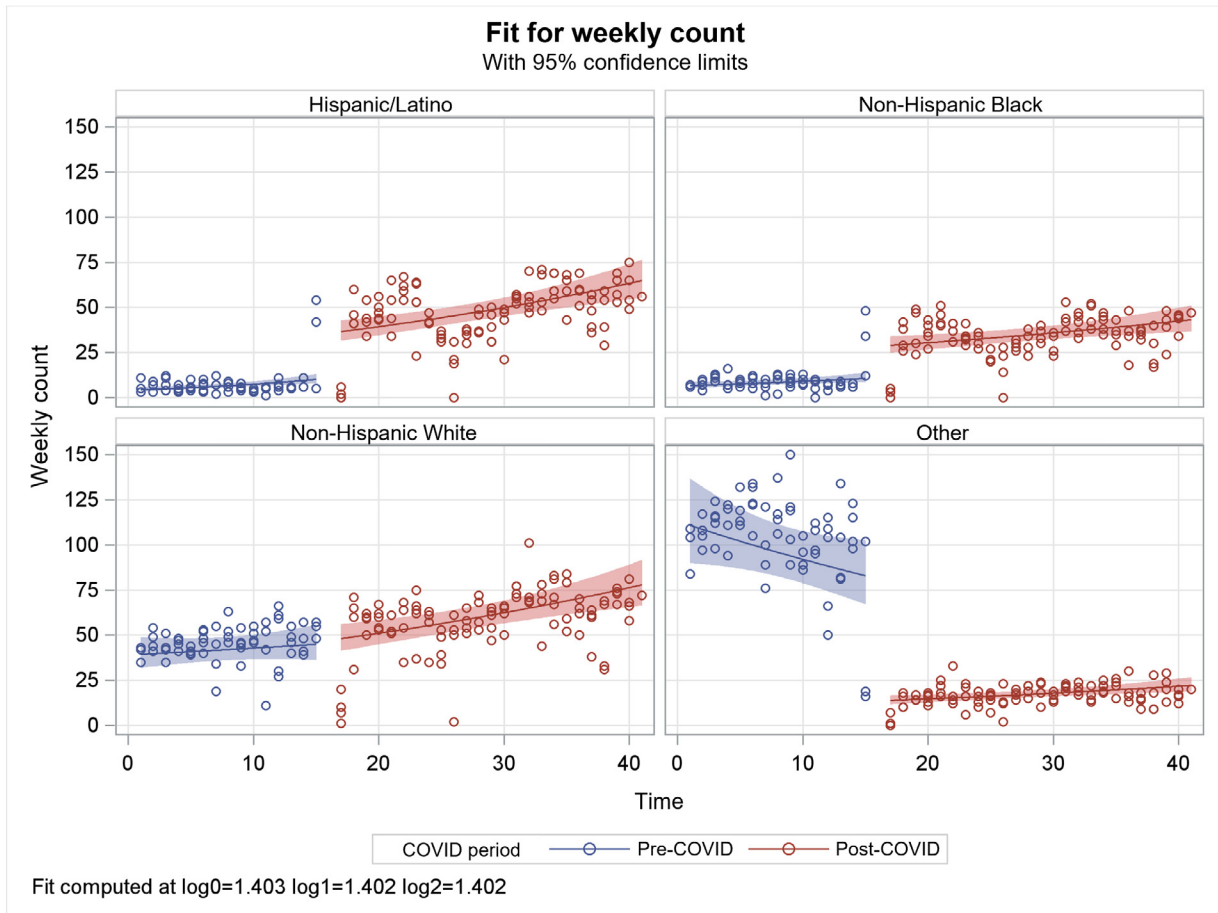
(80.9%) (data not shown). The weekly volume of positive COVID-19 tests did not have a significant effect on weekly preventive imaging volumes between race and ethnicity categories (data not shown). Demographic-based analyses on low-dose chest CT and aortic ultrasounds were not performed owing to insufficient weekly volumes per race and ethnicity category for robust statistical analysis.

## DISCUSSION

At the authors' tertiary care medical center, the COVID-19 pandemic and the resulting public health measures and restrictions were associated with a significant decrease in volume for 3 of 4 preventive imaging studies with known high or moderate net value. After the state

government's mandated shutdown, bilateral mammograms had the greatest decrease (14.8%) in weekly imaging studies than the preshutdown weekly volumes, followed by aortic ultrasound and then bone density examinations. This mirrors the findings of another study that reported screening mammography and bone density (DEXA) scans as having the largest initial decreases in volume among radiology studies during the pandemic at 6 academic medical systems.<sup>22</sup>

The authors found a small increase of 6.1% in low-dose CT chest examinations. Future study may examine whether this increase was a result of incidental findings on lung imaging of patients who presented with COVID-19-related symptoms during the pandemic necessitating imaging. Normalizing each preventive screening examination to total radiology imaging



**Figure 5.** Interrupted time series analysis for weekly volumes of bone density scans by race and ethnicity.

Hispanic and Latino and non-Hispanic Black patients show a significant immediate increase in screening levels after shutdown (triple and double preshutdown levels, respectively), whereas patients categorized as Other race show a significant immediate decrease in screening levels to approximately one fifth of preshutdown volumes. Hispanic and Latino patients and patients categorized as Other race show a significant increase in volume trend over time after shutdown. The gap in each graph separates preshutdown (before March 16, 2020) from postshutdown (after May 9, 2020) periods.

**Table 3.** Ratio of Means and Confidence Limits Associated With Interrupted Time Series Analysis of Weekly Volumes of Bone Density Scans by Race and Ethnicity

Race and ethnicity	Ratio of means	95% confidence limits		p-value
Level change				
Hispanic or Latino	3.19	2.24	4.55	<0.0001**
Non-Hispanic Black	2.52	1.77	3.59	<0.0001**
Non-Hispanic White	1.05	0.76	1.44	0.76
Other	0.17	0.13	0.24	<0.0001**
Slope change				
Hispanic or Latino	0.96	0.94	0.99	0.02*
Non-Hispanic Black	0.98	0.95	1.01	0.23
Non-Hispanic White	1.01	0.99	1.03	0.38
Other	1.04	1.02	1.07	0.001*

Note: Boldface indicates statistical significance (\* $p < 0.05$  and \*\* $p < 0.0001$ ).



examinations and performing a 2-tailed, unequal variance *t*-test demonstrated a statistically significant decrease in bilateral mammograms, bone density examinations, and aortic ultrasounds from the pre- to post-shutdown period. This suggests that the preventive screening examinations mentioned earlier underwent a significant drop in volume in comparison with total radiology examinations after shutdown, which are predominantly composed of diagnostic examinations such as those requested by the emergency department and inpatient teams. This effect may be due to the perception that in comparison with diagnostic examinations, preventive examinations were nonurgent and eligible for delays. There was no statistically significant change in low-dose CT chest examinations after normalization, similar to another study that found relatively unchanged lung cancer screening rates in 25 states in the U.S. in 2019–2020, suggesting that this trend may be in part due to underutilization of prepandemic screening.<sup>23</sup>

In the study population, there was no significant difference in levels of weekly mammogram screening volumes between pre- and postshutdown periods among the different race and ethnicity categories with the exception of the Hispanic and Latino group, which showed a statistically significant decrease to three quarters of its preshutdown level. Although Other patients also showed a trend toward a decreased level, it did not reach statistical significance, likely because the volumes were already beginning to decrease before shutdown. For weekly bone density screening volumes, there was an unexpected significant increase for Hispanic and non-Hispanic Black patients but a significant steep decrease for Other patients. These included patients for whom race was null, unavailable/unknown, declined, Asian, American Indian or Alaska Native, or some other race or those who had multiple races documented and were not ethnically Hispanic or Latino. Although the underlying cause for these findings is unknown, the authors speculate that patients whose race was null or unavailable/unknown may represent a population for whom documentation in the health system is poor overall and who have fewer interactions with the health system, making them potentially more vulnerable to care gaps. Of note, demographic-based analyses in the literature typically exclude null or unavailable/unknown race data. In this study, this group appears to be the driver for decreases in bone density examination volumes in the postpandemic shutdown period. It is possible that by excluding these groups from demographic-based analyses, important trends may be overlooked. Further study is warranted in other populations to assess this possibility and the practical and clinical implications of these

findings. To the authors' knowledge, this study provides the first analysis of the impact of the pandemic on race and ethnicity trends in bone density (DEXA) scans in the literature.

The number of total positive COVID-19 tests was not associated with a significant difference in the screening volumes among the different race and ethnicity categories.

### Limitations

A limitation of these analyses is the fact that race and ethnicity data obtained from the electronic health record can be incomplete and/or subject to changing documentation practices. Furthermore, this study was limited to a single academic center, which may make generalization difficult.

## CONCLUSIONS

In conclusion, the COVID-19 pandemic was associated with a significant decrease ( $p=0.001$ ,  $0.003$ , and  $<0.001$ ) in multiple preventive imaging studies at a tertiary care medical center in Texas. This study also provides the first evidence for race- and ethnicity-based differences in the effect of the pandemic on bone density screens. Given that the threat of COVID-19 has overall decreased from its apogee, it may be warranted for health systems to revisit their preventive screening examinations to determine which patients should be actively engaged for follow-up care.

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## CREDIT AUTHOR STATEMENT

Jenny L. Weon: Visualization, Methodology, Data curation, Writing – second draft, Writing - review & editing. Yin Xi: Formal analysis, Writing – review & editing. Yee Seng Ng: Formal analysis, Writing – review & editing. Lauren N. Cooper: Visualization, Data curation, Writing – review & editing. Marlon I. Diaz: Writing – review & editing. Robert W. Turer: Writing - review & editing. Samuel A. McDonald: Writing – review & editing. DuWayne L. Willett: Writing – review & editing. Christoph U. Lehmann: Conceptualization, Writing – review & editing. Ling Chu: Conceptualization, Writing – original draft, Writing – review & editing.

## SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at [doi:10.1016/j.focus.2024.100270](https://doi.org/10.1016/j.focus.2024.100270).

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