**The Role of SHIELD Test Centers in Reducing COVID-19 ICU Admissions in Disadvantaged Communities**

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**Abstract**

**Background**

The COVID-19 pandemic, particularly with variants Alpha, Delta, and Omicron, presented major challenges in managing severe cases. Disadvantaged communities were disproportionately affected, especially during the Delta and Omicron waves. SHIELD Illinois, a statewide saliva-based testing program, aimed to increase testing access, but its impact on COVID-19 outcomes in these communities remains unclear. This study investigates the impact of SHIELD test centers on the rate of COVID-19 admissions to intensive care units (ICUs) in the communities they serve, with a particular focus on the socioeconomic factors of these communities in the greater Chicago area.

**Method**

We conduct a secondary analysis using data from the Electronic Health Record (EHR) system of a large quaternary care medical center in western Chicago suburb and the SHIELD Illinois Testing Program, covering the Alpha (March–June 2021), Delta (August–November 2021), and Omicron (December 2021–March 2022) waves. A linear mixed-effects regression model and robustness check assess the relationship between SHIELD test center availability and ICU admissions, adjusting for SHIELD center density and area deprivation index scores.

**Result**

Increasing SHIELD centers during Omicron is associated with a reduction in ICU admissions. A lag analysis further confirms that enhanced SHIELD center effectiveness leads to lower ICU admission rates, with an even more pronounced reduction in disadvantaged communities.

**Conclusion**

These findings highlight the importance of strategically deploying SHIELD test centers to reduce severe outcomes and ensure equitable healthcare responses in future pandemics.

**Keywords**

SHILED Illinois; COVID-19 ICU admission; Socioeconomic disparities; Linear mixed-effect model; Pandemic response strategies

**Background**

The World Health Organization declared COVID-19 a pandemic on March 11, 2020, and since then, it has caused over 7 million deaths globally (1–3). COVID-19 is a highly variable disease, with symptoms ranging from asymptomatic cases to critical illness, resulting in death in 1-2% of patients (4). (5)COVID-19 patients experience high rates of Intensive Care Unit (ICU) admission ranging from XX\_XX (5) (6) up to 99% of those admitted require respiratory support and 26%die in the ICU.

The emergence of the Alpha, Delta, and Omicron variants significantly increased the critical care burden and negative outcomes during the COVID-19 pandemic. The Alpha variant, dominant in early 2021, was linked to XX %higher hospitalization and ICU admission rates. However, the Delta variant, more transmissible and severe, led to a sharp increase in ICU admissions and deaths, particularly among unvaccinated populations (7). In contrast, the Omicron variant, though spreading at a much faster rate, exhibited distinct characteristics compared to Delta, leading to different patterns in healthcare utilization and outcomes

The COVID-19 pandemic disproportionately affected disadvantaged communities compared to more advantaged areas (17,18). As early as the spring and summer of 2020, evidence emerged showing that disadvantaged neighborhoods were linked to higher COVID-19 prevalence in the United States (19,20). Minority communities and individuals living in poverty experienced a significantly higher proportion of COVID-19 cases and deaths (21,22). WHY? Previous research has demonstrated increased COVID transmission or deaths associated with area deprivation index (ADI), as an indicator of community social disadvantage (23,24).

According to the National Institutes of Health, testing is particularly crucial for vulnerable populations and communities with high ADI scores, enabling early detection and helping prevent the virus's spread in disproportionately affected areas (26). Targeted testing programs in these communities are essential for mitigating adverse health outcomes related to COVID-19.

One such initiative is the University of Illinois System’s testing program, SHIELD Illinois, which provides a cutting-edge saliva-based COVID-19 test to K-12 schools, colleges, universities, businesses, and the community centers across Illinois (27).

Recent studies have assessed the effectiveness of SHIELD Illinois in managing COVID-19, but its specific impact on ICU admissions, particularly in socioeconomically disadvantaged areas, remains underexplored. This study aims to address this gap by investigating the relationship between SHIELD test center availability and COVID-19 ICU admission rates, with a focus on the moderating role of socioeconomic factors. Additionally, we evaluate the effect of SHIELD test centers in reducing ICU admissions across different COVID-19 waves, particularly in disadvantaged communities. The findings of this study underscore the potential benefits of expanding test center access to mitigate severe COVID-19 outcomes, emphasizing the critical need for equitable resource distribution in future pandemic responses.

**Methods**

**Study Design and Population**

This cohort study was a secondary analysis using deidentified data from the EHR data of ICU patients at Loyola University Medical Center, and the SHIELD Illinois Testing Program. The Loyola University Chicago Institutional Review Board (IRB) approved the study.

Loyola University Medical Center (LUMC) is a regional academic health system and a nationally ranked quaternary care facility with 547 licensed beds, located in Chicago’s western suburbs (32,33). LUMC’s extensive catchment area and the high number of ICU admissions make it an ideal representative for examining the effectiveness of SHIELD testing and its correlation with COVID-19 ICU outcomes.

We used datasets from the ICU at LUMC and SHIELD testing data covering January 2020 to December 2023. To ensure a relevant and accurate analysis of COVID-19 ICU outcomes, a filtration process was applied to the original ICU dataset. This filtration was necessary to focus on the zip codes most affected by ICU admissions, thereby improving the reliability of the analysis. The dataset includes 29,779 patient visits from 585 zip codes across Illinois, providing a robust sample for analysis. The initial dataset was refined by selecting the top 25% of zip codes with the highest frequency of patients served by LUMC. Figure 1 illustrates the data filtration process used to refine the ICU dataset, focusing on COVID-19 ICU admission rates. This reduction to 147 zip codes, depicted in Figure 2, allowed for a more targeted examination of the areas that experienced the greatest impact from ICU admissions during the pandemic. Selecting the top 25% helps to reduce noise in the dataset by excluding zip codes with lower patient volumes, where the data might be less representative of broader trends. This strategic selection allowed us to focus on the areas that were most significantly affected by ICU admissions at LUMC, thereby enhancing the robustness and reliability of our analysis of COVID-19 ICU admission rates. The next step involved refining the dataset to focus exclusively on patients treated for COVID-19, achieved by filtering out non-COVID-19 cases using the appropriate ICD-10 codes for COVID-19 diagnoses (see Appendix 1), standardized codes used to identify and classify COVID-19 cases. The final dataset included only COVID-19 patients from the 147 selected zip codes, spanning the same 2020-2023 timeframe. This refined dataset was then used for further analysis in the study.

A flowchart of a patient

Description automatically generated

**Figure 1**: Data Filtration Diagram

A map with different colored areas

Description automatically generated

**Figure 2:** Distribution of 147 zip codes with COVID-19 patients frequently served by LUMC

Independent variables. Area deprivation index

Number of SHIELD test centers. The effective number of SHIELD test centers was the dependent variable, defined as the proportion of a test center’s service to a given area. Although these centers are in facilities such as schools within specific zip codes, students often attend schools outside their residential areas. Since students represent their home communities, it is crucial to account for the effective number of centers to reflect their broader reach across adjacent regions. To calculate the effective number of SHIELD test centers each month, we determined the proportion of samples from each center and aggregated these proportions to find the effective number of SHIELD test centers per zip code (see Appendix 2).

Other variables.

Dependent variable. We use the COVID-19 ICU admission rate as the dependent variable in this study, calculated as the number of ICU admissions per zip code per month, normalized by the population of each zip code, and multiplied by 1,000 for scaling. This measure allows us to standardize the ICU admission data across zip codes of varying population sizes (see Appendix 3). Table 1 provides a brief description of each variable included in the dataset.

**Table 1:** Variable description

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variable | Type | Class | Description | Mean | SD |
| COVID-19 ICU admission rate | Dependent | Continuous | The rate of ICU admission for COVID-19 per zip code, adjusted for population size. It is calculated by dividing the total COVID-19 ICU admissions by the zip code’s population and multiplying by 1000 to standardize the rate per 100,000 people. | 0.044 | 0.091 |
| Zip code | Independent | Categorical | 147 unique zip codes across Illinois, where LUMC frequently treated COVID-19 patients |  |  |
| Total COVID-19 ICU admission per zip code per month | Independent | Continuous | Total number of COVID-19 ICU admissions recorded each month for each zip code | 1.152 | 1.961 |
| Zip code population | Independent | Continuous | The population of each zip code | 35,432.58 | 20,722.64 |
| Effective number of SHIELD test centers | Independent | Continuous | the proportion of a zip code served by a test center | 1.59 | 2.676 |
| State ADI | Independent | Categorical | The ADI score for each zip code | 3.00 (low ADI)  6.09 (high ADI) | 1.81 (low ADI)  1.81 (high ADI) |
| Several control variables were considered to account for factors that may also influence COVID-19 ICU admission rates. These include population density, gender distribution, age distribution, racial and ethnic composition, pre-existing health conditions (such as diabetes and heart disease), insurance status, and marital status across different zip codes. | | | | | |

**Statistical Analyses**

In this study, we employed three linear mixed-effects regression (LMER) models to investigate the association between the effective number of SHIELD test centers and the COVID-19 ICU admission rate. We focused on data from March 2021 to June 2021 for the Alpha wave, August 2021 to November 2021 for the Delta wave (38), and December 2021 to March 2022 for the Omicron wave (2). The Beta and Gamma COVID-19 waves are not considered because of the small number of patients involved (39). The models include fixed effects such as the effective number of SHIELD centers per zip code per month and the ADI category. We incorporate a zip code-level random intercept for the monthly COVID-19 ICU admission rate clustering. The details of the models are as follow:

* Model 1 evaluates the direct effect of the effective number of SHIELD centers on ICU admission rates without considering any additional covariates or interaction terms.
* Model 2 introduces the ADI (High Disadvantaged) variable to examine how socioeconomic deprivation influences ICU outcomes, allowing for a deeper understanding of disparities across zip codes.
* Model 3 builds on the previous models by incorporating an interaction term between the effective number of SHIELD centers and ADI (High Disadvantaged). This interaction term helps identify whether the presence of SHIELD centers has a differential impact in highly disadvantaged areas compared to low disadvantaged ones.

Additionally, we conducted robustness checks using lag analysis to assess the impact of SHIELD testing on the COVID-19 ICU admission rate across different waves. We examined the effects with two-month lags to determine whether the timing of testing influenced subsequent COVID-19 ICU admissions (40). All analyses were conducted using R statistical software version 2024.04.1, and the data analysis period spanned from March 1, 2024, to August 9, 2024. Additionally, assistance from ChatGPT, a large language model developed by OpenAI, is used for language editing and clarity improvements. The authors have reviewed and approved all final content to ensure accuracy and integrity.

**Results**

The preliminary analysis provides insight into how the COVID-19 ICU admissions rate and the effective number of test centers have evolved during the different COVID-19 waves. We examined the overall trends in the COVID-19 ICU admission rate and the availability of SHIELD test centers across all zip codes over the study period. Figure 3 illustrates the relationship between the effective number of SHIELD test centers and COVID-19 ICU admission rates, both averaged over time, across various zip codes categorized by their ADI levels. Averaging over time minimizes short-term fluctuations, enabling more reliable comparisons across zip codes and deprivation levels. The data shows that during the peaks of the pandemic, particularly during the Delta and Omicron waves, the number of SHIELD test centers increased significantly in both highly disadvantaged and low-disadvantaged areas. However, low-disadvantaged areas consistently maintained a higher number of effective test centers throughout the period. One possible explanation must be related to the unbalanced number of zip codes served by LUMC. Despite the rise in test centers, COVID-19 ICU admission rates remained notably higher in high disadvantaged zip codes, especially during these waves. This suggests that, even with increased access to testing, socioeconomically disadvantaged areas faced a disproportionately heavier burden of severe COVID-19 cases, underscoring the persistent health disparities in these communities during the pandemic.

**Omicron Wave**

**Delta Wave**

**Alpha Wave**

**Figure 3:** Trends in COVID-19 ICU admission rates and effective number of SHIELD test centers across zip codes over time

**Linear Mixed-Effect Regression Model**

Table 2 summarizes regression models examining the relationship between the effective number of SHIELD test centers and COVID-19 ICU admission rates during the Alpha, Delta, and Omicron waves. While none of the models indicate a significant impact of SHIELD test centers in disadvantaged areas during the Alpha wave, Model 2 during the Delta wave shows a positive and statistically significant effect () for areas with a higher ADI. This suggests that these zip codes experienced higher COVID-19 ICU admission rates, reflecting a socioeconomic disparity in the burden of severe COVID-19 cases. For the Omicron wave, Model 2 shows a positive and statistically significant impact of ADI ( ,), indicating that high disadvantaged zip codes experienced higher COVID-19 ICU admission rates than low disadvantaged areas. Additionally, Model 3 reveals that an increase in the effective number of SHIELD centers in high disadvantaged ADI areas is associated with a reduction in the COVID-19 admission rate (*p* < 0.1). Thus, during the Omicron wave, adding one SHIELD test center in more disadvantaged zip codes is estimated to reduce the COVID-19 ICU admission rate from 0.063 to 0.057 per 1,000 population.

**Table 2**: Impact of SHIELD test centers and ADI on COVID-19 ICU admission rates

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Dependent Variable: COVID-19 ICU Admission Rate | | | | | | | | |
| Independent Variable | Model 1  (Alpha) | Model 1  (Delta) | Model 1  (Omicron) | Model 2  (Alpha) | Model 2  (Delta) | Model 2  (Omicron) | Model 3  (Alpha) | Model 3  (Delta) | Model 3  (Omicron) |
| Effective Number of SHIELD Centers | -0.00542 (0.00542) | 0.00004 (0.00088) | -0.00249 (0.00165) |  |  |  | -0.00853  (0.00957) | 0.00086  (0.00104) | 0.00030  (0.00217) |
| ADI (High Disadvantaged) |  |  |  | 0.00873 (0.00839) | 0.01609**\*** (0.00935) | 0.02076**\*** (0.01259) | 0.00833  (0.00883) | 0.02103\*\*  (0.01012) | 0.03842\*\*  (0.01652) |
| Effective Number of SHIELD Centers\*ADI (High Disadvantaged) |  |  |  |  |  |  | 0.00408 (0.01162) | -0.00247 (0.00199) | -0.00594\* (0.00331) |
| Number of observations | 573 | 588 | 588 | 573 | 588 | 588 | 573 | 588 | 588 |
| Mean of the dependent variable in the control group | 0.03 | 0.04 | 0.04 | 0.03 | 0.04 | 0.04 | 0.03 | 0.04 | 0.04 |
| Conditional R squared | 0.59 | 0.60 | 0.76 | 0.59 | 0.60 | 0.76 | 0.60 | 0.59 | 0.76 |
| Intraclass Correlation Coefficient (ICC) | 0.60 | 0.60 | 0.76 | 0.60 | 0.60 | 0.76 | 0.60 | 0.59 | 0.76 |
| *NOTE*: The LMER model included fixed effects such as the effective number of SHIELD centers per zip code per month and the ADI category. The model included a random effect for zip code. The unit of observation is the number of zip codes that have patients in LUMC ICU. Regression coefficients are shown with robust standard errors in parentheses. \*\*\*p<0.01, \*\*p<0.05, \*p<0.1 | | | | | | | | | |

Table 3 displays a regression analysis investigating the influence of SHIELD test centers and ADI on COVID-19 ICU admission rates with a two-month delay. While none of the models indicate a significant impact of SHIELD test centers in disadvantaged areas during the Alpha wave, in the Delta wave, Model 1 presents a negative and statistically significant estimate (, *p* < 0.1), indicating a considerable reduction in the COVID-19 ICU admission rate two months after an increase in the effective number of SHIELD test centers. Thus, during the Delta wave, adding one SHIELD test center is estimated to reduce the COVID-19 ICU admission rate from 0.045 to 0.043 per 1,000 population.

Also, model 2 shows a positive and statistically significant estimate (, *p* < 0.1) for the high disadvantaged zip codes, suggesting that these areas experienced significantly higher COVID-19 ICU admission rates two months after testing. In the Omicron wave, Model 2 shows a positive and statistically significant estimate (, *p* < 0.1) for the high disadvantaged zip codes. This suggests that these experienced significantly higher COVID-19 ICU admission rates two months after testing. Also, Model 3 presents a negative estimate (, *p* < 0.1) for the interaction between the effective number of SHIELD test centers and high disadvantaged zip codes. As a result, during the Omicron wave, adding one SHIELD test center is estimated to lower the COVID-19 ICU admission rate in highly disadvantaged zip codes from 0.063 to 0.056 per 1,000 population. For all models in the analysis, multicollinearity is assessed using the Variance Inflation Factor (VIF), with all VIF values remaining below 4. This indicates that multicollinearity is not a concern in the models, ensuring reliable coefficient estimates.

**Table 3**: Impact of SHIELD test centers and ADI on COVID-19 ICU admission rates (two-month lag)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Dependent Variable: COVID-19 ICU Admission Rate | | | | | | | | |
| Independent Variable | Model 1  (Alpha) | Model 1  (Delta) | Model 1  (Omicron) | Model 2  (Alpha) | Model 2  (Delta) | Model 2  (Omicron) | Model 3  (Alpha) | Model 3  (Delta) | Model 3  (Omicron) |
| Effective Number of SHIELD Centers | -0.00154 (0.00314) | -0.00199**\*** (0.00114) | -0.00236 (0.00158) |  |  |  | 0.00049  (0.00366) | -0.00034  (0.00154) | 0.00038  (0.00199) |
| ADI (High Disadvantaged) |  |  |  | 0.00885 (0.00840) | 0.01609**\*** (0.00935) | 0.02076**\*** (0.01259) | 0.01204  (0.00885) | 0.02384\*\*  (0.01178) | 0.04066\*\*  (0.01604) |
| Effective Number of SHIELD Centers\*ADI (High Disadvantaged) |  |  |  |  |  |  | -0.00806 (0.00713) | -0.00313 (0.00230) | -0.00678\*\* (0.00323) |
| Number of observations | 570 | 588 | 588 | 570 | 588 | 588 | 570 | 588 | 588 |
| Mean of the dependent variable in the control group | 0.03 | 0.04 | 0.04 | 0.03 | 0.04 | 0.04 | 0.03 | 0.04 | 0.04 |
| Conditional R squared | 0.59 | 0.59 | 0.76 | 0.59 | 0.60 | 0.76 | 0.59 | 0.59 | 0.77 |
| Intraclass Correlation Coefficient (ICC) | 0.59 | 0.59 | 0.76 | 0.59 | 0.60 | 0.76 | 0.60 | 0.59 | 0.76 |
| *NOTE*: The LMER model included fixed effects such as the effective number of SHIELD centers per zip code per month and the ADI category. The model included a random effect for zip code. The unit of observation is the number of zip codes that have patients in LUMC ICU. Regression coefficients are shown with robust standard errors in parentheses. \*\*\*p<0.01, \*\*p<0.05, \*p<0.1 | | | | | | | | | |

**Discussion**

Our study evaluated how SHIELD testing influences the severity of outcomes, particularly ICU admissions, with a focus on disadvantaged communities. WHAT IS YOUR MAIN CONCLUSION? This study demonstrates that the impact of the SHIELD testing program was not solely dependent on the number of testing centers but on their effectiveness in reducing COVID-19 ICU admissions, particularly in socioeconomically disadvantaged areas. Our findings suggest that higher disadvantaged areas consistently experienced higher ICU admission rates despite an increase in test centers, emphasizing the importance of targeted resource allocation.

Recent studies have utilized SHIELD data to evaluate its effectiveness in managing COVID-19. For example, Saidani *et al.* (29) used SHIELD data to optimize the allocation of resources for testing, determining the optimal number of machines and operators needed based on daily sample testing rates. Holman *et al.* (30) leveraged SHIELD data to examine COVID-19 transmission in early care and education settings, finding that implementing a Test-to-Stay strategy resulted in low transmission rates and reduced school absences. Ivanov *et al.* (31) investigated the impact of different enrollment policies on testing and positivity rates in Illinois schools, showing that an opt-out policy led to higher testing rates and lower positivity rates, which could have prevented 20% of lost school days.

The results of this study highlight the critical role the SHIELD testing program plays in managing the COVID-19 pandemic, with particular emphasis on the proportion of testing centers actively serving communities. In this analysis, the total number of SHIELD centers operating in each zip code per month was calculated. However, relying solely on the total number of SHIELD centers could be misleading, as it does not account for whether these centers were actively utilized or accessible to the community. Thus, we considered the effective number of SHIELD centers serving each zip code, rather than the total number. Our results showed that the root mean square error (RMSE) between the average number of SHIELD test centers and the average effective number across all zip codes over time was 0.94, indicating a close alignment between these two metrics (see Appendix4). While some variation exists, this small RMSE suggests that, in general, the centers were effective in serving their communities.

As the overall number of SHIELD test centers increased during major pandemic waves, the proportion of centers effectively serving their respective zip codes significantly reduced COVID-19 ICU admission rates. The LMER models’ results demonstrate the evolving impact of SHIELD test centers throughout the pandemic. During the Alpha wave, the presence of test centers did not notably reduce ICU admissions, likely because testing efforts were not yet fully optimized or widespread. However, by the Delta and Omicron waves, the data suggest that the effectiveness of these centers improved, particularly in disadvantaged areas with higher ADI scores. The significant positive association observed during the Delta and Omicron waves indicates that socioeconomically disadvantaged zip codes experienced disproportionately higher ICU admission rates, highlighting ongoing disparities in the pandemic’s burden. Notably, the reduction in ICU admissions with an increase in the effective number of SHIELD test centers during the Omicron wave suggests that, once these centers actively served their communities, they played a critical role in mitigating severe outcomes. This finding underscores the importance of not just the availability of test centers but also their active utilization and accessibility in reducing COVID-19’s most severe effects, particularly in vulnerable populations.

The results from the lag analysis further illustrate the evolving impact of SHIELD test centers, especially when considering a two-month delay in their effect on COVID-19 ICU admissions. During the Alpha wave, the presence of SHIELD test centers did not significantly reduce ICU admissions in disadvantaged areas, likely because the testing infrastructure was still in its early stages and not fully optimized. By the Delta wave, however, an increase in the effective number of SHIELD test centers was associated with a significant reduction in ICU admissions two months later. This delayed effect suggests that enhanced testing efforts eventually played a critical role in reducing severe outcomes. Specifically, increasing the number of effective SHIELD test centers appears to have significantly eased the burden on healthcare systems during the Delta wave, underscoring the importance of sustained and targeted testing efforts. Despite this, disadvantaged zip codes continued to face disproportionately higher ICU admission rates, as reflected in the positive association found during both the Delta and Omicron waves. This highlights the persistent challenges faced by these communities, where broader socioeconomic barriers may have limited the immediate benefits of increased testing. Nonetheless, the reduction in ICU admissions associated with an increase in the effective number of SHIELD test centers during the Omicron wave, particularly in high-ADI areas, suggests that targeted testing interventions can make a substantial difference over time. These findings demonstrate that by strategically increasing testing in disadvantaged communities, significant reductions in severe outcomes can be achieved, even with a delayed effect.

The main limitation of this study is to use ICU data from only one hospital, which may limit the generalizability of our findings. The LUMC ICU cohort reflects the diversity of Cook County, where it is located and where most zip codes it serves are based. We compared the characteristics of LUMC ICU cohort with the population characteristics of Cook County’s and the national average, as they are reported in 2020 Census (41). With 19.0% Black/African American patients, LUC closely aligns with Cook County’s 23.8%, much higher than the national average of 13.4%. LUC ICU also has 43.3% female patients, comparable to Cook County’s 51.4% and the national average of 50.8%. This shows that LUC serves a racially and demographically diverse population. With respect to socioeconomical diversity, LUMC ICU serves a population where 35.0% speak a non-English language, matching Cook County and far exceeding the national average of 21.5%. Cook County’s higher poverty rate (13.0% vs. the national 11.4%) suggests that LUMC ICU also serves economically disadvantaged individuals. With Cook County’s Hispanic population at 18.5%, LUMC ICU is representative of the area’s diverse socioeconomic and linguistic makeup. The diverse cohort, both socioeconomically and demographically, helps provide insights into the impact of SHIELD test centers in diverse populations. Nevertheless, future studies should include data from multiple hospitals to better capture the broader impact.

Additional limitations include the fact that the SHIELD Illinois program was conducted solely within Illinois, primarily near urban areas, without consideration of data from other states or more rural regions. This restricts the ability to evaluate SHIELD's effectiveness in different geographic contexts. Future research should assess similar programs across multiple states to provide more generalizable findings. Furthermore, key factors such as comorbidities, vaccination status, and early treatment interventions were not accounted for in this study, which may influence ICU outcomes. Including these variables in future research would offer a more comprehensive understanding. Lastly, the voluntary nature of SHIELD participation may have introduced selection bias, as wealthier districts were more likely to adopt the program early. Addressing these limitations will provide a clearer assessment of SHIELD's overall impact and help guide equitable resource allocation in future pandemic responses.

**Conclusion**

This study demonstrates that the impact of the SHIELD testing program was not solely dependent on the number of testing centers but on their effectiveness in reducing COVID-19 ICU admissions, particularly in socioeconomically disadvantaged areas. Our findings suggest that higher disadvantaged areas consistently experienced higher ICU admission rates despite an increase in test centers, emphasizing the importance of targeted resource allocation. The strategic placement and utilization of SHIELD centers in these communities were crucial for mitigating severe health outcomes. Future public health strategies should prioritize not only the expansion of testing facilities but also their optimal placement and operation in vulnerable areas to maximize their effectiveness in reducing severe outcomes during pandemics. Further research will focus on refining the placement of testing centers to improve both coverage and equity in disadvantaged regions.

**Abbreviations**

***ICU:*** Intensive Care Unit

***ADI:*** Area Deprivation Index

***EHR:*** Electronic Health Record

***IRB:*** Institutional Review Board

***LUMC:*** Loyola University Medical Center

***LMER:*** Linear Mixed-Effects Regression

***VIF:*** Variance Inflation Factor

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**Appendix 1: ICD-10 codes related to COVID-19**

Table A.1 shows a list of ICD-10 codes used to classify COVID-19-related conditions and diagnoses. Each code represents a specific health condition directly associated with COVID-19, ranging from exposure to the virus to post-COVID complications.

**Table A.1:** ICD-10 codes related to COVID-19

|  |  |
| --- | --- |
| COVID-19-relatedICD-10 code | Description |
| Z11.52 | Contact with and (suspected) exposure to COVID-19 |
| M35.81 | Multisystem Inflammatory Syndrome (MIS) |
| J12.82 | Pneumonia due to Coronavirus disease 2019 |
| U07.1 | COVID-19 |
| U09.9 | Post-COVID-19 condition, unspecified |
| B97.29 | Other Coronavirus as the cause of disease classified elsewhere |
| J20.8 | Acute bronchitis confirmed as due to COVID-19 |
| J22 | Lower or acute respiratory infection due to COVID-19 |
| J98.8 | Respiratory infection due to COVID-19 |
| J80 | Acute Respiratory Distress Syndrome (ARDS) due to COVID-19 |

**Appendix 2: Quantifying the Effective Coverage of SHIELD Test Centers**

In this model, represents the index for each SHIELD test center, corresponds to each zip code, and denotes time. The variable ​ is the number of COVID-19 samples collected from zip code by test center in time , while ​ represents the total number of samples collected from zip code by all test centers in in time . The proportion of samples collected by test center iii from zip code in time , denoted as ​. The effective number of SHIELD test centers serving zip code in time , denoted as , is then determined by summing these proportions across all test centers, capturing the distribution of service provided by the centers in relation to the zip code. This approach quantifies the contribution of multiple centers in testing coverage for each zip code.

**Appendix 3: Mathematical Calculation of COVID-19 ICU Admission Rate**

The total number of ICU admissions in zip code during time is represented by , and the population of zip code is denoted as ​. The COVID ICU admission rate for zip code during time , denoted as , is calculated as the ratio of the total ICU admissions to the population of the zip code. This rate captures the proportion of ICU admissions related to COVID-19 in a given zip code relative to its population, providing a standardized measure of the ICU burden on the local healthcare system. The formula is:

This formula calculates the number of ICU admissions per 1,000 people for a given zip code in time

**Appendix 4: Trends of SHIELD test centers and effective number of SHIELD centers over time**

Figure A.1 shows the trends of number of SHIELD test center versus effective number of SHIELD test centers for all zip codes over time.

**Figure A.1:** Trends of SHIELD test centers and effective number of SHIELD centers over time for all zip codes

**Declarations**

**Ethics approval and consent to participate**

Not Applicable

**Consent for publication**

The authors affirm that all participants involved in this study, or their legal guardians, have given their consent for the publication of any potentially identifying information contained within the manuscript. No personal or sensitive data (such as images, personal health information, or identifiable demographics) will be included that could compromise the privacy or anonymity of the participants. Where applicable, participants provided informed consent in accordance with ethical guidelines and institutional policies. Furthermore, this manuscript does not contain any individual-level data or other content requiring consent for publication.

**Availability of data and materials**

Not Applicable

**Competing interests**

The authors declare no competing interests.

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A.K. was responsible for design of the study, data analysis, and manuscript writing. A.W. contributed valuable insights into the results and analyses and assisted in reviewing and editing the manuscript. F.I. and M.S. played key roles in data preprocessing and graphic design. W.P., M.S., S.A., and S.T. conceptualized the study, reviewed the manuscript, provided critical feedback, and contributed to funding acquisition (PI: S.T.) Additionally, S.A. and S.T. contributed to manuscript editing and analysis insights.

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. Understanding the differing impacts of these variants is crucial for evaluating COVID-19 interventions and outcomes (8–16) Understanding the factors that influence ICU admissions, including the role of interventions such as testing programs, is crucial.