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RESEARCH ARTICLE

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The association of strained ICU capacity with hospital patient racial and ethnic composition and federal relief during the COVID-19 pandemic

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Abstract

Objective: To identify the association between strained intensive care unit (ICU) capacity during the COVID-19 pandemic and hospital racial and ethnic patient composition, federal pandemic relief, and other hospital characteristics.

Data Sources: We used government data on hospital capacity during the pandemic and Provider Relief Fund (PRF) allocations, Medicare claims and enrollment data, hospital cost reports, and Social Vulnerability Index data.

Study Design: We conducted cross-sectional bivariate analyses relating strained capacity and PRF award per hospital bed with hospital patient composition and other characteristics, with and without adjustment for hospital referral region (HRR).

Data Collection: We linked PRF data to CMS Certification Numbers based on hospital name and location. We used measures of racial and ethnic composition generated from Medicare claims and enrollment data. Our sample period includes the weeks of September 18, 2020 through November 5, 2021, and we restricted our analysis to short-term, general hospitals with at least one intensive care unit (ICU) bed. We defined "ICU strain share" as the proportion of ICU days occurring while a given hospital had an ICU occupancy rate ≥ 90%.

Principal Findings: After adjusting for HRR, hospitals in the top tercile of Black patient shares had higher ICU strain shares than did hospitals in the bottom tercile (30% vs. 22%, $p < 0.05$) and received greater PRF amounts per bed ($118,864 vs. $92,407, $p < 0.05$). Having high versus low ICU occupancy relative to pre-pandemic capacity was associated with a modest increase in PRF amounts per bed after adjusting for HRR ($107,319 vs. $96,627, $p < 0.05$), but there were no statistically significant differences when comparing hospitals with high versus low ICU occupancy relative to contemporaneous capacity.

Conclusions: Hospitals with large Black patient shares experienced greater strain during the pandemic. Although these hospitals received more federal relief, funding was not targeted overall toward hospitals with high ICU occupancy rates.

KEYWORDS
acute inpatient care, health care disparities, health policy/politics/law/regulation, health care financing/insurance/premiums

What is known on this topic

- There are substantial racial and ethnic disparities in COVID-19 infections, hospitalizations, and mortality.
- At the same time, there is a large degree of racial and ethnic segregation across hospitals.
- Because COVID-19 surges continue to strain hospital operations, there is concern that Black and Hispanic patients may have been more likely than White patients to receive care in overwhelmed facilities.

What this study adds

- This study identified that hospitals with large Black patient shares experienced greater intensive care unit (ICU) strain during the COVID-19 pandemic.
- These hospitals did receive more funding; however, federal relief overall was not targeted at hospitals with high ICU occupancy rates.

1 | INTRODUCTION

As of February 2022, there have been over 78 million confirmed cases of COVID-19 and over 900,000 reported COVID-19 deaths in the United States.[1] Hospital strain, which reduces the ability to deliver high-quality care,[2] has been a concern throughout the pandemic. COVID-19 surges have strained hospital operations and staff and have created an especially large burden for intensive care units (ICUs).[3] Recent studies have found that hospital strain is associated with increases in COVID-19 mortality rates.[4–7] To manage regional capacity, assist stressed hospitals, and address inequities in care—both during the current pandemic and in future public health crises should they arise—policymakers will need to identify the characteristics of hospitals that are most likely to be overwhelmed.

In this study, we use national hospital-level data to assess variations in ICU strain during the pandemic and to evaluate the association between strained capacity and the racial and ethnic composition of hospital patient populations and other characteristics of the hospital and the community in which the hospital is situated. Our primary focus is on differences related to race and ethnicity in light of previously documented large disparities in COVID-19 infection, hospitalization, and mortality.[6,8–11] Given that COVID-19 hospitalization rates are higher among Black and Hispanic versus White individuals and that there is a large degree of segregation across hospitals by race and ethnicity,[12–14] it is conceivable that Black and Hispanic patients may have been more likely to receive care in overwhelmed facilities. In addition to evaluating differences by race and ethnicity, we assess whether ICU strain varies by other characteristics of patient populations, community characteristics, and operational and financial characteristics.

Existing research highlights that hospitals in counties with higher levels of social vulnerability have been more likely to experience strained capacity during the pandemic.[15] Our study builds on this work in critical ways. First, we incorporate information on the racial and ethnic composition of hospital patient populations. Second, in addition to comparing hospitals across the nation, we also evaluate whether there are disparities within hospital referral regions (HRRs). This distinction is important; differences in levels of strain across hospitals in a given region present an opportunity for policymakers and public health officials to reduce hospital burden by facilitating patient sharing. Finally, we extend previous analyses to include the period when COVID-19 vaccines became available to the general population and when the more virulent and transmissible Delta variant emerged.[16] These developments changed the trajectory of the pandemic and may have altered the nature of COVID-19 disparities. For example, following the availability of COVID-19 vaccines, hospitalizations have been driven by non-vaccinated populations, and disparities in access to vaccines or uptake due to vaccine hesitancy could have led to further inequities in COVID-19 hospitalization rates and hospital strain.[17–20]

Given the concern that hospital strain may be disproportionately experienced by hospitals that treat more racial and ethnic minority patients, this study evaluates whether federal relief funds have been targeted toward hospitals with high levels of strain, as well as the association of relief with other hospital characteristics. We evaluate the distribution of funds through the Provider Relief Fund (PRF) program, which was created in March 2020 through the Coronavirus Aid, Relief, and Economic Security (CARES) Act of 2020 and has allocated $129 billion to hospitals and other health care providers through April 2022.[21–25] The PRF program is intended to cover providers' health care expenses or lost revenues due to the pandemic.[21] PRF allocations have included $66 billion in general distributions on the basis of providers' pre-pandemic Medicare or total patient revenues, financial losses during the pandemic, and other factors.[26–28] The program has also allocated targeted distributions, including $22 billion for hospitals with a large numbers of COVID-19 admissions overall or per bed (with $2 billion earmarked for safety net hospitals); $14 billion for safety net hospitals; $12 billion for rural providers; $9 billion for skilled nursing facilities and nursing homes; and less than $1 billion for Tribal hospitals, clinics, and urban health centers.[27,29] Most of the criteria for the PRF do not directly relate to strain, though some—such as safety net status—may be associated with a greater risk of stressed capacity. As noted, PRF allocations have also included targeted funds for hospitals with a large number of COVID-19 admissions, though the extent to which these hospitals also had strained capacity is unclear, and this funding source ended in June 2020.[30]

2 | METHODS

2.1 | Data on hospital strain

We generated measures of strain based on hospital capacity data released by the Department of Health & Human Services (HHS). Among other things, these data include the average number of staffed, adult ICU beds available and occupied by week for each Medicare-certified hospital from July 31, 2020 onwards.[31] Our main outcome of interest is the "ICU strain share", which we define as the share of ICU days occurring while a given hospital had strained capacity. We in turn define strained capacity as an ICU occupancy rate greater than or equal to 90%. The HHS data identify weekly averages of hospital capacity and therefore offer an approximation of daily strain.

2.2 | Data on Provider Relief Fund allocations

We identified Provider Relief Fund (PRF) general and targeted distributions based on data released through the Health Resources & Services Administration. These data include the provider name, city, and state for each recipient. We relied on a version that included cumulative payments through July 15, 2021, that is, shortly after the start of the fourth pandemic wave, as defined below.[22] Cumulative PRF allocations increased only slightly through the end of 2021 (from $118 to $120 billion when we checked on December 26, 2021). We used perfect and fuzzy matching techniques to link these data to Centers for Medicare & Medicaid Services (CMS) Certification Numbers (see online Appendix S1 for details). In scenarios where a single PRF award was related to multiple hospitals (e.g., a health system), we apportioned the amount based on 2019 bed counts, which we pulled from the RAND Hospital Data file. We were ultimately able to match $71 billion in PRF awards—including $58 billion for the set of hospitals in our sample—with positive allocations for 89% of short-term, Medicare-certified hospitals. We assumed that the remaining hospitals did not receive a PRF award.

2.3 | Data on hospital patient composition and social vulnerability

We obtained estimates from 100% fee-for-service (FFS) Medicare claims and enrollment data of the share of beneficiaries admitted to a given hospital in 2018 who were Black or Hispanic and the average ZIP-code poverty rate of admitted beneficiaries. Race and ethnicity variables were created using the Medicare Bayesian Improved Surname Geocoding (MSBIG) 2.0 method, which combines CMS administrative data with surname and geographic data to generate more accurate estimates of race and ethnicity.[32] The MBSIG 2.0 method generates predicted probabilities that a given beneficiary falls into one of six racial and ethnic groups—American Indian/Alaska Native, Asian/Pacific Islander, Black, Hispanic, White, and multiracial (i.e., non-Hispanic and more than one group)—which were summed to create predicted hospital-level shares.[32,33] The poverty rate variable was created by merging beneficiary ZIP codes with 2014–2018 American Community Survey data on poverty rates and then taking the average for a given hospital.

We supplemented this information with 2018 county-level Social Vulnerability Index (SVI) data from the Centers for Disease Control and Prevention (CDC). The SVI is a composite of 15 social factors related to socioeconomic status, household composition, race and ethnicity/language, and housing/transportation, and is intended to reflect the extent to which a given community will have difficulty responding to crises, such as the COVID-19 pandemic.[34]

2.4 | Data on hospital operational and financial characteristics

We relied on RAND Hospital Data from 2019 (i.e., the year prior to the pandemic) to identify the following hospital characteristics: the Medicare Disproportionate Payment Percentage (DPP) (a measure of safety net status used to distribute Medicare Disproportionate Share Hospital [DSH] payments and targeted PRF allocations), three measures of financial health (days of cash on hand, operating margin, and assets-to-liabilities ratio), baseline ICU and total beds, and outpatient revenue share (to indicate susceptibility to revenue losses during the pandemic).[25] The RAND Hospital Data file is a cleaned version of cost report data submitted by each Medicare-certified hospital to the Healthcare Provider Cost Reporting Information System.[35]

2.5 | Sample construction

We combined datasets using Certification Numbers and geographic identifiers and applied several sample restrictions (Appendix Table A1). First, we began with the set of short-term, general hospitals in the 2019 RAND Hospital Data file. These data encompass all US hospitals except for federal hospitals and some children's hospitals.[36] Second, we excluded hospitals that ever reported having no staffed ICU beds during the pandemic. In doing so, we dropped over one-third (37%) of our original sample—including over three-quarters of critical access hospitals (78%), by construction. Third, we dropped hospitals that were ever missing data on ICU capacity or never had ICU admissions. Fourth, we dropped hospitals with outlier PRF amounts (the top 0.5%, i.e., greater than approximately $584,000 per bed). Finally, we excluded a small number of hospitals that could not be matched to an HRR. Our final sample included 2589 hospitals, representing about four-sevenths (57%) of short-term, general hospitals in the 2019 RAND Hospital Data file and the vast majority (92%) of ICU beds (Appendix Table A1).

We focused on the period ranging from the start of the third wave of the COVID-19 pandemic to the end of the fourth wave. The majority of COVID-19 deaths (60% as of February 16, 2022) occurred during this period.[37] We defined the third wave as beginning during the week of September 18, 2020 and ending after the week of March 19, 2021. This reflects the period when levels of ICU strain were increasing prior to the peak and decreasing afterward. We used similar criteria to define the fourth wave as beginning during the week of July 2, 2021 and ending after the week of November 5, 2021. The Delta variant became the dominant strain in the United States toward the beginning of this wave, while the first confirmed case of the Omicron variant in the United States occurred shortly afterward (November 22, 2021).[38,39]

2.6 | Analysis

We estimated linear regression models relating ICU strain shares—that is, the proportion of ICU days at a given hospital that occurred during a period of strained capacity—with patient racial and ethnic composition. Because we are interested in both overall disparities and disparities across hospitals within regions, we estimated models with and without adjust for HRR. We did not adjust for other characteristics in our main analyses, as we are defining disparities to include any differences in strain between hospitals that treat many versus few racial and ethnic minority patients. In other words, we are evaluating one aspect of structural racism—which the CDC defines as "[s]tructures, policies, practices, and norms resulting in differential access to the goods, services, and opportunities of society by 'race' (e.g., how major systems– the economy, politics, education, criminal justice, health, etc. – perpetuate unfair advantage)"—and therefore would not want to adjust for differences across institutions.[40] In line with this approach, we also conducted bivariate analyses relating ICU strain share with other hospital characteristics. Finally, we repeated these analyses to evaluate the association between relief funds per hospital bed and patient racial and ethnic composition, along with other hospital characteristics. We weighted regressions by the number of ICU days at a given hospital during the sample period and we estimated robust standard errors clustered by HRR. This study has been reviewed and approved by the RAND Corporation Human Subjects Protection Committee.

We conducted several supplementary analyses and robustness checks. First, we estimated multivariable regression models that parallel the bivariate regression models described above. Second, we explored factors that might explain any differences associated with patient racial and ethnic composition. To do so, we: (1) estimated separate regression models that adjusted for one hospital characteristic in addition to patient racial and ethnic composition, (2) identified the models that led to the largest reductions in patient racial and ethnic composition point estimates, and (3) estimated a model that included the three characteristics that led to the largest decrease. Third, we reran our analyses based on what the ICU strain share would have been had the number of beds remained at pre-pandemic (2019) levels. This measure captures the extent to which hospitals were providing large amounts of ICU care relative to baseline capacity. Fourth, we reran our analyses of ICU strain to separately evaluate the third and fourth waves of the pandemic and the period in between. Finally, we separately evaluated relief fund amounts that were allocated before the third wave—and would therefore have been available to hospitals throughout our sample period—and starting with the third wave.

3 | RESULTS

3.1 | Summary statistics

Table 1 lists summary statistics for each variable in our analysis. The average ICU strain share—that is, the share of ICU days occurring at hospitals with ICU occupancy rates at or above 90%—was 26% over the sample period. A much larger share of ICU days (65% vs. 26%) occurred at hospitals with ICU occupancy at or above 90% of 2019 beds. In other words, hospitals moderated the effect of the pandemic on their operations by adding a substantial number of ICU beds. Hospitals received $102,157 per hospital bed through the PRF program on average, about two-thirds (66%) of which was distributed prior to the third wave.

3.2 | Trends in COVID cases and ICU strain share

Figure 1 plots unadjusted trends in average daily COVID-19 case rates and ICU strain shares. The ICU strain share closely tracks COVID-19 case rates lagged by 2 weeks, with a correlation of 0.62. Levels of ICU strain increased substantially during the third and fourth waves of the pandemic and reached a peak during the week of August 27, 2021, when 41% of ICU days occurred at hospitals with strained capacity.

3.3 | Geographic variation in ICU strain share

Figure 2 maps hospital strain shares across HRRs during our sample period. Although the mean ICU strain share was 26%, levels of strain varied widely throughout the country. ICU strain shares were the highest in the Owensboro, Kentucky and Waco Texas HRRs (both at 81%), while they were <1% in sixteen HRRs, including the New Haven and Bridgeport, Connecticut HRRs. Although ICU strain was highest in the South, there were many regions in other areas of the country with high levels of strain (e.g., 59% in the Flint, Michigan HRR) and many Southern regions that had low levels of strain (e.g., 1% in the Monroe, Louisiana HRR). Appendix Figure 1 maps ICU occupancy relative to 2019 beds, showing that hospitals throughout the country were providing high levels of care relative to their baseline capacity.

TABLE 1 Hospital-level summary statistics

	Mean	Standard deviation	CV	N=
ICU strain				
ICU occupancy rate				
Overall	77.8%	15.1%	0.19	2,589
Share ≥90%	26.2%	31.2%	1.19	2,589
ICU occupancy/2019 beds				
Overall	154.4%	157.4%	1.02	2,444
Share ≥90%	65.3%	41.0%	0.63	2,444
PRF amounts				
March 2020 through July 2021	$102,157	$89,630	0.88	2,589
March 2020 through August 2020	$67,827	$75,297	1.11	2,589
September 2020 through July 2021	$34,788	$51,355	1.48	2,589
Socioeconomic characteristics				
FFS Medicare patient race and ethnicity				
Share Black	12.1%	13.1%	1.08	2,578
Share Hispanic	8.6%	13.4%	1.55	2,578
Share White	74.1%	19.9%	0.27	2,578
Average FFS Medicare patient ZIP-code poverty rate	14.4%	4.6%	0.32	2,578
DPP				
DSH hospital	93.4%	24.8%	0.27	2,589
DPP if DSH hospital	36.3%	15.0%	0.41	2,204
Hospital county SVI percentile	57.1%	22.8%	0.40	2,588
Region				
Northeast	16.1%	36.7%	2.29	2,589
Midwest	22.2%	41.5%	1.87	2,589
South	43.7%	49.6%	1.13	2,589
West	18.0%	38.4%	2.13	2,589
Operational and financial characteristics				
Ownership				
Nonprofit	67.8%	46.7%	0.69	2,589
For-profit	16.1%	36.8%	2.28	2,589
Government	16.1%	36.7%	2.29	2,589
Teaching hospital				
No	27.4%	44.6%	1.63	2,589
Minor	39.5%	48.9%	1.24	2,589
Major	33.2%	47.1%	1.42	2,589
Operating margin	5.2%	14.1%	2.72	2,550
Current asset-to-liabilities ratio	174.9%	5527.5%	31.60	2,542
Days of cash on hand	120	311	2.60	2,167
Outpatient share	55.2%	12.5%	0.23	2,549

Note: Summary statistics weighted by total ICU occupancy over the sample period.
Abbreviations: CV, coefficient of variation; DPP, disproportionate payment percentage; DSH, disproportionate share hospital; FFS, fee-for-service; ICU, intensive care unit; PRF, Provider Relief Fund; SVI, social vulnerability index.

3.4 | Association of ICU strain with hospital characteristics

Table 2 presents regression results that assess the association of ICU strain with hospital characteristics. Having a high versus low Black patient share (top vs. bottom tercile) was associated with a 5.3 pp increase in the ICU strain share overall ($p < 0.10$) (a 24% difference) and a 7.8 pp increase in the ICU strain share after adjusting for HRR ($p < 0.05$) (a 36% difference). The latter result indicates that there were disparities in ICU strain across hospitals even when comparing

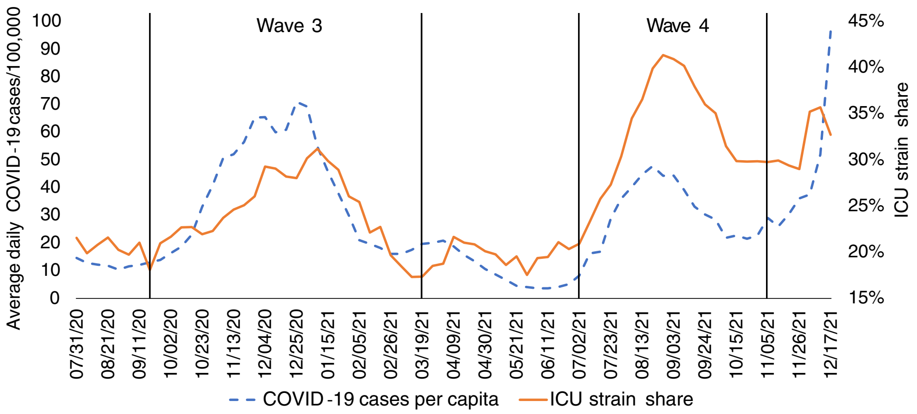

FIGURE 1 COVID-19 cases and ICU strain share, by week. ICU strain share is the share of ICU days occurring when a given hospital had an ICU occupancy rate at or above 90%. ICU strain share trends are for hospitals in sample ($N = 2{,}589$). COVID-19 cases per capita represent the broader US population and come from usafacts.org. ICU, intensive care unit. [Color figure can be viewed at wileyonlinelibrary.com]

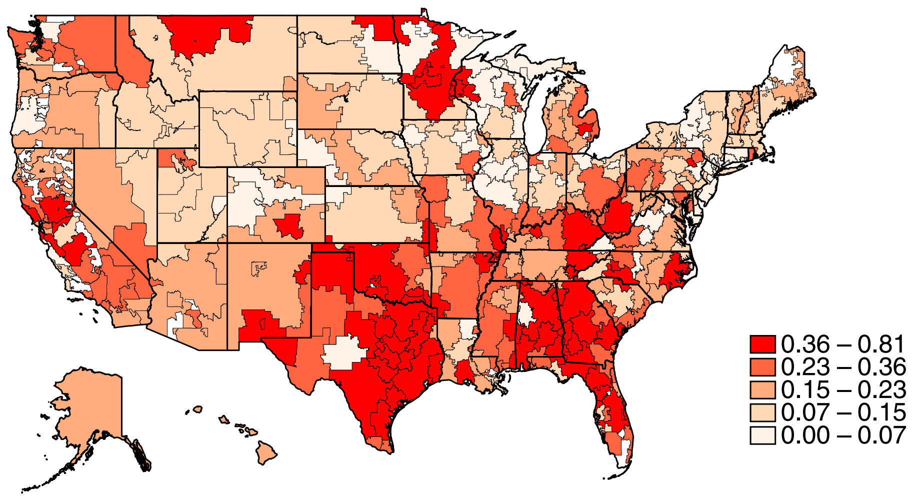

FIGURE 2 ICU strain shares, by HRR. ICU strain share is the share of ICU days in a given HRR occurring when a given hospital had an ICU occupancy rate at or above 90%. Data are from 2,589 hospitals in sample, covering 306 HRRs. Legend categories represent quantiles weighted by total ICU occupancy during the sample period. HRR, hospital referral region; ICU, intensive care unit. [Color figure can be viewed at wileyonlinelibrary.com]

facilities in the same health care market. Differences relating to Hispanic patient shares were not statistically significant. Findings related to race and ethnicity were similar when separately evaluating ICU strain shares during the third wave of the pandemic, the fourth wave, and the period in between, though results for Black patient shares were not statistically significant for the latter two periods in models without adjustments for HRR (Appendix Tables A2–A4).

When evaluating other hospital characteristics, we found that ICU strain shares were positively associated with average patient ZIP-code poverty rates (11.5 pp [$p < 0.01$] when comparing the top to bottom tercile, as we do throughout for continuous variables), county-level SVI (10.8 pp [$p < 0.01$]), and for-profit and government relative to nonprofit ownership (12.9 pp [$p < 0.01$] and 6.0 pp [$p < 0.05$], respectively), and were negatively associated with asset-to-liabilities ratios (−9.1 pp [$p < 0.01$]), days of cash on hand (−13.6 pp [$p < 0.01$]), and outpatient revenue shares (−8.0 pp [$p < 0.05$]). After adjusting for HRR, only the positive association with average patient ZIP-code poverty rates and the negative association with asset-to-liabilities ratios retained statistical significance (4.9 pp [$p < 0.10$] and −7.0 pp [$p < 0.01$], respectively). Associations of ICU strain share with DPP index, teaching hospital status, and operating margins were not statistically significant.

Appendix Table A5 presents a parallel set of results where the outcome reflects what the ICU strain share would have been had beds remained at pre-pandemic levels. As noted, this would have resulted in a much higher ICU strain share on average (65% vs. 26%). Point estimates for having a high versus low Black patient share were much larger under this approach (23.5 pp vs. 7.8 pp when comparing within-HRR analyses). Some hospital characteristics that did not have a statistically significant relationship with actual ICU strain shares were associated with high ICU occupancy levels relative to pre-pandemic capacity. For example, after adjusting for HRR, the ICU strain share based on pre-pandemic capacity was much higher among hospitals with high versus low Hispanic patient shares (20.9 pp [$p < 0.01$]) and high DPP indices versus non-DSH hospitals (34.0 pp [$p < 0.01$]), but these characteristics were not associated with statistically significant differences in ICU strain shares based on contemporaneous capacity (Table 2). Similarly, after adjusting for HRR, having high versus low assets-to-liabilities ratios was associated with greater levels of ICU strain based on pre-pandemic capacity (10.4 pp [$p < 0.01$]) but with a lower actual ICU strain share (−7.0 pp [$p < 0.01$]).

Appendix Table A6 presents results from multivariable regression analyses. When focusing on within-HRR analyses, adjusting for hospital characteristics led to a decrease in the high versus low Black patient share point estimate from 7.8 to 4.9 pp (a 38% decline) and eliminated the statistical significance of this result (see Appendix Table A6 vs. Table 2). In other words, observed hospital characteristics explained a portion of the disparities in ICU strain share related to patient racial and ethnic composition. ICU strain shares were positively associated with government versus non-profit ownership (7.8 pp [$p < 0.05$]) and negatively associated with asset-to-liabilities ratios (−7.7 pp [$p < 0.05$]) and outpatient revenue shares (−5.9 pp

TABLE 2 Association of ICU strain share with hospital characteristics

		Overall				Adjusted for HRR		
		N=	Pred. val. (%)	Marg. effect (pp)	95% CI	Pred. val. (%)	Marg. effect (pp)	95% CI
Overall		2,589	26.2			26.2		
Socioeconomic characteristics								
Share of FFS Medicare patients Black	<4.3% (ref)	2,578	22.0			21.8		
	4.3%–12.5%		29.4	7.4***	(1.9, 12.9)	27.2	5.4**	(0.3, 10.4)
	12.5%–91.3%		27.3	5.3*	(−0.8, 11.3)	29.6	7.8**	(0.9, 14.7)
Share of FFS Medicare patients Hispanic	<1.8% (ref)	2,578	27.2			27.1		
	1.8%–6.1%		21.5	−5.7*	(−11.5, 0.0)	24.8	−2.3	(−8.2, 3.5)
	6.2%–91.7%		29.9	2.7	(−5.8, 11.3)	26.7	−0.4	(−8.4, 7.5)
Average FFS Medicare patient ZIP-code poverty rate	4.7%–12.2% (ref)	2,578	20.7			23.8		
	12.2%–15.5%		25.8	5.1*	(−0.7, 10.9)	26.1	2.3	(−2.6, 7.3)
	15.5%–42.5%		32.2	11.5***	(5.9, 17.2)	28.7	4.9*	(−0.5, 10.4)
DPP index	Not DSH (ref)	2,589	21.8			25.6		
	0.09–0.29		29.2	7.4**	(0.4, 14.4)	28.0	2.4	(−5.5, 10.2)
	0.29–0.39		24.5	2.7	(−4.2, 9.6)	25.6	0.0	(−7.1, 7.1)
	0.39–1.07		25.8	4.0	(−3.4, 11.5)	25.0	−0.6	(−9.1, 7.9)
Hospital county SVI percentile	<49th (ref)	2,588	22.3			24.0		
	49th–69th		23.1	0.8	(−5.2, 6.8)	26.1	2.1	(−3.5, 7.7)
	69th+		33.1	10.8***	(4.6, 16.9)	28.4	4.4	(−2.0, 10.7)
Operational and financial characteristics								
Ownership	Nonprofit (ref)	2,589	23.1			25.6		
	For-profit		36.0	12.9***	(4.6, 21.3)	27.4	1.8	(−4.3, 7.9)
	Government		29.2	6.0**	(0.4, 11.7)	27.5	1.9	(−4.5, 8.4)
Teaching	No (ref)	2,589	26.7			24.4		
	Minor		28.5	1.8	(−2.8, 6.3)	25.8	1.4	(−2.9, 5.7)
	Major		23.0	−3.8	(−8.9, 1.4)	28.1	3.7	(−1.9, 9.4)
Operating margin	<1.8% (ref)	2,550	24.5			24.8		
	1.8%–8.8%		25.9	1.4	(−4.1, 7.0)	26.3	1.5	(−4.4, 7.3)
	>8.8%		27.4	2.9	(−3.0, 8.8)	26.6	1.7	(−4.0, 7.4)
Current asset-to-liabilities ratio	<1.4 (ref)	2,542	30.9			30.5		
	1.4–2.5		25.1	−5.9**	(−11.0, −0.7)	23.7	−6.9***	(−11.9, −1.8)
	>2.5		21.8	−9.1***	(−13.9, −4.3)	23.6	−7.0***	(−11.6, −2.3)
Days of cash on hand	<4 (ref)	2,167	33.9			28.4		
	4–128		26.1	−7.8**	(−14.5, −1.0)	27.7	−0.7	(−7.9, 6.4)
	>128		20.3	−13.6***	(−20.3, −6.9)	24.1	−4.3	(−11.6, 3.0)
Outpatient share	0.7%–49.5% (ref)	2,549	31.6			28.6		
	9.5%–60.4%		22.6	−9.0**	(−16.0, −1.9)	24.3	−4.3	(−10.7, 2.1)
	60.4%–99.7%		23.6	−8.0**	(−14.2, −1.8)	24.9	−3.7	(−9.7, 2.2)

Note: Table presents estimates of bivariate regression models, with and without adjustment for HRR. Observations are at the hospital level. Regressions are weighted by total ICU occupancy over the sample period. Standard errors are clustered by HRR. ICU strain share is the share of ICU days occurring when a given hospital had an ICU occupancy rate at or above 90%.

Abbreviations: CI, confidence interval; DPP, Disproportionate Payment Percentage; DSH, Disproportionate Share Hospital; FFS, fee-for-service; HRR, hospital referral region; ICU, intensive care unit; marg., marginal; pp, percentage point; pred. Val., predicted value; PRF, Provider Relief Fund; SVI, Social Vulnerability Index.

***p < 0.01. **p < 0.05. *p < 0.10.

TABLE 3 Association of PRF amount per hospital bed (in $1,000s) with hospital characteristics

			Overall			Adjusted for HRR		
		N=	Pred. value	Marg. effect	95% CI	Pred. value	Marg. effect	95% CI
Overall		2,589	$102.2			$102.2		
ICU capacity								
Average occupancy rate	≤74.2% (ref)	2,589	$108.8			$97.9		
	74.2%–85.0%		$119.1	$10.4	(−$11.7, $32.4)	$109.8	$11.9	(−$2.5, $26.4)
	85.1%+		$78.3	−$30.5***	(−$47.0, −$14.0)	$98.7	$0.8	(−$13.0, $14.7)
Average occupancy per 2019 bed	≤86.5% (ref)	2,444	$89.6			$9.6		
	86.7%–143.6%		$100.2	$10.6	(−$3.3, $24.5)	$102.5	$5.9	(−$4.9, $16.7)
	143.6%+		$116.7	$27.2***	($6.9, $47.4)	$107.319	$10.7*	(−$1.5, $22.9)
Socioeconomic characteristics								
Share of FFS Medicare patients Black	<4.2% (ref)	2,578	$90.1			$92.4		
	4.2%–12.3%		$98.5	$8.3	(−$14.6, $31.3)	$95.3	$2.9	(−$13.2, $19.0)
	12.3%–92.0%		$118.0	$27.9***	($8.9, $46.8)	$118.9	$26.5**	($6.2, $46.7)
Share of FFS Medicare patients Hispanic	<1.8% (ref)	2,578	$90.2			$91.5		
	1.8%–6.2%		$100.7	$10.5*	(−$2.0, $23.0)	$97.2	$5.6	(−$12.2, $23.5)
	6.2%–92.1%		$115.6	$25.4	(−$8.7, $59.6)	$117.8	$26.3*	(−$2.0, $54.6)
Average FFS Medicare patient ZIP-code poverty rate	4.6%–12.0% (ref)	2,578	$107.1			$81.7		
	12.0%–15.4%		$96.1	−$11.0	(−$30.8, $8.8)	$102.8	$21.0***	($5.4, $36.7)
	15.4%–42.6%		$103.4	−$3.7	(−$25.4, $18.0)	$122.1	$40.3***	($23.8, $56.9)
DPP index	Not DSH (ref)	2,589	$96.6			$88.6		
	0.09–0.29		$84.9	−$11.6	(−$27.4, $4.2)	$89.0	$0.4	(−$16.7, $17.5)
	0.29–0.39		$91.7	−$4.9	(−$20.5, $10.7)	$96.5	$7.9	(−$8.3, $24.1)
	0.39–1.07		$131.0	$34.4**	($4.2, $64.7)	$123.9	$35.3***	($16.3, $54.2)
Hospital county SVI percentile	<49th (ref)	2,588	$103.9			$94.0		
	49th–69th		$106.7	$2.8	(−$21.0, $26.7)	$102.3	$8.3	(−$7.4, $24.0)
	69th+		$95.8	−$8.1	(−$26.2, $10.0)	$110.2	$16.2**	($0.7, $31.8)
Operational and financial characteristics								
Ownership	Nonprofit (ref)	2,589	$109.5			$103.2		
	For-profit		$36.9	−$72.6***	(−$87.3, −$58.0)	$55.4	−$47.7***	(−$56.7, −$38.8)
	Government		$136.4	$26.9***	($7.9, $45.8)	$144.8	$41.6***	($25.5, $57.7)
Teaching	No (ref)	2,589	$83.0			$97.3		
	Minor		$77.1	−$5.9	(−$15.1, $3.2)	$85.6	−$11.7***	(−$19.5, −$3.8)
	Major		$147.7	$64.6***	($37.0, $92.3)	$125.9	$28.6***	($13.1, $44.1)
Operating margin	<1.8% (ref)	2,550	$133.6			$123.0		
	1.8%–8.8%		$99.3	−$34.4***	(−$51.2, −$17.5)	$101.5	−$21.5***	(−$32.9, −$10.2)
	>8.8%		$77.4	−$56.3***	(−$71.7, −$40.8)	$85.8	−$37.3***	(−$48.6, −$25.9)
Current asset-to-liabilities ratio	<1.4 (ref)	2,542	$98.0			$99.9		
	1.4–2.5		$101.4	$3.4	(−$9.3, $16.1)	$103.2	$3.3	(−$7.9, $14.5)
	>2.5		$111.2	$13.2	(−$3.3, $29.8)	$107.5	$7.6	(−$4.7, $19.8)
Days of cash on hand	<4 (ref)	2,167	$65.8			$75.9		
	4–128		$116.5	$50.6***	($34.3, $67.0)	$112.6	$36.6***	($23.9, $49.3)
	> 128		$119.6	$53.8***	($34.4, $73.2)	$113.3	$37.4***	($22.3, $52.5)

TABLE 3 (Continued)

			Overall			Adjusted for HRR		
		N=	Pred. value	Marg. effect	95% CI	Pred. value	Marg. effect	95% CI
Outpatient share	0.7%–49.5% (ref)	2,549	$82.0			$79.4		
	9.5%–60.4%		$101.5	$19.5**	($2.2, $36.9)	$99.6	$20.2***	($8.1, $32.3)
	60.4%–99.7%		$126.9	$44.9***	($27.9, $61.9)	$131.5	$52.2***	($41.3, $63.0)

Note: Table presents estimates of bivariate regression models, with and without adjustment for HRR. Observations are at the hospital level. Regressions are weighted by total ICU occupancy over the sample period. Standard errors are clustered by HRR. ICU strain share is the share of ICU days occurring when a given hospital had an ICU occupancy rate ≥90%.
Abbreviations: CI, confidence interval; DPP, Disproportionate Payment Percentage; DSH, Disproportionate Share Hospital; FFS, fee-for-service; HRR, hospital referral region; ICU, intensive care unit; marg., marginal; pred., predicted; PRF, Provider Relief Fund; SVI, Social Vulnerability Index.
***$p < 0.01$. **$p < 0.05$. *$p < 0.10$.

[$p < 0.10$]); none of the remaining results were statistically significant. Appendix Exhibit 7 presents results from regression models that separately adjust for different hospital characteristics to identify factors that individually explain a relatively large share of the association between Black patient shares and ICU strain. Adjusting for average patient ZIP-code poverty rate, teaching status, and days of cash on hand led to the largest decreases in Black patient share point estimates.

3.5 | Association of PRF allocations with hospital characteristics

Table 3 presents regression results that assess the association of PRF amount per hospital bed with ICU strain, patient composition, and other hospital characteristics. Providing high versus low levels of ICU care relative to baseline capacity was associated with greater PRF amounts per hospital bed ($27,160, a 30% difference [$p < 0.01$]), but the opposite was true when comparing hospitals with high versus low levels of ICU strain relative to contemporaneous beds (−$30,524, a 28% difference [$p < 0.01$]). This pattern was concentrated among PRF allocations made before the third wave (Appendix Tables A8 and A9). After adjusting for HRR, the former association was smaller ($10,692 [$p < 0.10$]) and the latter association was close to $0 and no longer statistically significant. Neither within-HRR association was statistically significant when separately evaluating PRF allocations made before and starting with the third wave (Appendix Tables A8 and A9). Having a high versus low Black patient share was associated with greater PRF amounts per hospital bed overall ($27,853 [$p < 0.01$]) and after adjusting for HRR ($26,457 [$p < 0.05$]), while having a high versus low Hispanic patient share was associated with greater relief only after adjusting for HRR ($26,276 [$p < 0.10$]).

Among other hospital characteristics, we found that the following had a statistically significant and positive association with PRF amounts per hospital bed: high DPP indices versus non-DSH hospitals ($34,422 [$p < 0.05$]), government versus nonprofit and nonprofit versus for-profits ownership ($26,893 [$p < 0.01$] and $72,624 [$p < 0.01$], respectively), major versus non-teaching hospitals ($64,648 [$p < 0.01$]), low versus high operating margins ($56,261 [$p < 0.01$]), high versus low days of cash on hand ($53,785 [$p < 0.01$]), and high versus low outpatient revenue shares ($44,933 [$p < 0.01$]). After adjusting for HRR, these results retained statistical significance and the same sign, and there were also positive and statistically significant associations with average patient ZIP-code poverty rates and county-level SVI.

Appendix Table A10 presents results from multivariable regression analyses. When focusing on within-HRR analyses, observed hospital characteristics explained most of the positive association between PRF allocations and Black patient shares. In particular, controlling for these variables reduced the high versus low Black patient share point estimate from $26,457 to $7,513 (a 72% decline) (see Appendix Table A10 vs. Table 2). The Hispanic patient share point estimate decreased by a smaller amount (from $26,276 to $20,739) but also lost statistical significance. PRF allocations per bed were positively associated with average ZIP-code poverty rates ($20,004 [$p < 0.05$]) and outpatient revenue shares ($39,770 [$p < 0.01$]) and negatively associated with operating margins (−$12,438 [$p < 0.05$]); other associations were not statistically significant.

Appendix Table A11 identifies the extent to which different hospital characteristics explain the positive association between PRF allocations and Black and Hispanic patient shares. Adjusting for average patient ZIP-code poverty rate, DPP index, or teaching status approximately halved the Black patient share point estimate. Adjusting for all three more than explained the positive association with Black patient shares and reduced the Hispanic patient share point estimate by 82%. Adjusting for outpatient share alone slightly increased the Black and Hispanic patient share point estimates. Finally, adjusting for average ICU occupancy rates did not substantially affect Black or Hispanic patient share point estimates. In other words, although higher Black patient shares were associated with greater levels of ICU strain, disparities in ICU strain were not driving differences in relief fund allocations based on patient racial and ethnic composition.

4 | DISCUSSION

We found that over one quarter (26%) of ICU days occurred in hospitals with strained capacity during the third through fourth waves of the COVID-19 pandemic, with higher levels of burden in hospitals caring for a disproportionate share of Black patients. We observed disparities relating to Black patient shares when looking at the nation as a whole, as well as when comparing across hospitals within a given region. ICU strain would have been much higher—and disparities would have been greater—had hospitals not substantially expanded ICU capacity over 2019 levels. Although this study focuses on ICU occupancy rates, expanding capacity itself has stressed facility operations and may have negatively affected quality. For example, to accommodate COVID-19 surges, hospitals have had to expand care into nontraditional spaces (e.g., by adding beds to hallways), hire temporary staff, and operate without adequate supplies and staff.[41–43]

Our findings align with a recent study which also observed inequities in hospital strain. The authors found that ICU strain was much more common among hospitals in counties with high versus low SVI, which was driven by differences in socioeconomic, race and ethnicity, and language component measures.[15] We expanded upon this work by incorporating data on the socioeconomic patient composition of hospitals. Beyond offering a more granular view of inequities across hospitals, this allowed us to evaluate whether disparities persisted when comparing facilities within a given region, which we found to be the case. Another contribution of our work is that we analyzed additional months of data, covering a period of dramatic change in the dynamics of the pandemic.

Our findings also align with a separate study that found large disparities in COVID-19 inpatient mortality rates relating to the hospitals where Black and White patients received their care.[44] Differences across hospitals may reflect underlying disparities in quality, as well as an unequal distribution of COVID-19 strain. These results align with research predating the pandemic which also found disparities in quality based on where patients received their care.[45–48] Another recent study found evidence of disparities in COVID-19 inpatient mortality rates among Hispanic versus White Medicare patients after accounting for the hospital where beneficiaries received their care, which may reflect differences in comorbidities, social determinants of health, or provider bias.[49] Other studies evaluating COVID-19 inpatient mortality rates have not found statistically significant disparities but have relied on smaller sample sizes, often focusing on a single health care system.[50]

Our finding that there were significant disparities in ICU strain within regions suggests an important role for policy intervention. Indeed, the HHS Office of the Assistant Secretary for Preparedness and Response released guidance for state and local policymakers and stakeholders to create centralized coordination centers which would facilitate the transfer of patients from strained hospitals to facilities with greater capacity (a process known as "load-balancing").[51] These initiatives involve monitoring bed availability across a region and intervening to ensure load balance, such as by directing ambulance traffic to hospitals with lower occupancy rates, overseeing patient referrals, and mandating that hospitals accept patients from strained facilities.[51] Some regions have already established coordination centers, which could serve as models for other areas.[52]

Another policy intervention to reduce inequities and ameliorate hospital strain would be to direct additional relief to overwhelmed facilities, especially those that have limited resources and may have difficulty expanding capacity. We found that having high versus low ICU occupancy relative to baseline capacity was associated with greater PRF amounts per hospital bed. However, after adjusting for region, relief funds were only 11% greater for hospitals that were operating at high rates relative to baseline capacity. In addition, having high versus low ICU occupancy relative to contemporaneous beds was associated with less federal relief and no statistically significant difference in funding after adjusting for HRR. Our finding that PRF allocations were positively associated with outpatient revenue shares—an indicator of susceptibility to COVID-19-related revenue loss—highlights a potential tension in federal relief: policymakers may want to target assistance to hospitals providing substantial amounts of care as well as to hospitals that have lost revenue during the pandemic, which may be two very different sets of facilities.

We found mixed results when assessing the equity of PRF allocations. For example, when comparing facilities within HRRs, having a high versus low Black patient share was associated with $26,457 in additional PRF funds per bed. Adjusting for the DPP index—which was used to allocate a portion of PRF funds—explained about half of this association. Nonetheless, our results suggest that some aspects of PRF funding may have had inequitable effects. For example, having fewer days of cash on hand was associated with smaller PRF allocations. Other studies have also evaluated the relationship between PRF allocations with hospital characteristics and found collectively that relief funds are positively associated with some measures of need (e.g., high Medicaid patient revenue shares and patient ZIP-code Black resident shares), but negatively associated with others (e.g., low days of cash on hand and high patient ZIP-code Hispanic resident shares).[23–25]

These findings suggest that policymakers may want to further elucidate the objectives of relief programs and identify more targeted ways to achieve these goals during future public health crises. For example, Grogan et al. recommended that policymakers explicitly evaluate whether given funding criteria would ameliorate or exacerbate racial and ethnic disparities.[25] Indeed, we found evidence that distributing funds on the basis of lost revenues—using outpatient revenue shares as a proxy—may have reduced the share of funds that went to hospitals with high versus low Black and Hispanic patient shares. Policymakers may also want to consider explicitly earmarking relief to hospitals that have or are at high risk of experiencing strained capacity. Although the PRF program distributed some funding based on COVID-19 caseloads and other criteria that may relate to strained capacity, our findings suggest that there is room for improvement in targeting relief funds.

Our study has limitations. First, our data on patient composition are restricted to FFS Medicare beneficiaries. That said, this is an important population, especially in the context of COVID-19-related severe illness. FFS Medicare accounts for the majority of Medicare beneficiaries (58% in 2021) and, as of January 2022, individuals ages 65 and older alone accounted for nearly three-quarters (74%) of COVID-19 deaths.[53,54] Second, our approach to matching PRF allocations with hospitals was imperfect, given that the data did not include standardized identifiers. We were able to match $71 of $118 billion in PRF awards during our sample period to hospitals, with positive allocations for 89% of short-term, Medicare-certified hospitals. The remaining $47 billion includes funding for other hospital and provider types but may also include allocations for hospitals in sample that we were unable to identify. It is difficult to know the extent of missing data and to anticipate whether data are systematically missing for certain types of hospitals in a manner that could bias our results. Third, ICU occupancy and capacity data were reported by hospitals in the midst of the pandemic. It is therefore conceivable that these data are incomplete, though we are not aware of comparable data about ICU strain with the same level of breadth. Fourth, our analysis focused on hospitals with ICU beds and therefore omitted most critical access hospitals. It will be crucial for future research to evaluate the experiences of these facilities given their unique vulnerabilities. Finally, our analysis is restricted to the third and fourth waves of an ever-changing pandemic. As with most COVID-19 research, it will be important to evaluate whether these results hold over time. Nonetheless, it is conceivable that disparities in strain may persist over time to the extent that hospitalization rates continue to be higher among Black individuals in the context of a segregated health care system.

To summarize, hospitals with large Black patient shares experienced greater strain during the pandemic. This effect held when comparing hospitals within the same region. Although these hospitals received more federal relief, funding was not targeted overall toward hospitals with high ICU occupancy rates. Policymakers seeking to relieve hospital strain and reduce inequities could implement programs to facilitate patient sharing across hospitals and better target PRF allocations toward hospitals in need.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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