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Is pre-pandemic hospital quality associated with hospitals' ability to respond to the COVID-19 pandemic?

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Is pre-pandemic hospital quality associated with hospitals' ability to respond to the COVID-19 pandemic?

Examining associations between risk-adjusted mortality for patients hospitalized with COVID-19 and pre-COVID hospital quality.

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Patient and public involvement**:** Patients and/or the public were not involved in the design, conduct, or reporting, or dissemination plans of this research.

Data availability statement
Raw claims data used to calculate hospital-level risk-standardized mortality rates are not publicly available, but researchers can request this data from CMS through a data vendor (ResDAC); Star Ratings data, hospital characteristics file (CMS Place of Service) and COVID utilization files are publicly available.

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Abstract

Objectives

The extent to which care quality influenced outcomes for hospitalized COVID-19 is unknown. Our objective was to determine if pre-pandemic hospital quality is associated with mortality among Medicare patients hospitalized with COVID-19.

Design

This is a retrospective observational study. We calculated hospital-level risk-standardized in-hospital and 30-day mortality rates (RSMRs) for patients hospitalized with COVID-19, and correlation coefficients between RSMRs and pre-COVID hospital quality, overall and stratified by hospital characteristics

Setting

Short-term acute-care hospitals in the United States.

Participants

Hospitalized Medicare Beneficiaries (Fee-For-Service and Medicare Advantage) age 65 and older hospitalized with COVID-19, discharged between April 1, 2020-September 30, 2021.

Intervention/Exposure

Pre-COVID hospital quality.

Outcomes

Risk-standardized COVID-19 in-hospital and 30-day mortality rates (RSMRs).

Results

In-hospital (n=4,256) risk-standardized mortality rates (RSMRs) for Medicare patients hospitalized with COVID-19 (April 2020-September 2021) ranged from 4.5% to 59.9% (median,18.2%; interquartile range [IQR]: 14.7%-23.7%); 30-day RSMRs ranged from 12.9% to 56.2% (IQR: 24.6%-30.6%). COVID-19 RSMRs were negatively correlated with Star Rating summary scores (in-hospital RSMR correlation coefficient: -0.41, $p<0.0001$; 30-day RSMR: -0.38, $p<0.0001$). Correlations with in-hospital RSMRs were strongest for Patient Experience (-0.39, $p<0.0001$) and Timely and Effective Care (-0.30, $p<0.0001$) group scores; 30-day RSMRs were strongest for Patient Experience (-0.34, $p<0.0001$) and Mortality (-0.33, $p<0.0001$) groups. Patients admitted to 1-star hospitals had higher odds of mortality [in-hospital OR=1.87, 95% (CI 1.83 -1.91); 30-day OR=1.46, 95% (CI 1.43-1.48)] compared with 5-star hospitals. If all hospitals performed like an average 5-star hospital, we estimate 38,000 fewer COVID-related deaths would have occurred within 30 days of admission between April 2020-September 2021.

Conclusions

Hospitals with better pre-pandemic quality may have care structures and processes that allowed for better care delivery during the COVID-19 pandemic. Understanding the relationship between pre-COVID hospital quality and COVID-19 outcomes will allow policymakers and hospitals to better prepare for future public health emergencies.

Strengths and Limitations

- This study provides data on risk-standardized COVID-19 outcomes from more than a million Medicare beneficiaries and hospital quality for more than four thousand hospitals across the United States and uses a comprehensive and publicly reported measure of hospital quality to assess pre-COVID hospital readiness/resilience.

- This study is based on an analysis of claims data and therefore is subject to the limitations of the proper coding of principal and secondary diagnoses.
- Because of limitations in data availability, we could not include assess the impact of COVID-19 vaccination on the results.

Introduction

Prior to the COVID-19 pandemic, and despite struggles to respond to an earlier flu epidemic, hospitals likely did not prioritize preparation for a future pandemic [1]. This lack of adequate preparation likely contributed in part to the death of more than a million people in the United States alone. As the World Health Organization (WHO) and the United States, and Europe consider the risk of future pandemics [2] it is important to understand how to identify hospitals in need of better preparedness for future public health emergencies.

During normal operations, high-quality hospitals can deliver evidence-based, timely, patient-centered, and equitable care when adequately staffed with high-quality workers who can support good communication [3]. High-quality hospitals have better patient outcomes, including lower risk-standardized mortality rates, for specific conditions (such as pneumonia and heart failure) and specific procedures (such as heart surgery), and evidence shows that care quality for one condition is associated with care quality for other conditions [4]. Therefore, during normal operations, structures and processes of care may transfer across teams and patients, however we do not know if this is true during a major stressor such as a pandemic.

During a pandemic, resilient hospitals may be able to continue to deliver high quality care despite the stressor. Research suggests that some of the same characteristics associated with high quality during normal operations, such as communication and adherence to evidence-based processes, are also associated with readiness/resilience [5-7]. We therefore hypothesized that pre-pandemic hospital quality could be a marker of hospital readiness/resilience, and that hospitals with higher quality prior to the pandemic would be more likely to be able to respond to the pandemic and translate the same structures and processes across care teams and patients, resulting in better patient outcomes. To test this hypothesis, we first developed a measure of hospital response to the pandemic (ability to deliver high quality care as measured by patient outcomes), by calculating hospital-level risk-standardized COVID-19 mortality rates among patients hospitalized with COVID-19 (COVID-19 RSMRs). We then explored the relationship between a marker of pre-COVID hospital quality (the hospital summary score used to calculate CMS's Overall Hospital Star Rating – hereafter "Star Rating summary score" –and its components) and COVID-19 RSMRs. We stratified the association between pre-COVID hospital quality and COVID outcomes by hospital characteristics and explored the relationship between COVID outcomes and hospital COVID burden.

METHODS

Data Sources

We used administrative claims data from the Center for Medicare and Medicaid Services (CMS) that included patients diagnosed with COVID-19 who were admitted to hospitals in the United States and its territories between April 1, 2020, and September 30, 2021. We used the CMS Provider of Services files to obtain hospital characteristics [8]. To examine the impact of the level of hospital "COVID burden" on these results, we used hospital-reported data provided to the public by The U.S. Department of Health and Human Services (HHS) [9].

Study Cohort

We examined all Medicare Fee-for-Service (FFS), and Medicare Advantage (MA) hospital-submitted inpatient admission claims with a principal or secondary (present on admission) discharge diagnosis of COVID-19 (ICD-10 code U07.1) for patients discharged from an acute care or Critical Access Hospital (CAH) between April 1, 2020, to September 30, 2021.

Measures of Pre-COVID Hospital Quality and COVID burden

To characterize pre-COVID hospital quality, we used the Star Rating summary score (April 2021 release) used to calculate CMS' Overall Hospital Quality Star Rating on *Care Compare,* which summarizes existing hospital quality information by assigning hospitals 1-5 stars based on their performance in measures within groups (Appendix, Figure 1A). Version 4.0 categorizes measures into 5 groups – Mortality (7 measures), Readmission (11), Safety of Care (8), Patient Experience (8), and Timely and Effective Care (14) [10,11]. Summary scores are calculated using a weighted average of group scores and Star Rating categories are assigned based on hospitals' summary scores. All quality measures included in this analysis used performance data prior to 2020 (Appendix, Table 1A). Hospitals with insufficient data for a star rating are not included in the analyses of associations. We calculated hospital COVID-19 burden as the weekly average number of laboratory-confirmed COVID-19 hospitalizations for all adult patients (not limited to Medicare patients) divided by the number of hospital beds.

Outcome Assessment

We calculated hospital-level risk-standardized mortality rates for COVID-19 patients (Risk-Standardized Mortality Rates [RSMRs]; in-hospital and within 30-days from the date of admission) using hierarchical logistic regression models [12-15]. The models adjust for components of the Charlson Comorbidity Index, including age (Appendix, Table 2A) [16]. The commonly used Charlson Comorbidity Index calculates a risk score for each patient using 19 International Classification of Diseases (ICD) diagnosis codes from administrative data. Hospital RSMRs are the ratio of a hospital's "predicted" to "expected" mortality, multiplied by national observed mortality rate. The approach simultaneously models data at patient and hospital levels to account for the variation in mortality within and between hospitals [17].

Statistical Analyses

We calculated volume-weighted Pearson correlations to evaluate associations between hospital-level RSMRs and pre-COVID quality (Star Rating summary and group scores), and stratified correlations by hospital characteristics. We calculated these associations for each hospital with a Star Rating summary score, and for each hospital with a group score (see Figure 1, Table 3, and Table 4 for the number of hospitals in each category). For sensitivity analyses, we limited our sample to hospitals with ≥25 COVID-19 patients and re-calculated results after removing hospitals with the 20 highest and lowest 30-day RSMRs (based on the distribution of outliers) to explore the impact of COVID-19 on RSMR outliers. In addition, we repeated the analyses limiting the data period to the early pandemic (from March 2020 to September 2020) to assess if associations between Star Rating summary scores and COVID-19 mortality rates differed earlier in the pandemic. We then examined correlations between COVID-19 RSMRs and the Star Rating summary score and each of its components (group scores), as well as between COVID-19 RSMRs and COVID burden, calculated as the weekly average number of laboratory-confirmed COVID-19 hospitalizations for all patients (not limited to Medicare patients) divided by the number of hospital beds. To estimate the number of deaths that might be attributable to care in a lower-quality hospital, we applied the mean COVID-19 RSMR for hospitals within the 5-star ratings category to the total number of patients admitted to the hospital with COVID-19 between April 1, 2020, and September 30, 2021, and subtracted that value from the total (observed) number of patients admitted with COVID-19 who died within 30-days.

To examine the impact of COVID-19 hospitalization volume we examined results for hospitals with at least 25 COVID-19 patients. As a sensitivity analysis to determine the impact of outliers on the observed associations, we re-calculated correlation coefficients (among all hospitals) after removing hospitals with the 20 highest and 20 lowest 30-day COVID-19 RSMRs, and the 20 highest and 20 lowest Star Rating summary scores. To examine the adequacy of risk adjustment using the CCI, we calculated the c-statistic for both in-hospital and 30-day mortality models.

All analyses used SAS Enterprise Guide and SAS 9.4 and were performed by two authors (SXL and YW).

RESULTS

Variation in hospital-level COVID-19 RSMRs and Stratification by Hospital Characteristics

Between April 1, 2020, and September 30, 2021, 1,229,071 Medicare Beneficiaries were with a diagnosis of COVID-19 were admitted to 4,343 U.S hospitals. Among those admitted patients, 230,358 (18.7%) died in the hospital, and 338,358 patients (27.5%) died within 30 days of admission. Patient characteristics are shown in Table 1.

At the hospital level, we found striking variation in risk-standardized mortality rates (RSMRs). Among the 4,343 hospitals with at least one COVID-19 patient, in-hospital RSMRs ranged from 4.5% to 59.9%; the median in-hospital RSMR was 18.2% (interquartile range [IQR]: 14.7%-23.7%). 30-day RSMRs also varied widely, from 12.9% to 56.2% (IQR: 24.6%-30.6%). Results were similar for hospitals with at least 25 cases.

In-hospital RSMRs differed by hospital characteristic. Mean in-hospital RSMRs were significantly (p<.0001) higher in the following: urban hospitals (vs. rural), hospitals with more (vs. fewer) beds, teaching hospitals (vs. non-teaching hospitals), hospitals not designated as CAHs (vs. CAHs) and for-profit (vs. non-profit or government owned) hospitals (Table 2). Differences in mean in-hospital mortality rates between hospitals in different nurse-to-bed ratios were small. Differences in 30-day RSMRs by hospital characteristic were also small but statistically significant except for urban vs. rural where the difference was not significant (Table 2). Results were similar for hospitals with at least 25 cases.

To determine if the level of COVID-19 burden might explain these results, we examined the association between hospital-level COVID burden calculated using weekly hospital-reported COVID-19 utilization data (see Methods), and COVID-19 RSMRs. We found, however, only a weak relationship: the Pearson correlation coefficient was -0.04, (p=0.01) for in-hospital RSMRs, and -0.03 (p=0.03) for 30-day RSMRs.

Association between pre-COVID-19 hospital quality and hospital-level COVID-19 RSMRs

We examined how COVID-19 RSMRs differed by pre-COVID-19 hospital quality as defined by Star Rating category (1-star through 5-star). When hospitals were stratified by Star Rating category we found that in-hospital and 30-day RSMRs were systematically lower (better) with each increase in Star Rating category: For example, mean in-hospital RSMRs were 28.1% for 1-star hospitals (N=201) vs. 18.0% for 5-star hospitals (N=409); mean 30-day RSMRs were 32.1% for 1-star hospitals vs. 24.5% for 5-star hospitals (Table 2). Patients admitted to 1-star hospitals had higher odds of in-hospital (OR=1.87, 95% CI 1.54 to 1.62) and 30-day mortality (OR=1.46, 95% CI 1.31 to 1.39), compared with patients admitted to 5-star hospitals, after adjusting for the Charlson comorbidity index which includes age (see Appendix Table 2A).

We then calculated Pearson correlation coefficients between pre-COVID Star Rating performance (summary scores and the five individual measure group scores) and COVID-19 RSMRs with April 2020 through September 2021 data, near the peak of the Delta variant wave in the United States. Star Rating summary scores among 4,256 hospitals in our analysis were moderately inversely correlated with in-hospital (-0.41, p<0.0001) and 30-day (-0.38, p<0.0001) RSMRs (Figure 1). For in-hospital RSMRs, the Patient Experience and Timely and Effective Care group scores showed the strongest associations (-0.39, p<0.001; -30, p<0.0001, respectively). For 30-day RSMRs, Patient Experience and Mortality group scores showed the strongest associations (-0.34, p<0.0001; -0.33, p<0.001, respectively). When we limited our analyses of the associations between Star Rating summary scores and RSMRs in the early pandemic period (March 2020 through September 2020), the relationship between 30-day RSMRs and Star Rating Mortality group scores was weaker (Pearson correlation coefficient, -0.12, p<0.0001) compared with the 18 month period of this study (Pearson correlation coefficient -0.34, p<0.0001) (data not shown).

In stratified analyses by hospital characteristics, stronger correlations were seen between 30-day hospital RSMRs and the Star Rating summary score and its component group scores for: larger vs. smaller bed-size hospitals (-0.43 for hospitals with 400+ beds vs. -0.22 for hospitals with 1-99 beds), hospitals with academic affiliation vs. without (-0.46 vs. -0.32), hospitals in urban vs. rural locations (-0.41 vs. -0.21, respectively), government and not-for-profit hospitals vs. for-profit (-0.59 and -0.45 vs. -0.11, respectively), and non-CAH vs CAH (-0.39 vs. -0.13, respectively); differences by nurse-to-bed ratio categories were small (Table 3). Differences by hospital characteristic for in-hospital RSMRs were generally smaller compared with observations for 30-day RSMRs (Table 4).

To examine the impact of COVID-19 hospitalization volume we examined results for hospitals with at least 25 COVID-19 patients; we found that among the 3,405 hospitals that met these criteria, results were similar (data not shown) to results with hospitals with at least one COVID-19 hospitalization. As a sensitivity analysis to determine the impact of outliers on the observed associations, we re-calculated correlation coefficients (among all hospitals) after removing hospitals with the 20 highest and 20 lowest 30-day COVID-19 RSMRs, and the 20 highest and 20 lowest Star Rating summary scores and found the correlation was similar (-0.40, p<0.0001, n=4,196 hospitals). Finally, c-statistics for the in-hospital and 30-day mortality models were 0.609 and 0.663, respectively, demonstrating adequate risk adjustment for the purposes of this study.

DISCUSSION

Using data from a representative sample of more than 1.2 million COVID-19-associated hospitalizations of Medicare Beneficiaries across more than 4,300 hospitals, risk-standardized 30-day mortality rates were associated with pre-COVID-19 hospital quality. Associations were stronger in quality domains associated with communication and the use of processes. A potential explanation for the observed association between pre-COVID-19 hospital quality and COVID-19 outcomes is that hospitals may have been able to transfer those effective care structures and processes used during normal operations to the care of patients with COVID-19 during the pandemic. Pre-COVID-19 hospital quality also reflects, at least in part, a hospital's readiness/resilience to respond to stressors and provide high-quality care under stress. In our study, differences in hospital readiness, as measured by pre-COVID-19 hospital quality, had serious consequences; on average, a patient admitted to a lower-quality (1-star hospital) was 87% and 46% more likely to die in the hospital and within 30 days, respectively, compared with a patient admitted to a higher quality (5-star) hospital (absolute differences of 11 percentage points for in-hospital and 7.6 percentage points for 30-day mortality).

This study has some important strength and limitations. The strengths of this study include that it represents COVID-19 outcomes from more than a million Medicare beneficiaries and hospital quality for more than four thousand hospitals across the United States. In addition, we calculated risk-standardized mortality rates to assess patient outcomes. Our study also used a comprehensive and publicly reported measure of hospital quality to assess pre-COVID hospital readiness/resilience. We also examined, as a potential confounder, hospital-level COVID-19 burden.

This study has the limitations of any observational study, including that no direct causal relationship can be attributed to the associations between hospital quality and mortality rates for patients hospitalized with COVID-19. In addition, RSMRs were adjusted for age and comorbidities, we did not include a time variable in the risk model, although we did examine associations during the early and later part of the pandemic and did not see marked differences except for the association with the pre-COVID-19 Mortality group score and COVID-19 RSMRs. Because hospital-level COVID-19 burden became available starting in August 2020, we were not able to include it in the risk model. Therefore, while the results do not directly assess the confounding effect of COVID-19 burden on the associations between pre-COVID hospital quality and COVID-19 RSMRs, we did examine the associations between hospital-level COVID burden with both the outcome (COVID-19 RSMRs) and the exposure (pre-COVID Star Rating). Because burden was not substantially related to either the exposure or outcome, we expect this variable would not be an important confounder in the associations. In addition, we were not able to explore the relationship between these observations and a patient's vaccination status, due to lack of reliable patient-level data within claims; ICD-10 vaccination status code became effective April 1, 2022. Finally, COVID-19 mortality rates were calculated with Medicare Advantage and Medicare FFS claims for patients aged 65 and older; most of the measures in Star Rating are based on Medicare FFS patients.

Our results are, in part, consistent with and extend upon the findings of other work examining drivers of mortality rates in patients admitted to ICUs at 70 hospitals between March and June of 2020. Study authors found that at the patient level, while most of the variation in mortality (70%) was explained by the physiology of the patient at ICU admission, demographics (primarily age) and comorbidities, hospital quality (among other hospital factors) was also a contributing factor [23]. The findings from our work expand this observation by examining hospital-level associations with quality not limited to the ICU, to all patients diagnosed with COVID-19 over an 18-month period for more than a million patients at over four thousand hospitals.

Our findings suggest that quality domains such as communication (represented by the Patient Experience group score), and quality domains tied more closely to processes and checklists (reflected within the Timely & Effective Care and Mortality group scores) are associated with better outcomes in patients hospitalized with COVID-19. During regular operations, the development of, and adherence to, evidence-based care processes that are tied to better outcomes is a hallmark of high quality-hospitals [18-21], and it is possible that hospitals that were able to rapidly translate those capabilities were better positioned to care for patients hospitalized with COVID-19.

The outcome variation and association found in this work cannot likely be tied to any single care process or outcome and was beyond the scope of national data available. For example, one study found wide variation in adherence to ARDS protocols for patients with COVID-19 and while not statistically significant, hospitals with better protocol adherence had lower mortality rates [22]. Concentrating expertise and processes in a single setting may also have been an effective protocol; patients admitted to hospitals dedicated to the care of COVID-19 patients had better outcomes compared with hospitals that did not specialize [23].

There are many other hospital-level factors that may have influenced even a prepared hospital's ability to respond to the pandemic. For example, one study found that after controlling for other factors, ICU patients in hospitals with a higher proportion of patients with social risk factors had worse outcomes [24]. In our study we found that urban location, larger bed size, teaching affiliation, and government or non-profit ownership had a stronger association between worse performance on Star Rating summary scores and higher 30-day COVID-19 RSMRs. Several of these characteristics are also associated with a larger proportion of patients with social risk factors but could also reflect differences in the geographic impact of COVID-19 over time. In addition, urban location, larger bed size, and teaching affiliation are often overlapping characteristics, and urban areas were early pandemic hotspots. Another study, however, did not find an association between academic status, profit status, or urban/non-urban setting and hospital RSERs during the first six months of the pandemic [25].

Another potential explanation for our findings could be that hospitals with better quality during normal operations also have more care quality-independent resources (e.g., financial resources) and those hospitals may have been able to pivot those resources to provide better care for patients with COVID-19, or to better care for their staff through purchase of supplies such as PPE. If this were true, one might predict that if resources were limited, hospital performance would decline as the level of COVID-19 burden increased. However, there is mixed evidence (from this work, and others) for the relationship between hospital-level COVID-19 mortality and measures of hospital and/or community level COVID-19 burden and differences between the association early vs. later in the pandemic [24-29]. In our study we found only a weak association between hospital-level mortality in patients hospitalized with COVID-19 and hospital-level COVID burden, defined by the total number of hospitalized patients with COVID divided by the number of hospital beds. Taken together, the evidence suggests that the capacities of hospitals to manage large patient loads may not have been a defining characteristic or may have been important mainly in the very early months of the pandemic. Future studies using additional measures (such as processes of care), additional data sources, including data from electronic health records and financial records, and data from multiple time points during and before the pandemic may help tease out the underlying drivers of the associations between pre-pandemic quality and outcomes for patients hospitalized with COVID-19.

CONCLUSION

Across a national sample of hospitals, we found that pre-pandemic hospital quality is associated with COVID-19 hospitalization outcomes suggesting that hospital quality on common care may be a marker of hospital readiness/resilience to respond to a stress/shock such as COVID-19. Hospitals with better pre-pandemic quality may have been able to better translate care structures or processes used during normal operations into better care for patients during the COVID-19 pandemic. These results can help policy makers at the local, state, and federal level plan for future challenges, and can help hospital leadership assess their readiness/resilience for a future pandemic.

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Contributors: MS, SL, ET, YW, and DP contributed to the conception and design of the study; JZ provided assistance with data access and management; YW and SL performed all analyses. DP drafted the manuscript. ET, AKV, JG and ZL contributed critical additions and conceptual revisions to the manuscript; LF and LGS assisted with interpretation of results; SB, EN, and KW were involved in the development of Star Ratings. DP serves as guarantor of the study.

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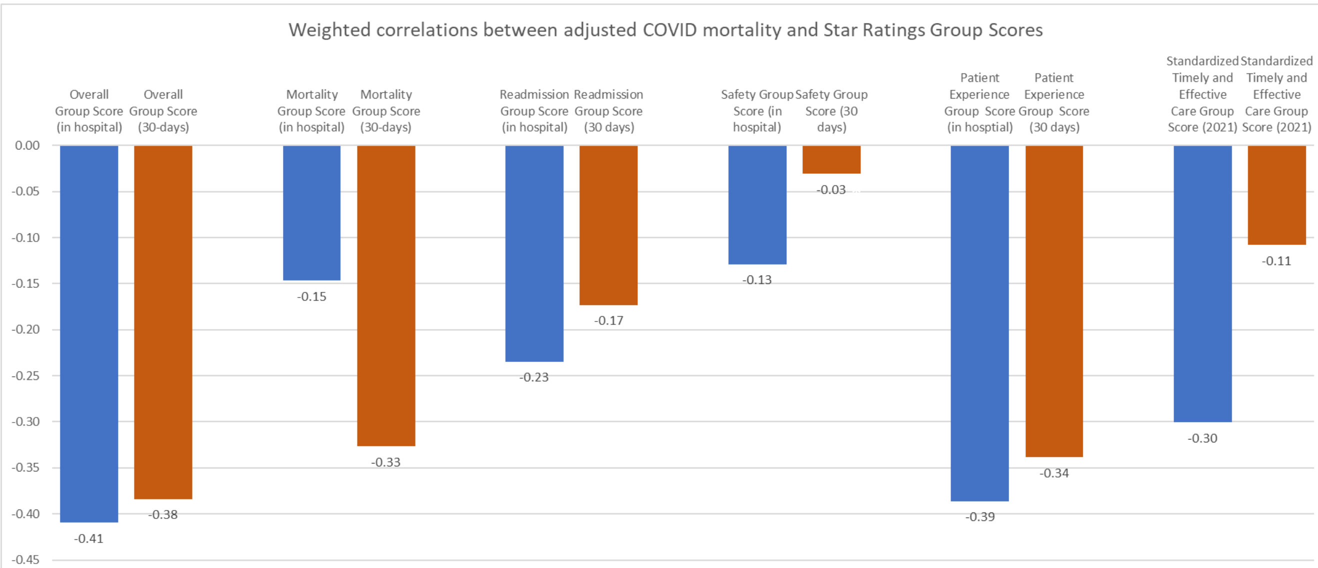
Table 1: Patient characteristics (number and frequency of Charlson comorbidity index variables)

Characteristic	Number	Percent
All	**1,229,071**	**100.00**
Age (mean, std)	77.8 (8)	--
Myocardial Infarction	150,083	12.21
Congestive Heart Failure	7,913	0.64
Peripheral Vascular Disease	95,170	7.74
Cerebrovascular Disease	85,694	6.97
Dementia	250,869	20.41
Chronic Pulmonary Disease	1,270	0.10
Connective Tissue Disease-Rheumatic Disease	42,123	3.43
Peptic Ulcer Disease	10,457	0.85
Mild Liver Disease	38,593	3.14
Diabetes without complications	375,261	30.53
Diabetes with complications	261,863	21.31
Paraplegia and Hemiplegia	16,228	1.32
Renal Disease	365,593	29.75
Cancer	68,182	5.55
Moderate or Severe Liver Disease	7,877	0.64
Metastatic Carcinoma	18,038	1.47
AIDS/HIV	1,130	0.09

Table 2. Mean Risk-Adjusted COVID-19 RSMRs by Hospital Characteristics (for hospitals with >=1 COVID admission) between April 1, 2020, and September 30, 2021.

Hospital Characteristic	Number of Hospitals	Mean In-Hospital RSMR (%)	SD (%)	Mean 30-Day RSMR	SD (%)
All Hospitals	4,343	19.7	7.3	27.8	4.9
Hospitals in Rural Area					
Rural	1,765	17.4	5.6	27.7	4.5
Urban	2,555	21.3	7.8	27.9	5.2
Bed Size					
1 to 99	2,078	16.7	5.4	27.3	4.3
100 to 199	792	21.0	7.9	28.4	5.5
200 to 299	502	22.8	7.3	28.5	5.1
300 to 399	364	23.6	8.1	28.7	5.5
400+	584	23.6	7.0	27.6	5.4
Teaching Status					
Teaching	1,180	22.2	7.5	27.7	5.3
Non-teaching	3,139	18.8	6.9	27.8	4.8
Critical Access Status					
Critical Access	1,256	16.2	4.3	27.1	3.6
Not Critical Access	3,064	21.2	7.7	28.1	5.4
Nurse-to-Bed Ratio					
<1	1,914	19.5	7.4	28.3	4.9
1 to <2	1,858	20.1	7.3	27.7	5.0
2+	548	19.0	6.4	26.6	4.6
Ownership					
Government	981	19.1	6.7	28.0	4.7
Not-For-Profit	2,648	19.5	7.0	27.2	4.8
For-Profit	690	21.5	8.5	29.8	5.2
Star Rating Category					
1-Star	201	29.1	8.8	32.1	5.5
2-Star	685	24.3	7.2	29.6	4.9
3-Star	1,002	22.8	6.5	28.5	4.8
4-Star	979	20.7	6.3	26.7	4.7
5-Star	449	18.0	5.8	24.5	4.9

Figure 1: Volume-Weighted Correlations between pre-COVID Hospital Quality Star Rating Summary Scores and In-hospital and 30-day Risk-Standardized COVID-19 Mortality Rates (RSMRs)



Blue bars represent correlation coefficients for in-hospital COVID-19 RSMRs and orange bars represent correlations for 30-day RSMRs.

All p-values are <0.0001.

The number of hospitals that qualified for analysis in each category are as follows: Summary score, n=4,256; Mortality Group score n=3,934; Readmission group score, n=4,182; Safety of Care group score, n=3,401; Patient Experience group score, n=3,198; Timely and Effective Care Group score, n=4,202.

Table 3: Hospital Characteristics and Correlation Between Star Rating Summary Scores and 30-day COVID-19 RSMRs

	Overall Group Score	Mortality Group Score	Readmission Group Score	Safety Group Score	Patient Experience Group Score	Standardized Timely and Effective Care Group Score
All Hospitals	-0.38 (4,256)	-0.33 (3,934)	-0.17 (4,182)	-0.03 (3,401)	-0.34 (3,318)	-0.11 (4,202)
Rural	-0.21 (1,738)	-0.29 (1,568)	-0.08 (1,685)	0.04 (1,067)	-0.16 (955)	-0.07 (1,711)
Urban	-0.41 (2,517)	-0.33 (2,366)	-0.19 (2,497)	-0.05 (2,334)	-0.38 (2,243)	-0.13 (2,490)
Beds: 1-99	-0.22 (2,028)	-0.24 (1,758)	-0.11 (1,958)	0.05 (1,205)	-0.23 (1,041)	-0.11 (1,987)
Beds: 100-199	-0.32 (786)	-0.31 (757)	-0.09 (783)	-0.02 (767)	-0.25 (742)	-0.19 (777)
Beds: 200-299	-0.40 (498)	-0.29 (485)	-0.21 (498)	-0.04 (492)	-0.34 (485)	-0.15 (498)
Beds: 300-399	-0.44 (364)	-0.22 (357)	-0.27 (364)	-0.18 (360)	-0.38 (358)	-0.12 (362)
Beds: 400+	-0.43 (579)	-0.40 (577)	-0.15 (579)	-0.03 (577)	-0.40 (572)	-0.09 (577)
Teaching Hospitals	-0.46 (1,166)	-0.35 (1,124)	-0.22 (1,162)	-0.10 (1,100)	-0.43 (1,081)	-0.11 (1,160)
Non-Teaching Hospitals	-0.32 (3,089)	-0.29 (2,810)	-0.13 (3,020)	0.01 (2,301)	-0.27 (2,117)	-0.14 (3,041)
Critical Access Hospital	-0.13 (1,231)	-0.13 (1,031)	-0.08 (1,174)	0.03 (412)	-0.25 (405)	-0.09 (1,199)

Not a Critical Access Hospital	-0.39 (3,024)	-0.33 (2,903)	-0.17 (3,008)	-0.04 (2,989)	-0.34 (2,733)	-0.11 (3,002)
Nurse-to-Bed Ratio <1	-0.35 (1,872)	-0.36 (1,659)	-0.10 (1,815)	-0.01 (1,334)	-0.29 (1,168)	-0.16 (1,836)
Nurse-to-Bed Ratio 1 to <2	-0.39 (1,847)	-0.31 (1,772)	-0.21 (1,836)	-0.04 (1,575)	-0.36 (1,546)	-0.11 (1,832)
Nurse-to-Bed Ratio 2+	-0.34 (536)	-0.29 (503)	-0.13 (531)	-0.05 (484)	-0.27 (484)	-0.10 (533)
Ownership: Government	-0.48 (957)	-0.44 (840)	-0.27 (499)	-0.15 (499)	-0.32 (499)	-0.18 (934)
Ownership: Not-for-Profit	-0.38 (2,625)	-0.32 (2,472)	-0.16 (2,120)	-0.04 (2,120)	-0.34 (2,120)	-0.12 (2,599)
Ownership: For-Profit	-0.12 (673)	-0.18 (622)	0.07 (579)	0.07 (579)	-0.[illegible]2 (579)	-0.14 (668)

** Footnote: Values represent Pearson correlation coefficients between Star Rating summary and group scores and hospital-level 30-day COVID-19 RSMR
* p-value not significant (>0.05)

Table 4: Hospital Characteristics and Correlation Between Star Rating Summary Scores and In-hospital COVID-19 RSMRs

	Correlation Coefficient (number of hospitals) All p values <.05 unless noted with an *					
Hospital Characteristic	**Hospital Summary Score**	**Mortality Group Score**	**Readmission Group Score**	**Safety of Care Group Score**	**Patient Experience Group Score**	**Timely and Effective Care Group Score**
All Hospitals	-0.41 (4,256)	-0.15 (3,934)	-0.24 (4,182)	-0.13 (3,193)	-0.39 (3,198)	-0.30 (4,202)
Rural	-0.32 (1,738)	-0.31 (1,568)	-0.17 (1,685)	-0.002* (1,067)	-0.244 (955)	-0.13 (1,711)
Urban	-0.42 (2,517)	-0.15 (2,366)	-0.23 (2,497)	-0.16 (2,334)	-0.39 (2,243)	-0.31 (2,490)
Beds: 1-99	-0.23 (2,028)	-0.16 (1,758)	-0.13 (1,958)	0.03* (1,205)	-0.30 (1,041)	-0.16 (1,987)
Beds: 100-199	-0.37 (786)	-0.17 (757)	-0.19 (783)	-0.12* (767)	-0.28 (742)	-0.27 (777)
Beds: 200-299	-0.39	-0.21	-0.21	-0.07*	-0.34	-0.23

	(498)	(485)	(498)	(492)	(485)	(498)
Beds: 300-399	-0.38 (364)	-0.11 (357)	-0.20 (364)	-0.28 (360)	-0.31 (358)	-0.23 (362)
Beds: 400+	-0.42 (579)	-0.16 (577)	-0.24 (579)	-0.17 (577)	-0.[illegible]1 (5[illegible]2)	-0.30 (577)
Teaching Hospitals	-0.47 (1,166)	-0.17 (1,124)	-0.29 (1,162)	-0.20 (1,100)	-0.[illegible]9 (1,[illegible]81)	-0.27 (1,160)
Non-Teaching Hospitals	-0.33 (3,089)	-0.14 (2,810)	-0.18 (3,020)	-0.05 (2,301)	-0.[illegible]8 (2,[illegible]17)	-0.29 (3,041)
Critical Access Hospital	-0.10 (1,231)	-0.16 (1,031)	-0.05* (1,174)	-0.06* (412)	-0.[illegible]8 (4[illegible]5)	-0.06 (1,199)
Not a Critical Access Hospital	-0.34 (3,024)	-0.16 (2,903)	-0.23 (3,008)	-0.15 (2,989)	-0.38 (2,793)	-0.29 (3,002)
Nurse-to-Bed Ratio <1	-0.40 (1,872)	-0.18 (1,659)	-0.19 (1,815)	-0.12 (1,334)	-0.34 (1,168)	-0.31 (1,836)
Nurse-to-Bed Ratio 1 to <2	-0.43 (1,847)	-0.13 (1,772)	-0.30 (1,836)	-0.15 (1,575)	-0.[illegible]2 (1,546)	-0.28 (1,832)
Nurse-to-Bed Ratio 2+	-0.39 (536)	0.13 (503)	-0.16 (531)	0.09 (492)	-0.42 (4[illegible]4)	-0.38 (533)

Ownership: Government	-0.59 (957)	-0.33 (840)	-0.43 (920)	-0.21 (594)	-0.[illegible]1 (4[illegible]9)	-0.35 (934)
Ownership: Not-for-Profit	-0.45 (2,625)	-0.15 (2,472)	-0.27 (2,594)	-0.14 (2,187)	-0.[illegible]5 (2,[illegible]20)	-0.30 (2,599)
Ownership: For-Profit	-0.11 (673)	-0.06* (622)	0.02* (6668)	<0.001* (620)	[illegible]9 ([illegible]9)	-0.28 (668)

* p-value not significant (>0.05)

APPENDIX

Table of Figures (Appendix)

Figure 1A. CMS Overall Hospital Star Rating Methodology

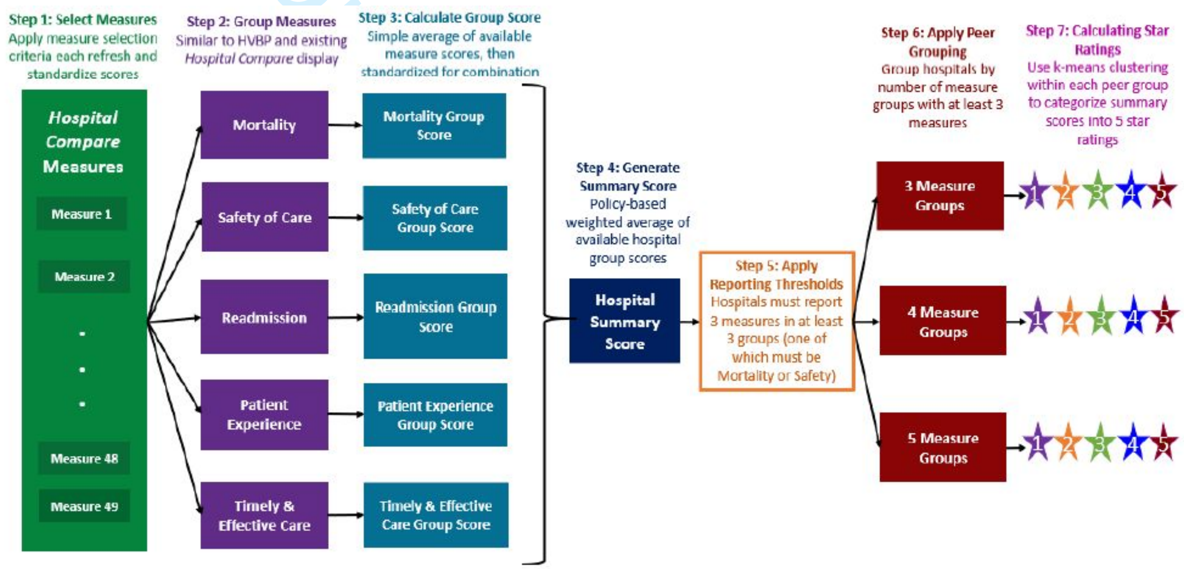


Table 1 A. Dates of data for measures in Overall Hospital Quality Star Rating on Care Compare for the April 2021 update

Mortality

Measure	Dates
MORT-30-AMI: 30-day death rate for heart attack patients	July 1, 2016 - June 30, 2019
MORT-30-CABG: Death rate for coronary artery bypass graft surgery patients	July 1, 2016 - June 30, 2019
MORT-30-COPD: Death rate for chronic obstructive pulmonary disease (COPD) patients	July 1, 2016 - June 30, 2019
MORT-30-HF: 30-day death rate for heart failure patients	July 1, 2016 - June 30, 2019
MORT-30-PN: 30-day death rate for pneumonia patients	July 1, 2016 - June 30, 2019
MORT-30-STK: Death rate for stroke patients	July 1, 2016 - June 30, 2019
PSI-4-SURG-COMP: Death rate among surgical inpatients with serious treatable complications	July 1, 2017 - June 30, 2019

Safety of Care

Measure	Dates
HAI-1: Central-line associated bloodstream infection (CLABSI)	January 1, 2019 - December 31, 2019
HAI-2: Catheter-associated urinary tract infection (CAUTI)	January 1, 2019 - December 31, 2019
HAI-3: Surgical site infection from colon surgery (SSI: Colon)	January 1, 2019 - December 31, 2019

Measure	Dates
HAI-4: Surgical site infection from abdominal hysterectomy (SSI-abdominal hysterectomy)	January 1, 2019 - December 31, 2019
HAI-5: Methicillin-resistant staphylococcus aureus (or MRSA) blood infections (Antibiotic-resistant blood infections)	January 1, 2019 - December 31, 2019
HAI-6: Clostridium difficile (or C. diff.) infections (Intestinal infections)	January 1, 2019 - December 31, 2019
COMP-HIP-KNEE: Rate of complications for hip and knee replacement patients	April 1, 2016 - March 31, 2019
PSI-90: Patient Safety and Adverse Events Composite	July 1, 2017 - June 30, 2019

Readmission

Measure	Dates
READM-30-CABG: Rate of unplanned readmission after coronary artery bypass graft (CABG) surgery	July 1, 2016 - June 30, 2019
READM-30-COPD: Rate of unplanned readmission for chronic obstructive pulmonary disease patients	July 1, 2016 - June 30, 2019
READM-30-Hip-Knee: 30-day rate of readmission for hip and knee replacement patients	July 1, 2016 - June 30, 2019
READM-30-HOSP-WIDE: Rate of readmission after discharge from hospital	July 1, 2018 - June 30, 2019
EDAC-30-AMI: Acute myocardial infarction excess days in acute care (EDAC)	July 1, 2016 - June 30, 2019
EDAC-30-HF: Heart failure excess day sin acute care (EDAC)	July 1, 2016 - June 30, 2019
EDAC-30-PN: Pneumonia excess day sin acute care (EDAC)	July 1, 2016 - June 30, 2019
OP-32: Facility 7-day risk standardized hospital visit rate after outpatient colonoscopy	January 1, 2017 - December 31, 2019
OP-35 ADM: Admissions visits for patients receiving outpatient chemotherapy	January 1, 2019 - December 31, 2019
OP-35 ED: Emergency department (ED) visits for patients receiving outpatient chemotherapy	January 1, 2019 - December 31, 2019
OP-36: Hospital visits after hospital outpatient surgery	January 1, 2019 - December 31, 2019

Patient Experience

Measure	Dates
H-COMP-1: Communication with nurses	January 1, 2019 - December 31, 2019
H-COMP-2: Communication with doctors	January 1, 2019 - December 31, 2019
H-COMP-3: Responsiveness of hospital staff	January 1, 2019 - December 31, 2019
H-COMP-5: Communication about medicines	January 1, 2019 - December 31, 2019
H-COMP-6: Discharge information	January 1, 2019 - December 31, 2019
H-COMP-7: Care transition	January 1, 2019 - December 31, 2019
H-CLEAN-HSP Cleanliness of hospital environment (Q8) + H-QUIET-HSP Quietness of hospital environment (Q9) / 2	January 1, 2019 - December 31, 2019
H-HSP-RATING Hospital rating (Q21) + H-RECMND: Willingness to recommend hospital (Q22) / 2	January 1, 2019 - December 31, 2019

Timely and Effective Care

Measure	Dates
IMM-3: Percent of healthcare workers vaccinated against Influenza	October 1, 2019 - March 31, 2020
OP-10: Outpatient PA scans of the abdomen that were “combination” (double) scans	July 1, 2018 - June 30, 2019
OP-13: Medicare patients who got cardiac imaging stress tests to screen for surgical risk before low-risk outpatient surgery	July 1, 2018 - June 30, 2019

Measure	Dates
OP-18b: Average time patients spent in the emergency department before being sent home	January 1, 2019 - December 31, 2019
OP-22: Percentage of patients who left the emergency department before being seen	January 1, 2019 - December 31, 2019
OP-23: Percentage of patients who came to the emergency department with stroke symptoms who received brain scan results within 45 minutes of arrival	January 1, 2019 - December 31, 2019
OP-29: Appropriate follow-up interval for normal colonoscopy in average risk patients	January 1, 2019 - December 31, 2019
OP-33: External beam radiotherapy for bone metastases	January 1, 2019 - December 31, 2019
OP-3b: Average number of minutes before outpatients with chest pain or possible heart attack who needed specialized care were transferred to another hospital	January 1, 2019 - December 31, 2019
OP-8: Outpatients with low back pain who had an MRI without trying recommended treatments first, such as physical therapy	July 1, 2018 - June 30, 2019
PC-01: Percent of newborns whose deliveries were scheduled too early (1-3 weeks early), when a scheduled delivery was not medically necessary	January 1, 2019 - December 31, 2019
SEP-1: Percentage of patients who received appropriate care for severe sepsis and septic shock	January 1, 2019 - December 31, 2019

Table 2 A. Components of the Charlson Risk Adjustment methodology[1]

Description
All
Age
Unknown: #, %
Mean, Standard Deviation
Minimum, Maximum
1st Percentile, 99th Percentile
1st Quartile, 3rd Quartile
Median, Quartile Range
Myocardial Infarction (Yes/No)
Congestive Heart Failure (Yes/No)
Peripheral Vascular Disease (Yes/No)
Cerebrovascular Disease (Yes/No)
Dementia (Yes/No)
Chronic Pulmonary Disease (Yes/No)
Connective Tissue Disease-Rheumatic Disease (Yes/No)
Peptic Ulcer Disease (Yes/No)
Mild Liver Disease (Yes/No)
Diabetes without complications (Yes/No)
Diabetes with complications (Yes/No)
Paraplegia and Hemiplegia (Yes/No)
Renal Disease (Yes/No)
Cancer (Yes/No)

Moderate or Severe Liver Disease (Yes/No)
Metastatic Carcinoma (Yes/No)
AIDS/HIV (Yes/No)

References (Appendix)

1. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 1987;40:373-383.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3-5
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6-7
Objectives	3	State specific objectives, including any prespecified hypotheses	3, 6-7
Methods			
Study design	4	Present key elements of study design early in the paper	1, 3, 7-10
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3, 7-8
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	3, 7, 8
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-10
Bias	9	Describe any efforts to address potential sources of bias	10
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9-10
		(*b*) Describe any methods used to examine subgroups and interactions	10
		(*c*) Explain how missing data were addressed	9
		(*d*) If applicable, explain how loss to follow-up was addressed	n/a
		(*e*) Describe any sensitivity analyses	10
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11, Table 1
		(b) Give reasons for non-participation at each stage	n/a
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11, Table 1
		(b) Indicate number of participants with missing data for each variable of interest	n/a
		(c) Summarise follow-up time (eg, average and total amount)	11
Outcome data	15*	Report numbers of outcome events or summary measures over time	11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-13
		(*b*) Report category boundaries when continuous variables were categorized	Tables 2-4
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	4, 12
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	13-14
Discussion			
Key results	18	Summarise key results with reference to study objectives	14-15
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	17-19
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Pre-COVID hospital quality and hospital response to COVID-19: Examining associations between risk-adjusted mortality for patients hospitalized with COVID-19 and pre-COVID hospital quality.

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Pre-COVID hospital quality and hospital response to COVID-19: Examining associations between risk-adjusted mortality for patients hospitalized with COVID-19 and pre-COVID hospital quality

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Raw claims data used to calculate hospital-level risk-standardized mortality rates are not publicly available, but researchers can request this data from CMS through a data vendor (ResDAC); Star Ratings data, hospital characteristics file (CMS Place of Service) and COVID utilization files are publicly available.

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Abstract

Objectives

The extent to which care quality influenced outcomes for hospitalized COVID-19 is unknown. Our objective was to determine if pre-pandemic hospital quality is associated with mortality among Medicare patients hospitalized with COVID-19.

Design

This is a retrospective observational study. We calculated hospital-level risk-standardized in-hospital and 30-day mortality rates (RSMRs) for patients hospitalized with COVID-19, and correlation coefficients between RSMRs and pre-COVID hospital quality, overall and stratified by hospital characteristics

Setting

Short-term acute-care hospitals and Critical Access Hospitals in the United States.

Participants

Hospitalized Medicare Beneficiaries (Fee-For-Service and Medicare Advantage) age 65 and older hospitalized with COVID-19, discharged between April 1, 2020-September 30, 2021.

Intervention/Exposure

Pre-COVID hospital quality.

Outcomes

Risk-standardized COVID-19 in-hospital and 30-day mortality rates (RSMRs).

Results

In-hospital (n=4,256) risk-standardized mortality rates (RSMRs) for Medicare patients hospitalized with COVID-19 (April 2020-September 2021) ranged from 4.5% to 59.9% (median,18.2%; interquartile range [IQR]: 14.7%-23.7%); 30-day RSMRs ranged from 12.9% to 56.2% (IQR: 24.6%-30.6%). COVID-19 RSMRs were negatively correlated with Star Rating summary scores (in-hospital correlation coefficient: -0.41, $p<0.0001$; 30-day: -0.38, $p<0.0001$). Correlations with in-hospital RSMRs were strongest for Patient Experience (-0.39, $p<0.0001$) and Timely and Effective Care (-0.30, $p<0.0001$) group scores; 30-day RSMRs were strongest for Patient Experience (-0.34, $p<0.0001$) and Mortality (-0.33, $p<0.0001$) groups. Patients admitted to 1-star hospitals had higher odds of mortality [in-hospital OR=1.87, 95% (CI 1.83 -1.91); 30-day OR=1.46, 95% (CI 1.43-1.48)] compared with 5-star hospitals. If all hospitals performed like an average 5-star hospital, we estimate 38,000 fewer COVID-related deaths would have occurred between April 2020-September 2021.

Conclusions

Hospitals with better pre-pandemic quality may have care structures and processes that allowed for better care delivery during the COVID-19 pandemic. Understanding the relationship between pre-COVID hospital quality and COVID-19 outcomes will allow policymakers and hospitals to better prepare for future public health emergencies.

Strengths and Limitations

- Our study includes data for more than a million patients and four thousand hospitals.

- Our study compared hospital quality before the pandemic with risk-standardized COVID outcomes.
- Sensitivity analyses did not refute the results of our study.
- Claims data are limited by proper coding practices.
- Claims data could not be used to assess the impact of vaccination.

Introduction

Prior to the COVID-19 pandemic, and despite struggles to respond to an earlier flu epidemic, hospitals likely did not prioritize preparation for a future pandemic [1]. This lack of adequate preparation likely contributed in part to the death of more than a million people in the United States alone. As the World Health Organization (WHO) and the United States, and Europe consider the risk of future pandemics [2] it is important to understand how to identify hospitals in need of better preparedness for future public health emergencies.

During normal operations, high-quality hospitals can deliver evidence-based, timely, patient-centered, and equitable care when adequately staffed with high-quality workers who can support good communication [3]. High-quality hospitals have better patient outcomes, including lower risk-standardized mortality rates, for specific conditions (such as pneumonia and heart failure) and specific procedures (such as heart surgery), and evidence shows that care quality for one condition is associated with care quality for other conditions [4]. Therefore, during normal operations, structures and processes of care may transfer across teams and patients, however we do not know if this is true during a major stressor such as a pandemic. During a pandemic, resilient hospitals may be able to continue to deliver high quality care despite the stressor. Research suggests that some of the same characteristics associated with high quality during normal operations, such as communication and adherence to evidence-based processes, are also associated with readiness/resilience [5-7]. We therefore hypothesized that pre-pandemic hospital quality could be a marker of hospital readiness/resilience, and that hospitals with higher quality prior to the pandemic would be more likely to be able to respond to the pandemic and translate the same structures and processes across care teams and patients, resulting in better patient outcomes. To test this hypothesis, we first developed a measure of hospital response to the pandemic (ability to deliver high quality care as measured by patient outcomes), by calculating hospital-level risk-standardized COVID-19 mortality rates among patients hospitalized with COVID-19 (COVID-19 RSMRs). We then explored the relationship between a marker of pre-COVID hospital quality (the hospital summary score used to calculate CMS's Overall Hospital Star Rating – hereafter "Star Rating summary score" –and its components) and COVID-19 RSMRs. We stratified the association between pre-COVID hospital quality and COVID outcomes by hospital characteristics and explored the relationship between COVID outcomes and hospital COVID burden.

We acknowledge that there is no gold standard of what defines a "high quality" hospital in quantitative terms. While there are existing and accepted quality frameworks, such as the US Institute of Medicine's six pillars of hospital quality (safety, effectiveness, patient-centeredness, timeliness, efficiency, and equity) [8], quality measures within these domains can differ, and there is no one "gold standard" on which individual measures to include or how to combine them into an overall quantitative assessment of hospital quality [9]. We therefore used a publicly available and publicly vetted definition of overall hospital quality (CMS Hospital Overall Star Rating) as the basis for our study [10].

METHODS

Data Sources

We used administrative claims data from the Center for Medicare and Medicaid Services (CMS) that included patients diagnosed with COVID-19 who were admitted to hospitals in the United States and its territories between April 1, 2020, and September 30, 2021. We used the CMS Provider of Services files to obtain hospital characteristics [11], including the urban/rural definition that is based on the US Office of Budget and Management (OMB) definition that designates urban counties as Metropolitan (a county containing a core urban area of 50,000 or more population) and Micropolitan (a county containing a core urban core of at least 10,000 (but less than 50,000) population. “Rural” encompasses all population, housing, and territory not included within an urban area [12,13]. To examine the impact of the level of hospital “COVID burden” on these results, we used hospital-reported data provided to the public by The U.S. Department of Health and Human Services (HHS) [14].

Study Cohort

We examined all Medicare Fee-for-Service (FFS), and Medicare Advantage (MA) hospital-submitted inpatient admission claims with a principal or secondary (present on admission) discharge diagnosis of COVID-19 (ICD-10 code U07.1) for patients discharged from an acute care or Critical Access Hospital (CAH) between April 1, 2020, to September 30, 2021.

Measures of Pre-COVID Hospital Quality and COVID burden

To characterize pre-COVID hospital quality, we used the Star Rating summary score (April 2021 release) used to calculate CMS' Overall Hospital Quality Star Rating on *Care Compare,* which summarizes existing hospital quality information by assigning hospitals 1-5 stars based on their performance in measures within groups (Appendix, Figure 1A). Version 4.0 categorizes measures into 5 groups – Mortality (7 measures), Readmission (11), Safety of Care (8), Patient Experience (8), and Timely and Effective Care (14) [15,16]. Summary scores are calculated using a weighted average of group scores and Star Rating categories are assigned based on hospitals' summary scores. All quality measures included in this analysis used performance data prior to 2020 (Appendix, Table 1A). Hospitals with insufficient data for a star rating are not included in the analyses of associations. We calculated hospital COVID-19 burden as the weekly average number of laboratory-confirmed COVID-19 hospitalizations for all adult patients (not limited to Medicare patients) divided by the number of hospital beds.

Outcome Assessment

We calculated hospital-level risk-standardized mortality rates for COVID-19 patients (Risk-Standardized Mortality Rates [RSMRs]; in-hospital and within 30-days from the date of admission) using hierarchical logistic regression models [17-20]. The models adjust for components of the Charlson Comorbidity Index, including age (Appendix, Table 2A) [21]. The commonly used Charlson Comorbidity Index calculates a risk score for each patient using 19 International Classification of Diseases (ICD) diagnosis codes from administrative data. Hospital RSMRs are the ratio of a hospital's "predicted" to "expected" mortality, multiplied by national observed mortality rate. The approach simultaneously models data at patient and hospital levels to account for the variation in mortality within and between hospitals [22].

Statistical Analyses

We calculated volume-weighted Pearson correlations to evaluate associations between hospital-level RSMRs and pre-COVID quality (Star Rating summary and group scores), and stratified correlations by hospital characteristics. We calculated these associations for each hospital with a Star Rating summary score, and for each hospital with a group score (see Results section for the number of hospitals in each category). For sensitivity analyses, we limited our sample to hospitals with ≥25 COVID-19 patients and re-calculated results after removing hospitals with the 20 highest and lowest 30-day RSMRs (based on the distribution of outliers) to explore the impact of COVID-19 on RSMR outliers. In addition, we repeated the analyses limiting the data period to the early pandemic (from March 2020 to September 2020) to assess if associations between Star Rating summary scores and COVID-19 mortality rates differed earlier in the pandemic. We then examined correlations between COVID-19 RSMRs and the Star Rating summary score and each of its components (group scores), as well as between COVID-19 RSMRs and COVID burden, calculated as the weekly average number of laboratory-confirmed COVID-19 hospitalizations for all patients (not limited to Medicare patients) divided by the number of hospital beds. To estimate the number of deaths that might be attributable to care in a lower-quality hospital, we applied the mean COVID-19 RSMR for hospitals within the 5-star ratings category to the total number of patients admitted to the hospital with COVID-19 between April 1, 2020, and September 30, 2021, and subtracted that value from the total (observed) number of patients admitted with COVID-19 who died within 30-days.

CMS assigns a star rating to hospitals that report 3, 4, or 5 measure groups (hospitals are peer-grouped prior to k-means clustering, and then are assigned a star rating – see Appendix) [23]. To examine the impact of the number of group scores hospitals reported to CMS and our observations, we re-calculated correlation coefficients after stratifying hospitals by their number of reported group scores (3, 4, or 5 measure groups). To examine the impact of COVID-19 hospitalization volume we examined results for hospitals with at least 25 COVID-19 patients. As a sensitivity analysis to determine the impact of outliers on the observed associations, we re-calculated correlation coefficients (among all hospitals) after removing hospitals with the 20 highest and 20 lowest 30-day COVID-19 RSMRs, and the 20 highest and 20 lowest Star Rating summary scores. To examine the adequacy of risk adjustment using the CCI, we calculated the c-statistic for both in-hospital and 30-day mortality models.

All analyses used SAS Enterprise Guide and SAS 9.4 and were performed by two authors (SXL and YW).

RESULTS

Variation in hospital-level COVID-19 RSMRs and Stratification by Hospital Characteristics

Between April 1, 2020, and September 30, 2021, 1,229,071 Medicare Beneficiaries were with a diagnosis of COVID-19 were admitted to 4,343 U.S hospitals. Among those admitted patients, 230,358 (18.7%) died in the hospital, and 338,358 patients (27.5%) died within 30 days of admission. Patient characteristics are shown in Table 1.

Table 1: Patient characteristics (number and frequency of Charlson comorbidity index variables)

Characteristic	Number	Percent
All	**1,229,071**	**100.00**
Age (mean, std)	77.8 (8)	--
Myocardial Infarction	150,083	12.21
Congestive Heart Failure	7,913	0.64
Peripheral Vascular Disease	95,170	7.74
Cerebrovascular Disease	85,694	6.97
Dementia	250,869	20.41
Chronic Pulmonary Disease	1,270	0.10
Connective Tissue Disease-Rheumatic Disease	42,123	3.43
Peptic Ulcer Disease	10,457	0.85
Mild Liver Disease	38,593	3.14
Diabetes without complications	375,261	30.53
Diabetes with complications	261,863	21.31
Paraplegia and Hemiplegia	16,228	1.32
Renal Disease	365,593	29.75
Cancer	68,182	5.55
Moderate or Severe Liver Disease	7,877	0.64
Metastatic Carcinoma	18,038	1.47
AIDS/HIV	1,130	0.09

At the hospital level, we found striking variation in risk-standardized mortality rates (RSMRs). Among the 4,343 hospitals with at least one COVID-19 patient, in-hospital RSMRs ranged from 4.5% to 59.9%; the median in-hospital RSMR was 18.2% (interquartile range [IQR]: 14.7%-23.7%). 30-day RSMRs also varied widely, from 12.9% to 56.2% (IQR: 24.6%-30.6%). Results were similar for hospitals with at least 25 cases.

In-hospital RSMRs differed by hospital characteristic. Mean in-hospital RSMRs were significantly (p<.0001) higher in the following: urban hospitals (vs. rural), hospitals with more (vs. fewer) beds, teaching hospitals (vs. non-teaching hospitals), hospitals not designated as CAHs (vs. CAHs) and for-profit (vs. non-profit or government owned) hospitals (Table 2). Differences in mean in-hospital mortality rates between hospitals in different nurse-to-bed ratios were small. Differences in 30-day RSMRs by hospital characteristic were also small but statistically significant except for urban vs. rural where the difference was not significant (Table 2). Results were similar for hospitals with at least 25 cases.

Table 2. Mean Risk-Adjusted COVID-19 RSMRs by Hospital Characteristics (for hospitals with >=1 COVID admission) between April 1, 2020, and September 30, 2021.*

Hospital Characteristic	Number of Hospitals	Mean In-Hospital RSMR (%)	SD (%)	Mean 30-Day RSMR	SD (%)
All Hospitals	4,343	19.7	7.3	27.8	4.9
Hospitals in Rural Area					
Rural	1,765	17.4	5.6	27.7	4.5
Urban	2,555	21.3	7.8	27.9**	5.2
Bed Size					
1 to 99	2,078	16.7	5.4	27.3	4.3
100 to 199	792	21.0	7.9	28.4	5.5
200 to 299	502	22.8	7.3	28.5	5.1
300 to 399	364	23.6	8.1	28.7	5.5
400+	584	23.6	7.0	27.6	5.4
Teaching Status					
Teaching	1,180	22.2	7.5	27.7	5.3
Non-teaching	3,139	18.8	6.9	27.8	4.8
Critical Access Status					
Critical Access	1,256	16.2	4.3	27.1	3.6
Not Critical Access	3,064	21.2	7.7	28.1	5.4
Nurse-to-Bed Ratio					
<1	1,914	19.5	7.4	28.3	4.9
1 to <2	1,858	20.1	7.3	27.7	5.0
2+	548	19.0	6.4	26.6	4.6
Ownership					
Government	981	19.1	6.7	28.0	4.7
Not-For-Profit	2,648	19.5	7.0	27.2	4.8
For-Profit	690	21.5	8.5	29.8	5.2
Star Rating Category					
1-Star	201	29.1	8.8	32.1	5.5
2-Star	685	24.3	7.2	29.6	4.9
3-Star	1,002	22.8	6.5	28.5	4.8
4-Star	979	20.7	6.3	26.7	4.7
5-Star	449	18.0	5.8	24.5	4.9

*All differences between categories (e.g., rural vs. urban; teaching vs. non-teaching) are significant (p<.05) except as indicated.
**Not significant (p=.316)

To determine if the level of COVID-19 burden might explain these results, we examined the association between hospital-level COVID burden calculated using weekly hospital-reported COVID-19 utilization data (see Methods), and COVID-19 RSMRs. We found, however, only a weak relationship: the Pearson correlation coefficient was -0.04, (p=0.01) for in-hospital RSMRs, and -0.03 (p=0.03) for 30-day RSMRs.

Association between pre-COVID-19 hospital quality and hospital-level COVID-19 RSMRs

We examined how COVID-19 RSMRs differed by pre-COVID-19 hospital quality as defined by Star Rating category (1-star through 5-star). When hospitals were stratified by Star Rating category we found that in-hospital and 30-day RSMRs were systematically lower (better) with each increase in Star Rating category: For example, mean in-hospital RSMRs were 28.1% for 1-star hospitals (N=201) vs. 18.0% for 5-star hospitals (N=409); mean 30-day RSMRs were 32.1% for 1-star hospitals vs. 24.5% for 5-star hospitals (Table 2). Patients admitted to 1-star hospitals had higher odds of in-hospital (OR=1.87, 95% CI 1.54 to 1.62) and 30-day mortality (OR=1.46, 95% CI 1.31 to 1.39), compared with patients admitted to 5-star hospitals, after adjusting for clinical characteristics using the Charlson comorbidity index which includes age (see Appendix Table 2A).

We then calculated Pearson correlation coefficients between pre-COVID Star Rating performance (summary scores and the five individual measure group scores) and COVID-19 RSMRs with April 2020 through September 2021 data, near the peak of the Delta variant wave in the United States. Star Rating summary scores among 4,256 hospitals in our analysis were moderately inversely correlated with in-hospital (-0.41, p<0.0001) and 30-day (-0.38, p<0.0001) RSMRs (Figure 1). For in-hospital RSMRs, the Patient Experience and Timely and Effective Care group scores showed the strongest associations (-0.39, p<0.001; -30, p<0.0001, respectively). For 30-day RSMRs, Patient Experience and Mortality group scores showed the strongest associations (-0.34, p<0.0001; -0.33, p<0.001, respectively). When we limited our analyses of the associations between Star Rating summary scores and RSMRs in the early pandemic period (March 2020 through September 2020), the relationship between 30-day RSMRs and Star Rating Mortality group scores was weaker (Pearson correlation coefficient, -0.12, p<0.0001) compared with the 18-month period of this study (Pearson correlation coefficient -0.34, p<0.0001) (data not shown).

In stratified analyses by hospital characteristics, stronger correlations were seen between 30-day hospital RSMRs and the Star Rating summary score and its component group scores for: larger vs. smaller bed-size hospitals (-0.43 for hospitals with 400+ beds vs. -0.22 for hospitals with 1-99 beds), hospitals with academic affiliation vs. without (-0.46 vs. -0.32), hospitals in urban vs. rural locations (-0.41 vs. -0.21, respectively), government and not-for-profit hospitals vs. for-profit (-0.59 and -0.45 vs. -0.11, respectively), and non-CAH vs CAH (-0.39 vs. -0.13, respectively); differences by nurse-to-bed ratio categories were small (Table 3). Differences by hospital characteristic for in-hospital RSMRs were generally smaller compared with observations for 30-day RSMRs (Table 4).

Table 3: Hospital Characteristics and Correlation Between Star Rating Summary Scores and 30-day COVID-19 RSMRs (Values represent Pearson correlation coefficients between Star Rating summary and group scores and hospital-level 30-day COVID-19 RSMR.)

	Correlation Coefficient (number of hospitals) All p values <0.05 unless noted with an					
Hospital Characteristic	**Overall Group Score**	**Mortality Group Score**	**Readmission Group Score**	**Safety of Care Group Score**	**Patient Experience Group Score**	**Standardized Timely and Effective Care Group Score**
All Hospitals	-0.38 (4,256)	-0.33 (3,934)	-0.17 (4,182)	-0.03* (3,401)	-0.34 (3,198)	-0.11 (4,202)
Rural	-0.21 (1,738)	-0.29 (1,568)	-0.08 (1,685)	0.04* (1,067)	-0.16 (955)	-0.07 (1,711)
Urban	-0.41 (2,517)	-0.33 (2,366)	-0.19 (2,497)	-0.05 (2,334)	-0.38 (2,243)	-0.13 (2,490)
Beds: 1-99	-0.22 (2,028)	-0.24 (1,758)	-0.11 (1,958)	0.05* (1,205)	-0.23 (1,041)	-0.11 (1,987)
Beds: 100-199	-0.32 (786)	-0.31 (757)	-0.09 (783)	-0.02* (767)	-0.25 (742)	-0.19 (777)
Beds: 200-299	-0.40 (498)	-0.29 (485)	-0.21 (498)	-0.04* (492)	-0.34 (485)	-0.15 (498)
Beds: 300-399	-0.44 (364)	-0.22 (357)	-0.27 (364)	-0.18 (360)	-0.38 (358)	-0.12 (362)

Beds: 400+	-0.43 (579)	-0.40 (577)	-0.15 (579)	-0.03* (577)	-0.40 (573)	-0.09 (577)
Teaching Hospitals	-0.46 (1,166)	-0.35 (1,124)	-0.22 (1,162)	-0.10 (1,100)	-0.43 (1,081)	-0.11 (1,160)
Non-Teaching Hospitals	-0.32 (3,089)	-0.29 (2,810)	-0.13 (3,020)	0.01* (2,301)	-0.27 (2,1[illegible]7)	-0.14 (3,041)
Critical Access Hospital	-0.13 (1,231)	-0.13 (1,031)	-0.08 (1,174)	0.03* (412)	-0.25 (40[illegible])	-0.09 (1,199)
Not a Critical Access Hospital	-0.39 (3,024)	-0.33 (2,903)	-0.17 (3,008)	-0.04 (2,989)	-0.34 (2,7[illegible]3)	-0.11 (3,002)
Nurse-to-Bed Ratio <1	-0.35 (1,872)	-0.36 (1,659)	-0.10 (1,815)	-0.01* (1,334)	-0.29 (1,[illegible]8)	-0.16 (1,836)
Nurse-to-Bed Ratio 1 to <2	-0.39 (1,847)	-0.31 (1,772)	-0.21 (1,836)	-0.04* (1,575)	-0.26 (1,546)	-0.11 (1,832)
Nurse-to-Bed Ratio 2+	-0.34 (536)	-0.29 (503)	-0.13 (531)	-0.05* (484)	-0.27 (484)	-0.10 (533)
Ownership: Government	-0.48 (957)	-0.44 (840)	-0.27 (499)	-0.15 (499)	-0.32 (499)	-0.18 (934)
Ownership: Not-for-Profit	-0.38 (2,625)	-0.32 (2,472)	-0.16 (2,120)	-0.04 (2,120)	-0.34 (2,1[illegible]0)	-0.12 (2,599)
Ownership: For-Profit	-0.12 (673)	-0.18 (622)	0.07* (579)	0.07* (579)	-0.12 (579)	-0.14 (668)

* p-value not significant (>0.05)

Table 4: Hospital Characteristics and Correlation Between Star Rating Summary Scores and In-hospital COVID-19 RSMRs

	Correlation Coefficient (number of hospitals) All p values <0.05 unless noted with an *					
Hospital Characteristic	**Hospital Summary Score**	**Mortality Group Score**	**Readmission Group Score**	**Safety of Care Group Score**	**Patient Experience Group Score**	**Timely and Effective Care Group Score**
All Hospitals	-0.41 (4,256)	-0.15 (3,934)	-0.24 (4,182)	-0.13 (3,193)	-0.39 (4,198)	-0.30 (4,202)
Rural	-0.32 (1,738)	-0.31 (1,568)	-0.17 (1,685)	-0.002* (1,067)	-0.44 (955)	-0.13 (1,711)
Urban	-0.42 (2,517)	-0.15 (2,366)	-0.23 (2,497)	-0.16 (2,334)	-0.39 (2,243)	-0.31 (2,490)
Beds: 1-99	-0.23 (2,028)	-0.16 (1,758)	-0.13 (1,958)	0.03* (1,205)	-0.30 (1,041)	-0.16 (1,987)
Beds: 100-199	-0.37 (786)	-0.17 (757)	-0.19 (783)	-0.12* (767)	-0.28 (742)	-0.27 (777)
Beds: 200-299	-0.39 (498)	-0.21 (485)	-0.21 (498)	-0.07* (492)	-0.34 (485)	-0.23 (498)
Beds: 300-399	-0.38 (364)	-0.11 (357)	-0.20 (364)	-0.28 (360)	-0.31 (358)	-0.23 (362)
Beds: 400+	-0.42 (579)	-0.16 (577)	-0.24 (579)	-0.17 (577)	-0.41 (572)	-0.30 (577)
Teaching Hospitals	-0.47 (1,166)	-0.17 (1,124)	-0.29 (1,162)	-0.20 (1,100)	-0.49 (1,081)	-0.27 (1,160)
Non-Teaching Hospitals	-0.33 (3,089)	-0.14 (2,810)	-0.18 (3,020)	-0.05 (2,301)	-0.28 (2,117)	-0.29 (3,041)

Critical Access Hospital	-0.10 (1,231)	-0.16 (1,031)	-0.05* (1,174)	-0.06* (412)	-0.[illegible]8 (40[illegible]5)	-0.06 (1,199)
Not a Critical Access Hospital	-0.34 (3,024)	-0.16 (2,903)	-0.23 (3,008)	-0.15 (2,989)	-0.[illegible]8 (2,7[illegible]3)	-0.29 (3,002)
Nurse-to-Bed Ratio <1	-0.40 (1,872)	-0.18 (1,659)	-0.19 (1,815)	-0.12 (1,334)	-0.[illegible]4 ([illegible]68)	-0.31 (1,836)
Nurse-to-Bed Ratio 1 to <2	-0.43 (1,847)	-0.13 (1,772)	-0.30 (1,836)	-0.15 (1,575)	[illegible]2 ([illegible]46)	-0.28 (1,832)
Nurse-to-Bed Ratio 2+	-0.39 (536)	0.13 (503)	-0.16 (531)	0.09 (492)	[illegible]2 ([illegible]4)	-0.38 (533)
Ownership: Government	-0.59 (957)	-0.33 (840)	-0.43 (920)	-0.21 (594)	[illegible]1 ([illegible]9)	-0.35 (934)
Ownership: Not-for-Profit	-0.45 (2,625)	-0.15 (2,472)	-0.27 (2,594)	-0.14 (2,187)	[illegible]5 ([illegible]20)	-0.30 (2,599)
Ownership: For-Profit	-0.11 (673)	-0.06* (622)	0.02* (6668)	<0.001* (620)	[illegible]9 (5[illegible]9)	-0.28 (668)

* p-value not significant (>0.05)

To address concerns that hospitals reporting 3 v. 4 v. 5 measure groups may have differing hospital quality and therefore explain results in this study, we re-calculated correlation coefficients after stratifying hospitals by their number of reported group scores. We found that while the strength of the association between the Summary Score and the 3-group strata (-0.27) is somewhat weaker compared with the 5-group strata (-0.39), the relationships are statistically significant for all three strata, and we also found the same pattern of associations with the in all three strata and all of the individual Group Scores (see Table 3A, Appendix). We also note that about three fourths of hospitals that receive a Star Rating report five measure groups. To examine the impact of COVID-19 hospitalization volume we examined results for hospitals with at least 25 COVID-19 patients; we found that among the 3,405 hospitals that met these criteria, results were similar (data not shown) to results with hospitals with at least one COVID-19 hospitalization. As a sensitivity analysis to determine the impact of outliers on the observed associations, we re-calculated correlation coefficients (among all hospitals) after removing hospitals with the 20 highest and 20 lowest 30-day COVID-19 RSMRs, and the 20 highest and 20 lowest Star Rating summary scores and found the correlation was similar (-0.40, p<0.0001, n=4,196 hospitals). Finally, c-statistics for the in-hospital and 30-day mortality models were 0.609 and 0.663, respectively, demonstrating adequate risk adjustment for the purposes of this study.

DISCUSSION

Using data from a representative sample of more than 1.2 million COVID-19-associated hospitalizations of Medicare Beneficiaries across more than 4,300 hospitals, risk-standardized 30-day mortality rates were associated with pre-COVID-19 hospital quality. Associations were stronger in quality domains associated with communication and the use of processes. A potential explanation for the observed association between pre-COVID-19 hospital quality and COVID-19 outcomes is that hospitals may have been able to transfer those effective care structures and processes used during normal operations to the care of patients with COVID-19 during the pandemic. Pre-COVID-19 hospital quality also reflects, at least in part, a hospital's readiness/resilience to respond to stressors and provide high-quality care under stress. In our study, differences in hospital readiness, as measured by pre-COVID-19 hospital quality, had serious consequences; on average, a patient admitted to a lower-quality (1-star hospital) was 87% and 46% more likely to die in the hospital and within 30 days, respectively, compared with a patient admitted to a higher quality (5-star) hospital (absolute differences of 11 percentage points for in-hospital and 7.6 percentage points for 30-day mortality).

This study has some important strengths and limitations. The strengths of this study include that it represents COVID-19 outcomes from more than a million Medicare beneficiaries and hospital quality for more than four thousand hospitals across the United States. In addition, we calculated risk-standardized mortality rates to assess patient outcomes. Our study also used a comprehensive and publicly reported measure of hospital quality to assess pre-COVID hospital readiness/resilience. We also examined, as a potential confounder, hospital-level COVID-19 burden.

This study has the limitations of any observational study, including that no direct causal relationship can be attributed to the associations between hospital quality and mortality rates for patients hospitalized with COVID-19. In addition, while RSMRs were adjusted for age and comorbidities, we did not include a time variable in the risk model, although we did examine associations during the early and later part of the pandemic and did not see marked differences except for the association with the pre-COVID-19 Mortality group score and COVID-19 RSMRs. Because hospital-level COVID-19 burden became available starting in August 2020, we were not able to include it in the risk model. Therefore, while the results do not directly assess the confounding effect of COVID-19 burden on the associations between pre-COVID hospital quality and COVID-19 RSMRs, we did examine the associations between hospital-level COVID burden with both the outcome (COVID-19 RSMRs) and the exposure (pre-COVID Star Rating). Because burden was not substantially related to either the exposure or outcome, we expect this variable would not be an important confounder in the associations. In addition, we were not able to explore the relationship between these observations and a patient's vaccination status, due to lack of reliable patient-level data within claims; ICD-10 vaccination status code became effective April 1, 2022. Furthermore, COVID-19 mortality rates were calculated with Medicare Advantage and Medicare FFS claims for patients aged 65 and older; most of the measures in Star Rating are based on Medicare FFS patients. Finally, while measures within Star Rating use data from 2016-2019, some measures are based on different time periods (some are one-year measures, others are three-year measures) [23]. However, within measure groups measures have similar reporting timelines and most (74%) of hospitals report all five measure groups, suggesting that comparisons are based on information that reflects the same quality signal. In addition, all pre-COVID data reflect performance between 2016 and 2019.

Furthermore, we have shown associations between individual components (group scores) of pre-COVID Star Rating, and COVID-19 mortality.

Our results are, in part, consistent with and extend upon the findings of other work examining drivers of mortality rates in patients admitted to ICUs at 70 hospitals between March and June of 2020. Study authors found that at the patient level, while most of the variation in mortality (70%) was explained by the physiology of the patient at ICU admission, demographics (primarily age) and comorbidities, hospital quality (among other hospital factors) was also a contributing factor [24]. The findings from our work expand this observation by examining hospital-level associations with quality not limited to the ICU, to all patients diagnosed with COVID-19 over an 18-month period for more than a million patients at over four thousand hospitals.

Our findings suggest that quality domains such as communication (represented by the Patient Experience group score), and quality domains tied more closely to processes and checklists (reflected within the Timely & Effective Care and Mortality group scores) are associated with better outcomes in patients hospitalized with COVID-19. During regular operations, the development of, and adherence to, evidence-based care processes that are tied to better outcomes is a hallmark of high quality-hospitals [25-28], and it is possible that hospitals that were able to rapidly translate those capabilities were better positioned to care for patients hospitalized with COVID-19.

The outcome variation and association found in this work cannot likely be tied to any single care process or outcome and was beyond the scope of national data available. For example, one study found wide variation in adherence to ARDS protocols for patients with COVID-19 and while not statistically significant, hospitals with better protocol adherence had lower mortality rates [29]. Concentrating expertise and processes in a single setting may also have been an effective protocol; patients admitted to hospitals dedicated to the care of COVID-19 patients had better outcomes compared with hospitals that did not specialize [30].

There are many other hospital-level factors that may have influenced even a prepared hospital's ability to respond to the pandemic. For example, one study found that after controlling for other factors, ICU patients in hospitals with a higher proportion of patients with social risk factors had worse outcomes [31]. In our study we found that urban location, larger bed size, teaching affiliation, and government or non-profit ownership had a stronger association between worse performance on Star Rating summary scores and higher 30-day COVID-19 RSMRs. Several of these characteristics are also associated with a larger proportion of patients with social risk factors but could also reflect differences in the geographic impact of COVID-19 over time. In addition, urban location, larger bed size, and teaching affiliation are often overlapping characteristics, and urban areas were early pandemic hotspots. Another study, however, did not find an association between academic status, profit status, or urban/non-urban setting and hospital RSERs during the first six months of the pandemic [32].

Another potential explanation for our findings could be that hospitals with better quality during normal operations also have more care quality-independent resources (e.g., financial resources) and those hospitals may have been able to pivot those resources to provide better care for patients with COVID-19, or to better care for their staff through purchase of supplies such as PPE. If this were true, one might predict that if resources were limited, hospital performance would decline as the level of COVID-19 burden increased. However, there is mixed evidence (from this work, and others) for the relationship between hospital-level COVID-19 mortality and measures of hospital and/or community level COVID-19 burden and differences between the association early vs. later in the pandemic [31-36]. In our study we found only a weak association between hospital-level mortality in patients hospitalized with COVID-19 and hospital-level COVID burden, defined by the total number of hospitalized patients with COVID divided by the number of hospital beds. Taken together, the evidence suggests that the capacities of hospitals to manage large patient loads may not have been a defining characteristic or may have been important mainly in the very early months of the pandemic. Future studies using additional measures (such as processes of care), additional data sources, including data from electronic health records and financial records, and data from multiple time points during and before the pandemic may help tease out the underlying drivers of the associations between pre-pandemic quality and outcomes for patients hospitalized with COVID-19.

On a broader scale, the COVID-19 pandemic has exposed disparities not just between hospitals, states, or regions, but in outcomes across the world. These disparities are driven by several different factors, including pre-pandemic healthcare system resilience/preparedness. For example, Haldane and colleagues [37] examined outcomes across 28 countries and characterized performance within a resilience/preparedness framework that includes (among others) health care service delivery and health care workforce (including the quality and quantity of the workforce), connected by two communication domains; communication across sectors (e.g., government and healthcare) and engagement with the community. While overall, the authors did not identify a “silver bullet” that characterized better outcomes (lower mortality per capita), they were able to identify core capabilities of higher performing countries which parallel our findings in this study. For example, in parallel with the concept that higher quality hospitals may have had more resources that could be deployed to address COVID-19, higher performing countries (those with lower per-capita COVID-19 deaths) were found to have been well-funded and could pivot their resources toward obtaining supplies, reallocating and training healthcare workers, and communicating with the public. Those well-funded and higher-performing systems were also better resourced to be able to continue to deliver primary care while addressing the surge of COVID-19 patients.

CONCLUSION

Across a national sample of hospitals, we found that pre-pandemic hospital quality is associated with COVID-19 hospitalization outcomes suggesting that hospital quality on common care may be a marker of hospital readiness/resilience to respond to a stress/shock such as COVID-19. Hospitals with better pre-pandemic quality may have been able to better translate care structures or processes used during normal operations into better care for patients during the COVID-19 pandemic. These results can help policy makers at the local, national, and international levels plan for future challenges, and can help hospital leadership assess their readiness/resilience for a future pandemic.

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Contributors: MS, SL, ET, YW, and DP contributed to the conception and design of the study; JZ provided assistance with data access and management; YW and SL performed all analyses. DP drafted the manuscript. ET, AKV, JG and ZL contributed critical additions and conceptual revisions to the manuscript; LF and LGS assisted with interpretation of results; SB, EN, and KW were involved in the development of Star Ratings. DP serves as guarantor of the study.

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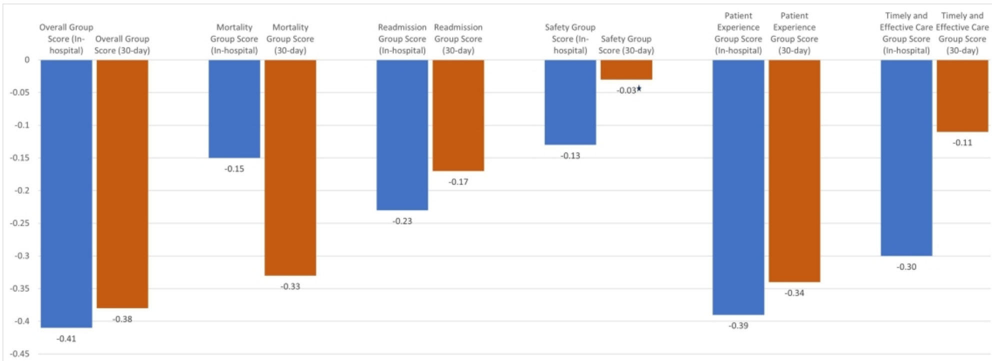

Volume-Weighted Correlations between pre-COVID Hospital Quality Star Rating Summary Scores and In-hospital and 30-day Risk-Standardized COVID-19 Mortality Rates (RSMRs) Blue bars represent correlation coefficients for in-hospital COVID-19 RSMRs and orange bars represent correlations for 30-day RSMRs. All p-values are <0.0001 except where indicated *Not significant (p=.07). The number of hospitals that qualified for analysis in each category are as follows: Summary score, n=4,256; Mortality Group score n=3,934; Readmission group score, n=4,182; Safety of Care group score, n=3,401; Patient Experience group score, n=3,198; Timely and Effective Care Group score, n=4,202.

228x82mm (300 x 300 DPI)

APPENDIX

Table of Figures (Appendix)

Figure 1A. CMS Overall Hospital Star Rating Methodology

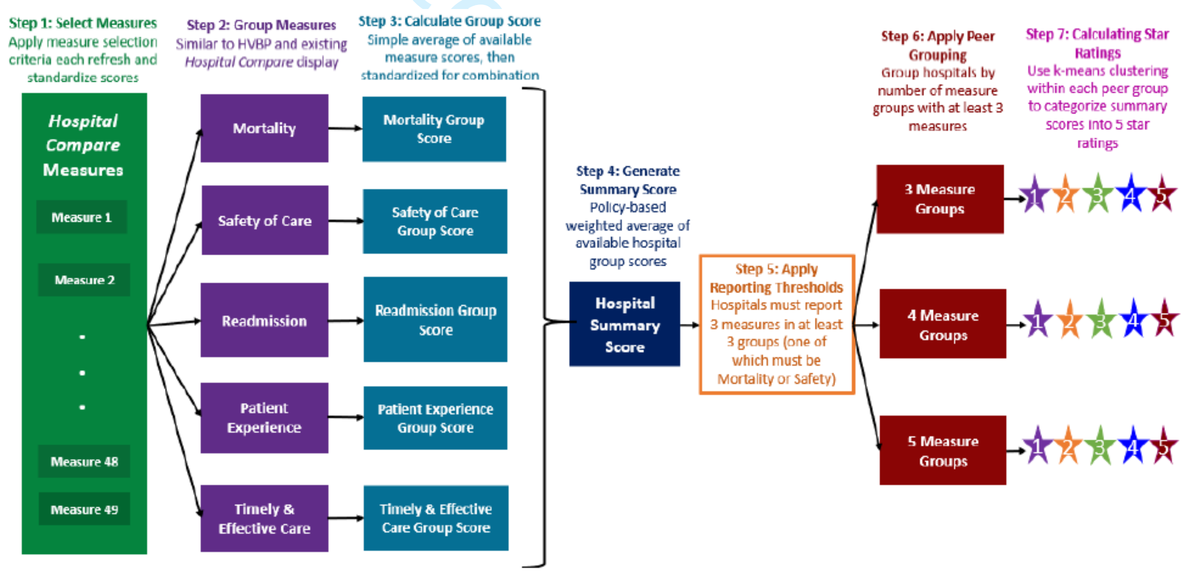

Table 1 A. Dates of data for measures in Overall Hospital Quality Star Rating on Care Compare for the April 2021 update

Mortality

Measure	Dates
MORT-30-AMI: 30-day death rate for heart attack patients	July 1, 2016 - June 30, 2019
MORT-30-CABG: Death rate for coronary artery bypass graft surgery patients	July 1, 2016 - June 30, 2019
MORT-30-COPD: Death rate for chronic obstructive pulmonary disease (COPD) patients	July 1, 2016 - June 30, 2019
MORT-30-HF: 30-day death rate for heart failure patients	July 1, 2016 - June 30, 2019
MORT-30-PN: 30-day death rate for pneumonia patients	July 1, 2016 - June 30, 2019
MORT-30-STK: Death rate for stroke patients	July 1, 2016 - June 30, 2019
PSI-4-SURG-COMP: Death rate among surgical inpatients with serious treatable complications	July 1, 2017 - June 30, 2019

Safety of Care

Measure	Dates
HAI-1: Central-line associated bloodstream infection (CLABSI)	January 1, 2019 - December 31, 2019
HAI-2: Catheter-associated urinary tract infection (CAUTI)	January 1, 2019 - December 31, 2019
HAI-3: Surgical site infection from colon surgery (SSI: Colon)	January 1, 2019 - December 31, 2019

Measure	Dates
HAI-4: Surgical site infection from abdominal hysterectomy (SSI-abdominal hysterectomy)	January 1, 2019 - December 31, 2019
HAI-5: Methicillin-resistant staphylococcus aureus (or MRSA) blood infections (Antibiotic-resistant blood infections)	January 1, 2019 - December 31, 2019
HAI-6: Clostridium difficile (or C. diff.) infections (Intestinal infections)	January 1, 2019 - December 31, 2019
COMP-HIP-KNEE: Rate of complications for hip and knee replacement patients	April 1, 2016 - March 31, 2019
PSI-90: Patient Safety and Adverse Events Composite	July 1, 2017 - June 30, 2019

Readmission

Measure	Dates
READM-30-CABG: Rate of unplanned readmission after coronary artery bypass graft (CABG) surgery	July 1, 2016 - June 30, 2019
READM-30-COPD: Rate of unplanned readmission for chronic obstructive pulmonary disease patients	July 1, 2016 - June 30, 2019
READM-30-Hip-Knee: 30-day rate of readmission for hip and knee replacement patients	July 1, 2016 - June 30, 2019
READM-30-HOSP-WIDE: Rate of readmission after discharge from hospital	July 1, 2018 - June 30, 2019
EDAC-30-AMI: Acute myocardial infarction excess days in acute care (EDAC)	July 1, 2016 - June 30, 2019
EDAC-30-HF: Heart failure excess day sin acute care (EDAC)	July 1, 2016 - June 30, 2019
EDAC-30-PN: Pneumonia excess day sin acute care (EDAC)	July 1, 2016 - June 30, 2019
OP-32: Facility 7-day risk standardized hospital visit rate after outpatient colonoscopy	January 1, 2017 - December 31, 2019
OP-35 ADM: Admissions visits for patients receiving outpatient chemotherapy	January 1, 2019 - December 31, 2019
OP-35 ED: Emergency department (ED) visits for patients receiving outpatient chemotherapy	January 1, 2019 - December 31, 2019
OP-36: Hospital visits after hospital outpatient surgery	January 1, 2019 - December 31, 2019

Patient Experience

Measure	Dates
H-COMP-1: Communication with nurses	January 1, 2019 - December 31, 2019
H-COMP-2: Communication with doctors	January 1, 2019 - December 31, 2019
H-COMP-3: Responsiveness of hospital staff	January 1, 2019 - December 31, 2019
H-COMP-5: Communication about medicines	January 1, 2019 - December 31, 2019
H-COMP-6: Discharge information	January 1, 2019 - December 31, 2019
H-COMP-7: Care transition	January 1, 2019 - December 31, 2019
H-CLEAN-HSP Cleanliness of hospital environment (Q8) + H-QUIET-HSP Quietness of hospital environment (Q9) / 2	January 1, 2019 - December 31, 2019
H-HSP-RATING Hospital rating (Q21) + H-RECMND: Willingness to recommend hospital (Q22) / 2	January 1, 2019 - December 31, 2019

Timely and Effective Care

Measure	Dates
IMM-3: Percent of healthcare workers vaccinated against Influenza	October 1, 2019 - March 31, 2020
OP-10: Outpatient PA scans of the abdomen that were “combination” (double) scans	July 1, 2018 - June 30, 2019
OP-13: Medicare patients who got cardiac imaging stress tests to screen for surgical risk before low-risk outpatient surgery	July 1, 2018 - June 30, 2019

Measure	Dates
OP-18b: Average time patients spent in the emergency department before being sent home	January 1, 2019 - December 31, 2019
OP-22: Percentage of patients who left the emergency department before being seen	January 1, 2019 - December 31, 2019
OP-23: Percentage of patients who came to the emergency department with stroke symptoms who received brain scan results within 45 minutes of arrival	January 1, 2019 - December 31, 2019
OP-29: Appropriate follow-up interval for normal colonoscopy in average risk patients	January 1, 2019 - December 31, 2019
OP-33: External beam radiotherapy for bone metastases	January 1, 2019 - December 31, 2019
OP-3b: Average number of minutes before outpatients with chest pain or possible heart attack who needed specialized care were transferred to another hospital	January 1, 2019 - December 31, 2019
OP-8: Outpatients with low back pain who had an MRI without trying recommended treatments first, such as physical therapy	July 1, 2018 - June 30, 2019
PC-01: Percent of newborns whose deliveries were scheduled too early (1-3 weeks early), when a scheduled delivery was not medically necessary	January 1, 2019 - December 31, 2019
SEP-1: Percentage of patients who received appropriate care for severe sepsis and septic shock	January 1, 2019 - December 31, 2019

Table 2 A. Components of the Charlson Risk Adjustment methodology[1]

Description
All
Age
Unknown: #, %
Mean, Standard Deviation
Minimum, Maximum
1st Percentile, 99th Percentile
1st Quartile, 3rd Quartile
Median, Quartile Range
Myocardial Infarction (Yes/No)
Congestive Heart Failure (Yes/No)
Peripheral Vascular Disease (Yes/No)
Cerebrovascular Disease (Yes/No)
Dementia (Yes/No)
Chronic Pulmonary Disease (Yes/No)
Connective Tissue Disease-Rheumatic Disease (Yes/No)
Peptic Ulcer Disease (Yes/No)
Mild Liver Disease (Yes/No)
Diabetes without complications (Yes/No)
Diabetes with complications (Yes/No)
Paraplegia and Hemiplegia (Yes/No)
Renal Disease (Yes/No)
Cancer (Yes/No)

Moderate or Severe Liver Disease (Yes/No)
Metastatic Carcinoma (Yes/No)
AIDS/HIV (Yes/No)

Table 3A: Associations between star rating group scores for hospitals reporting 3, 4, or 5 groups, and in-hospital and 30-day risk-standardized mortality in patients hospitalized with COVID-19.

	Correlation Coefficient (number of hospitals) All p values <0.05 unless noted with an *					
Hospital Characteristic	**Hospital Summary Score**	**Mortality Group Score**	**Readmission Group Score**	**Safety of Care Group Score**	**Patient Experience Group Score**	**Timely and Effective Care Group Score**
Peer Group 3: In-hospital RSMR	-0.29 (318)	-0.14 (292)	-0.28 (318)	-0.04* (186)	-0.35 (65)	-0.06* (312)
Peer Group 3: 30-day RSMR	-0.23 (318)	-0.25 (292)	-0.14 (218)	-0.03* (186)	-0.11* (65)	-0.10* (312)
Peer Group 4: In-hospital RSMR	-0.31 (540)	-0.07* (528)	-0.28 (540)	0.07* (487)	-0.39 (531)	-0.24 (539)
Peer Group 4: 30-day RSMR	-0.28 (540)	-0.18 (528)	-0.15 (540)	0.06* (487)	-0.36 (531)	-0.16 (539)
Peer Group 5: In-hospital RSMR	-0.40 (2,458)	-0.15 (2,458)	-0.22 (2,458)	-0.16 (2,458)	-0.38 (2,458)	-0.30 (2,458)
Peer Group 5: 30-day RSMR	-0.40 (2,458)	-0.33 (2,458)	-0.17 (2,458)	-0.04* (2,458)	-0.35 (2,458)	-0.10 (2,458)

*p-value not significant

References (Appendix)

1. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 1987;40:373-383.