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

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ABSTRACT

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

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

Setting Short-term acute care hospitals and critical access hospitals in the USA.

Participants Hospitalised Medicare beneficiaries (Fee-For-Service and Medicare Advantage) age 65 and older hospitalised with COVID-19, discharged between 1 April 2020 and 30 September 2021.

Intervention/exposure Pre-COVID-19 hospital quality.

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

Results In-hospital (n=4256) RSMRs for Medicare patients hospitalised with COVID-19 (April 2020–September 2021) ranged from 4.5% to 59.9% (median 18.2%; 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 days −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 to 1.91; 30-day OR 1.46, 95% CI 1.43 to 1.48) compared with 5-star hospitals. If all hospitals performed like an average 5-star hospital, we estimate 38 000 fewer COVID-19-related deaths would have occurred between April 2020 and September 2021.

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

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Our study includes data for more than a million patients and four thousand hospitals.
⇒ Our study compared hospital quality before the pandemic with risk-standardised COVID-19 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 influenza epidemic, hospitals likely did not prioritise preparation for a future pandemic.[1] This lack of adequate preparation may have contributed in part to the death of more than a million people in the USA alone. As the WHO and the USA, 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-centred 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-standardised mortality rates (RSMRs), 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, hypothesised that prepandemic 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-standardised COVID-19 mortality rates among patients hospitalised with COVID-19 (COVID-19 RSMRs). We then explored the relationship between a marker of pre-COVID-19 hospital quality (the hospital summary score used to calculate the Centers for Medicare and Medicaid Services (CMS) Overall Hospital Quality Star Rating—hereafter 'star rating summary score'—and its components) and COVID-19 RSMRs. We stratified the association between pre-COVID-19 hospital quality and COVID-19 outcomes by hospital characteristics and explored the relationship between COVID-19 outcomes and hospital COVID-19 burden.

We acknowledge that there is no gold standard for 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-centredness, timeliness, efficiency and equity),[3] quality measures within these domains can differ, and there is no one accepted 'gold standard' on which individual measures to include or how to combine them into an overall quantitative assessment of hospital quality.[8] We, therefore, used a publicly available and publicly vetted definition of overall hospital quality (CMS Overall Hospital Quality Star Rating) as the basis for our study.[9]

METHODS

Data sources

We used administrative claims data from the CMS that included patients diagnosed with COVID-19 who were admitted to hospitals in the USA and its territories between 1 April 2020 and 30 September 2021. We used the CMS Provider of Services files to obtain hospital characteristics,[10] 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.[11 12] To examine the impact of the level of hospital 'COVID-19 burden' on these results, we used hospital-reported data provided to the public by the US Department of Health and Human Services.[13]

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 (International Classification of Diseases, ICD-10 code U07.1) for patients discharged from an acute care or critical access hospital (CAH) between 1 April 2020 and 30 September 2021.

Measures of pre-COVID-19 hospital quality and COVID-19 burden

To characterise pre-COVID-19 hospital quality, we used the star rating summary score (April 2021 release) used to calculate CMS' Overall Hospital Quality Star Rating, which summarises existing hospital quality information by assigning hospitals 1–5 stars based on their performance in measures within groups (online supplemental appendix, figure 1A). Version 4.0 categorises measures into 5 groups—mortality (7 measures), readmission (11), safety of care (8), patient experience (8) and timely and effective care.[14] 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 (online supplemental 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 hospitalisations for all adult patients (not limited to Medicare patients) divided by the number of hospital beds.

Outcome assessment

We calculated hospital-level risk-standardised mortality rates (RSMRs) for COVID-19 patients (in-hospital and within 30 days from the date of admission) using hierarchical logistic regression models.[15–18] The models adjust for components of the Charlson Comorbidity Index, including age (online supplemental appendix, table 2A).[19] The commonly used Charlson Comorbidity Index calculates a risk score for each patient using 19

ICD diagnosis codes from administrative data. Hospital RSMRs are the ratio of a hospital's 'predicted' to 'expected' mortality, multiplied by the 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.[20]

Statistical analyses

We calculated volume-weighted Pearson correlations to evaluate associations between hospital-level RSMRs and pre-COVID-19 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 the 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 recalculated 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-19 burden, calculated as the weekly average number of laboratory-confirmed COVID-19 hospitalisations 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 1 April 2020 and 30 September 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 online supplemental appendix).[21] To examine the impact of the number of group scores hospitals reported to CMS and our observations, we recalculated 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 hospitalisation 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 recalculated 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 V.9.4 and were performed by two authors (S-XL and YW).

Table 1 Patient characteristics (number and frequency of Charlson Comorbidity Index variables)

Characteristic	No	Percent
All	1 229 071	100.00
Age (mean, SD)	77.8 (8)	--
Myocardial infarction	150 083	12.21
Congestive heart failure	7913	0.64
Peripheral vascular disease	95 170	7.74
Cerebrovascular disease	85 694	6.97
Dementia	250 869	20.41
Chronic pulmonary disease	1270	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	7877	0.64
Metastatic carcinoma	18 038	1.47
AIDS/HIV	1130	0.09

RESULTS

Variation in hospital-level COVID-19 RSMRs and stratification by hospital characteristics

Between 1 April 2020 and 30 September 2021, 1 229 071 Medicare beneficiaries with a diagnosis of COVID-19 were admitted to 4343 US 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 COVID-19 RSMRs. Among the 4343 hospitals with at least 1 COVID-19 patient, in-hospital RSMRs ranged from 4.5% to 59.9%; the median in-hospital RSMR was 18.2% (IQR 14.7%–23.7%). A 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 characteristics. Mean in-hospital RSMRs were significantly (p<0.0001) 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

Table 2 Mean risk-adjusted COVID-19 RSMRs by hospital characteristics (for hospitals with ≥1 COVID-19 admission) between 1 April 2020 and 30 September 2021*

Hospital characteristic	No of hospitals	Mean in-hospital RSMR (%)	SD (%)	Mean 30-day RSMR	SD (%)
All hospitals	4343	19.7	7.3	27.8	4.9
Hospitals in rural area					
Rural	1765	17.4	5.6	27.7	4.5
Urban	2555	21.3	7.8	27.9†	5.2
Bed size					
1–99	2078	16.7	5.4	27.3	4.3
100–199	792	21.0	7.9	28.4	5.5
200–299	502	22.8	7.3	28.5	5.1
300–399	364	23.6	8.1	28.7	5.5
400+	584	23.6	7.0	27.6	5.4
Teaching Status					
Teaching	1180	22.2	7.5	27.7	5.3
Non-teaching	3139	18.8	6.9	27.8	4.8
Critical access status					
Critical access	1256	16.2	4.3	27.1	3.6
Not critical access	3064	21.2	7.7	28.1	5.4
Nurse-to-bed ratio					
<1	1914	19.5	7.4	28.3	4.9
1 to <2	1858	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	2648	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 stars	685	24.3	7.2	29.6	4.9
3 stars	1002	22.8	6.5	28.5	4.8
4 stars	979	20.7	6.3	26.7	4.7
5 stars	449	18.0	5.8	24.5	4.9

*All differences between categories (eg, rural vs urban; teaching vs non-teaching) are significant (p<0.05) except as indicated.
†Not significant (p=0.316).
RSMRs, risk-standardised mortality rates.

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 versus 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-19 burden calculated using weekly hospital-reported COVID-19 utilisation data (see the Methods section) 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 (1–5 stars). 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 29.1% for 1-star hospitals (n=201) vs 18.0% for 5-star hospitals (n=449); mean

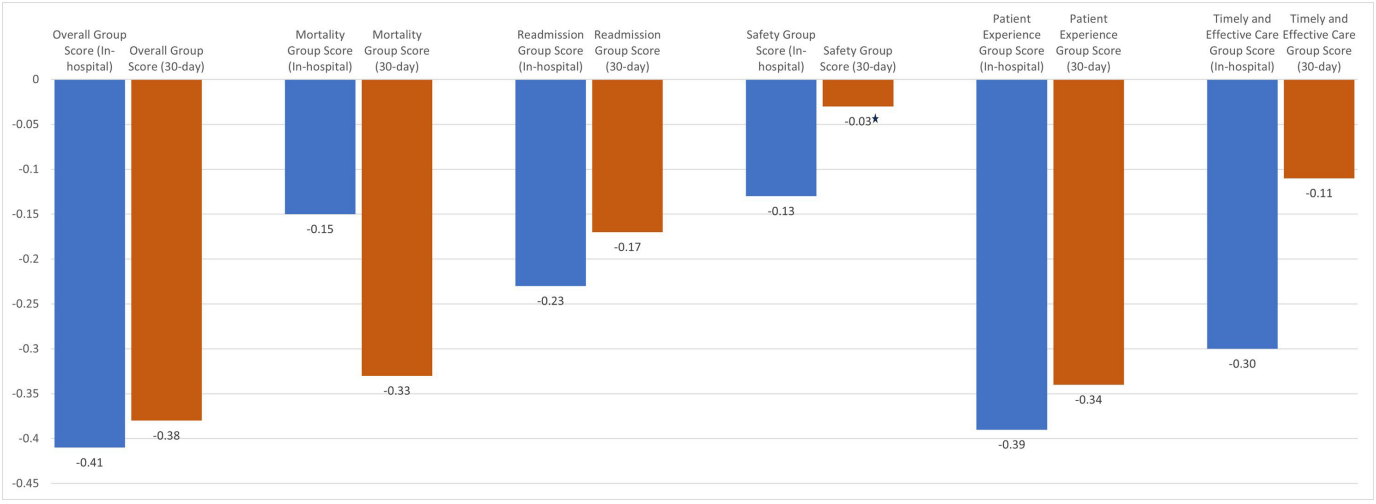

Figure 1 Volume-weighted correlations between pre-COVID-19 hospital quality star rating summary scores and in-hospital and 30-day risk-standardised COVID-19 mortality rates (RSMRs). Blue bars represent correlation coefficients for in-hospital COVID-19 RSMRs and orange bars represent correlations for 30-day RSMRs. All p values are <0.0001 except where indicated *not significant (p=0.07). A number of hospitals that qualified for analysis in each category are as follows: summary score ("overall group score"), n=4256; mortality group score n=3934; readmission group score, n=4182; safety of care group score, n=3401; patient experience group score, n=3198; timely and effective care group score, n=4202. RSMRs, risk-standardised mortality rates.

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 online supplemental appendix table, 2A).

We then calculated Pearson correlation coefficients between pre-COVID-19 star rating performance (summary scores and the five individual measure group scores) and COVID-19 RSMRs with April 2020–September 2021 data, near the peak of the Delta variant wave in the USA. Star rating summary scores among 4256 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–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 COVID-19 RSMRs and the star rating summary score and its component group scores for: larger versus smaller bed-size hospitals (−0.43 for hospitals with 400+ beds vs −0.22 for hospitals with 1–99 beds), hospitals with academic affiliation versus without (−0.46 vs −0.32), hospitals in urban versus rural locations (−0.41 vs −0.21, respectively), government and not-for-profit hospitals versus for-profit (−0.48 and −0.38 vs −0.12, respectively) and non-CAH versus 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 address concerns that hospitals reporting 3 vs 4 vs 5 measure groups may have differing hospital quality, and possibly confound the results of this study, we recalculated 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 between all three strata and all of the individual group scores (see table 3A, online supplemental 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 hospitalisation volume, we examined results for hospitals with at least 25 COVID-19 patients; we found that among the 3405 hospitals that met these criteria, results were similar (data not shown) to results with hospitals with at least one COVID-19 hospitalisation. As a sensitivity analysis to determine the impact of outliers on the observed associations, we recalculated correlation coefficients (among all hospitals) after removing hospitals with the 20 highest and 20 lowest 30-day COVID-19

Table 3 Hospital characteristics and associations 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 RSMRs).

	Correlation coefficient (no of hospitals) All p values <0.05 unless noted with a*					
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	−0.38 (4256)	−0.33 (3934)	−0.17 (4182)	−0.03* (3401)	−0.34 (3198)	−0.11 (4202)
Rural	−0.21 (1738)	−0.29 (1568)	−0.08 (1685)	0.04* (1067)	−0.16 (955)	−0.07 (1711)
Urban	−0.41 (2517)	−0.33 (2366)	−0.19 (2497)	−0.05 (2334)	−0.38 (2243)	−0.13 (2490)
Beds: 1–99	−0.22 (2028)	−0.24 (1758)	−0.11 (1958)	0.05* (1205)	−0.23 (1041)	−0.11 (1987)
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 (1166)	−0.35 (1124)	−0.22 (1162)	−0.10 (1100)	−0.43 (1081)	−0.11 (1160)
Non-teaching hospitals	−0.32 (3089)	−0.29 (2810)	−0.13 (3020)	0.01* (2301)	−0.27 (2117)	−0.14 (3041)
Critical access hospital	−0.13 (1231)	−0.13 (1031)	−0.08 (1174)	0.03* (412)	−0.25 (405)	−0.09 (1199)
Not a critical access hospital	−0.39 (3024)	−0.33 (2903)	−0.17 (3008)	−0.04 (2989)	−0.34 (2793)	−0.11 (3002)
Nurse-to-bed ratio <1	−0.35 (1872)	−0.36 (1659)	−0.10 (1815)	−0.01* (1334)	−0.29 (1168)	−0.16 (1836)
Nurse-to-bed ratio 1 to <2	−0.39 (1847)	−0.31 (1772)	−0.21 (1836)	−0.04* (1575)	−0.36 (1546)	−0.11 (1832)
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 (2625)	−0.32 (2472)	−0.16 (2120)	−0.04 (2120)	−0.34 (2120)	−0.12 (2599)
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).
RSMRs, risk-standardised mortality rates.

RSMRs, and the 20 highest and 20 lowest star rating summary scores and found the correlation was similar (−0.40, p<0.0001, n=4196 hospitals). Finally, the 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 hospitalisations of Medicare beneficiaries across more than 4300 hospitals, we found that risk-standardised 30-day mortality rates were significantly 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 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 may also reflect, 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 USA. In addition, we calculated RSMRs to assess patient outcomes. Our study also

Table 4 Hospital characteristics and associations between star rating summary scores and in-hospital COVID-19 RSMRs (values represent Pearson correlation coefficients between star rating summary and group scores and in-hospital COVID-19 RSMRs).

	Correlation coefficient (no of hospitals) All p values <0.05 unless noted with a*					
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 (4256)	−0.15 (3934)	−0.24 (4182)	−0.13 (3193)	−0.39 (3198)	−0.30 (4202)
Rural	−0.32 (1738)	−0.31 (1568)	−0.17 (1685)	−0.002* (1067)	−0.244 (955)	−0.13 (1711)
Urban	−0.42 (2517)	−0.15 (2366)	−0.23 (2497)	−0.16 (2334)	−0.39 (2243)	−0.31 (2490)
Beds: 1–99	−0.23 (2028)	−0.16 (1758)	−0.13 (1958)	0.03* (1205)	−0.30 (1041)	−0.16 (1987)
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 (1166)	−0.17 (1124)	−0.29 (1162)	−0.20 (1100)	−0.49 (1081)	−0.27 (1160)
Non-teaching hospitals	−0.33 (3089)	−0.14 (2810)	−0.18 (3020)	−0.05 (2301)	−0.28 (2117)	−0.29 (3041)
Critical access hospital	−0.10 (1231)	−0.16 (1031)	−0.05* (1174)	−0.06* (412)	−0.18 (405)	−0.06 (1199)
Not a critical access hospital	−0.34 (3024)	−0.16 (2903)	−0.23 (3008)	−0.15 (2989)	−0.38 (2793)	−0.29 (3002)
Nurse-to-bed ratio <1	−0.40 (1872)	−0.18 (1659)	−0.19 (1815)	−0.12 (1334)	−0.34 (1168)	−0.31 (1836)
Nurse-to-bed ratio 1 to <2	−0.43 (1847)	−0.13 (1772)	−0.30 (1836)	−0.15 (1575)	−0.42 (1546)	−0.28 (1832)
Nurse-to-bed ratio 2+	−0.39 (536)	0.13 (503)	−0.16 (531)	0.09 (492)	−0.42 (484)	−0.38 (533)
Ownership: Government	−0.59 (957)	−0.33 (840)	−0.43 (920)	−0.21 (594)	−0.41 (499)	−0.35 (934)
Ownership: not-for-profit	−0.45 (2625)	−0.15 (2472)	−0.27 (2594)	−0.14 (2187)	−0.45 (2120)	−0.30 (2599)
Ownership: for-profit	−0.11 (673)	−0.06* (622)	0.02* (6668)	<0.001* (620)	−0.19 (579)	−0.28 (668)

*P value not significant (>0.05).
RSMRs, risk-standardised mortality rates.

used a comprehensive and publicly reported measure of hospital quality to assess pre-COVID-19 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 hospitalised 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, which was stronger in the later part of the pandemic. 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-19 hospital quality and COVID-19 RSMRs, we did examine the associations between hospital-level COVID-19 burden with both the outcome (COVID-19 RSMRs) and the exposure (pre-COVID-19 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; the ICD-10 vaccination status code became effective 1 April 2022. Furthermore, COVID-19 mortality rates were calculated with MA 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 to 2019, some measures are based on different time periods (some are 1-year measures, others are 3-year measures).[21] However, within measure groups, measures have similar reporting timelines and most hospitals (74%) report all five measure groups, suggesting that comparisons are based on information that reflects the same quality signal. Furthermore, we have found associations between individual components (group scores) of pre-COVID-19 star rating and COVID-19 mortality.

Our results are, in part, consistent with and extend on the findings of other work examining drivers of mortality rates in patients admitted to ICUs at 70 hospitals between March and June 2020.[22] 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. 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 and effective care and mortality group scores) are associated with better outcomes in patients hospitalised 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,[23–26] and it is possible that hospitals that were able to rapidly translate those capabilities were better positioned to care for patients hospitalised with COVID-19.

The COVID-19 outcome variation and association found in this work cannot, however, likely be tied to any single care process (nor could this be determined in our study using the national data available). One study, however, found wide variation in adherence to Acute Respiratory Distress Syndrome (ARDS) protocols for patients with COVID-19 and while not statistically significant, hospitals with better protocol adherence had lower mortality rates.[27] Concentrating expertise and processes in a single setting may 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 specialise.[28]

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.[22] 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 geographical 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 COVID-19 outcomes during the first 6 months of the pandemic.[29]

Another potential explanation for our findings could be that hospitals with better quality during normal operations also have more care quality-independent resources (eg, 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 personal protective eqipment (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 versus later in the pandemic.[22 29–33] In our study we found only a weak association between hospital-level mortality in patients hospitalised with COVID-19 and hospital-level COVID-19 burden, defined by the total number of hospitalised patients with COVID-19 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 prepandemic quality and outcomes for patients hospitalised 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 prepandemic healthcare system resilience/preparedness. For example, Haldane *et al*[34] examined outcomes across 28 countries and characterised performance within a resilience/preparedness framework that includes healthcare service delivery and healthcare workforce (including the quality and quantity of the workforce), connected by two communication domains; communication across sectors (eg, government and healthcare) and engagement with the community. While overall, the authors did not identify a 'silver bullet' that characterised 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 towards 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 prepandemic hospital quality is associated with COVID-19 hospitalisation outcomes suggesting that hospital quality for common care may be a marker of hospital readiness/resilience to respond to a stress/shock such as COVID-19. Hospitals with better prepandemic 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 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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Competing interests S-XL, YW, JZ, JG, KM, EN, ZL, AV, LS and EWT receive salary support from the Centers for Medicare and Medicaid Services to develop, implement and maintain hospital performance outcome measures, including the methodology for the Overall Hospital Star Ratings, that are publicly reported. SB and MS are employed by CMS. LAF is employed by the Perelman School of Medicine at the University of Pennsylvania. DP is a subcontractor to Yale/CORE.

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

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by Yale School of Medicine IRB: Research on the Centers for Medicare and Medicaid Services (CMS) Data; Number: 0903004927. This is a retrospective study based on claims data (billing data) submitted by hospitals to the Centers for Medicare and Medicaid Services, as part of the billing/payment process.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Star rating data and COVID-19 utilisation data are available to the public through CMS. CMS claims data to calculate the COVID-19 outcome can be obtained through a third party.

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APPENDIX

Table of Figures (Appendix)

Figure 1A. CMS Overall Hospital Star Rating Methodology

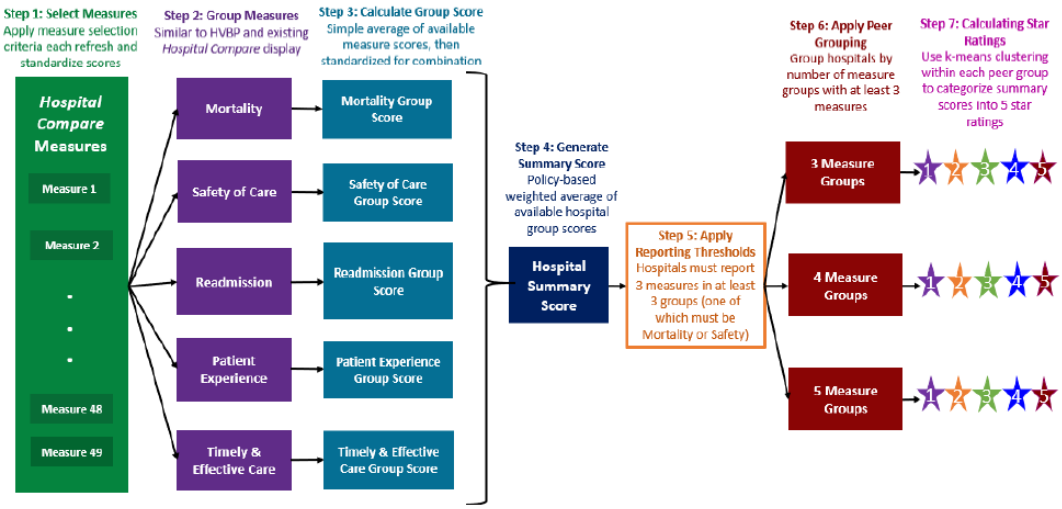

Table 1 A. Dates of data for measures in Overall Hospital Quality Star Rating on Care Compare for the April 2021 update

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

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