BMJ Public Health

Characteristics associated with high hospital spending over 1 year among patients hospitalised for COVID-19 in the USA: a cohort study

Sameer Nair-Desai,[1] Laura C Chambers ,[2] Mark J Soto,[3] Caroline Behr,[3] Leah Lovgren,[2] Tamsin Zandstra,[2] Scott A Rivkees ,[4] Ning Rosenthal,[5] Francesca L Beaudoin,[2,6] Thomas C Tsai[3,7]

To cite: Nair-Desai S, Chambers LC, Soto MJ, *et al*. Characteristics associated with high hospital spending over 1 year among patients hospitalised for COVID-19 in the USA: a cohort study. *BMJ Public Health* 2023;**1**:e000263. doi:10.1136/bmjph-2023-000263

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/bmjph-2023-000263).

Received 5 June 2023
Accepted 28 September 2023

For numbered affiliations see end of article.

Correspondence to
Dr Laura C Chambers; laura_chambers@brown.edu

ABSTRACT

Introduction Despite complex care needs during critical COVID-19, the associated long-term healthcare spending is poorly understood, limiting the ability of policy-makers to prioritise necessary care and plan for future medical countermeasures.

Methods We conducted a retrospective cohort study of adults hospitalised with COVID-19 in the USA (April–June 2020) using data from the national PINC AI Healthcare Database. Patients were followed for 365 days to measure hospital spending starting on the date of admission. We used a multivariable logistic model to identify characteristics associated with high spending.

Results Among 73 606 patients hospitalised with COVID-19, 73% were aged ≥50 years, 51% were female, and 37% were non-Hispanic white. Mean hospital spending per patient over 90 days was US$28 712 (SD=US$48 583) and over 365 days was US$31 768 (SD=US$52 811). Patients who received care in the intensive care unit (36% vs 23% no intensive care, p<0.001), received a non-recommended COVID-19 treatment (28% vs 25% no treatment, p<0.001), had a longer length of stay (p<0.001), and had Medicare (27% vs 22% commercial, p<0.001) or Medicaid (25% vs 22% commercial, p<0.001) insurance were associated with a higher predicted probability of high hospital spending over 365 days. Patients who received recommended treatment (21% vs 25% no treatment, p<0.001) and were Hispanic and any race (24% vs 26% non-Hispanic white, p<0.001), non-Hispanic Asian (25% vs 26% non-Hispanic white, p=0.011), 'other' or unknown race and ethnicity (24% vs 26% non-Hispanic white, p<0.001), or female (25% vs 26% male, p<0.001) were associated with a lower predicted probability of high hospital spending.

Conclusions Most hospital spending incurred over 1 year was for care within 90 days of admission. Patients receiving complex care or non-recommended treatments were associated with higher spending, while those receiving recommended treatments were associated with lower spending. These findings can inform pandemic preparedness planning.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Despite complex care needs during critical COVID-19 illness, the associated long-term healthcare spending is poorly understood, limiting the ability of policy-makers to prioritise necessary care and plan for future medical countermeasures.

WHAT THIS STUDY ADDS

⇒ Our study suggests that the average hospital spending per patient hospitalised for COVID-19 over 1 year was nearly US$32 000. Hospitalised COVID-19 patients receiving more complex acute care or non-recommended treatments were associated with higher spending, while those receiving recommended treatments were associated with lower spending.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ These findings provide important empirical foundations for the spending for a bundle of care associated with a COVID-19 hospitalisation episode and can inform future pandemic preparedness planning.

INTRODUCTION

The COVID-19 pandemic has resulted in over 100 million cases and one million deaths in the USA.[1] This extraordinary disease burden has caused unprecedented stress on the healthcare system. Additionally, the long-term health consequences of COVID-19 remain an urgent public health and medical priority. A substantial percentage of patients hospitalised for COVID-19 subsequently experience long-term symptoms of postacute sequelae of COVID-19 and/or postintensive care syndrome.[2–7] The extent of healthcare spending associated with COVID-19 among hospitalised people surviving to discharge remains critically important for policy-makers assessing the long-term consequences of

COVID-19 on healthcare and broader economic costs in the USA.[8–11]

Despite complex care needs during critical illness and the potential for long-term healthcare needs following acute infection, the associated long-term healthcare spending is poorly understood. Prior studies have estimated the spending associated with initial COVID-19 hospitalisations[12–14] but provide limited information on long-term spending following discharge. Additionally, due to the rapidly changing evidence landscape and misinformation that emerged during the COVID-19 pandemic, use of COVID-19 treatments such as ivermectin or hydroxychloroquine persisted without evidence of effectiveness. The spending associated with non-recommended treatments remains unknown. This is particularly salient as COVID-19 spending during the public health emergency was reimbursed by payors and available to patients without any cost-sharing. With healthcare access and coverage returning to prepandemic channels after expiration of the public health emergency, evidence on the healthcare spending associated with COVID-19 is important for policy-makers, clinicians and patients.

Therefore, the primary objectives of this study were to assess the hospital spending over 365 days among patients hospitalised with COVID-19 and identify sociodemographic, clinical and treatment-related factors associated with higher spending. A secondary objective was to identify common new diagnoses in the 365 days after COVID-19 hospitalisation among those with the highest spending.

METHODS

Data source

This study used data from January 2019 to June 2021 from the PINC AI Healthcare Database (PHD).[15] This database includes deidentified data from over one billion patient encounters at over 700 hospitals across the USA, accounting for nearly 25% of all inpatient admissions. The PHD has been used by the US Centers for Disease Control and Prevention and in prior studies assessing clinical outcomes and healthcare utilisation during the COVID-19 pandemic.[16–19] Compared with hospitals in the American Hospital Association, hospitals in the PHD were less likely to have fewer than 200 beds (57% vs 71%) and more likely to be teaching hospitals (72% vs 59%) (online supplemental e table 1).

Study design and sample

We conducted a retrospective cohort study of adults who had an inpatient hospital admission with a primary or secondary COVID-19 diagnosis (ICD-10 code U07.1) between April 2020 and June 2020 in the PHD (hereafter referred to as the 'index admission'). Patients who died during the index admission were excluded from this study. Patients were followed for 365 days starting on the date of their index admission to measure hospital spending and new clinical diagnoses.

Key measures

Outcomes

The primary outcome was total unadjusted hospital spending across encounter types over 365 days starting on the date of the index admission. Hospital spending included both variable and fixed expenses related to the delivered care such as labour, supplies and depreciation. Hospital spending did not include physician professional fees or care delivered outside of the hospital setting. Hospital spending over 365 days was categorised into quartiles based on the distribution among the study cohort. For the primary analyses, patients were classified as having 'high' spending (quartile 4) or lower spending (quartiles 1–3).

To gain insight into potential postacute sequelae of COVID-19, we considered new clinical diagnoses during the 365-day follow-up period among patients with at least one prior inpatient admission between January 2019 and March 2020 as a secondary outcome. New diagnoses made during, but not after, the index admission were excluded. Diagnosis categories were defined using the Clinical Classifications Software Refined.[20] To do this, we classified all diagnosis codes from encounters prior to and during the index admission and compared them to all classified diagnoses from after the index admission across encounter types. Diagnosis categories present after and not prior to or during the index admission were considered new diagnoses.

Other measures

Other measures considered included patient sociodemographic, index admission and hospital characteristics. Patient sociodemographic characteristics included age groups (18–34, 35–49, 50–64, 65–74, 75–84, or ≥85 years), race and ethnicity (Hispanic (any race), non-Hispanic Asian, non-Hispanic black, non-Hispanic white, or 'other' or unknown), sex (female or male), primary insurance type (commercial, Medicaid, Medicare, other, or none (self-pay)) and Elixhauser comorbidities.[21] Elixhauser comorbidities were defined based on diagnosis codes from all available claims during the study period. Index admission characteristics included length of hospital stay (days), intensive care unit (ICU) usage (yes or no), COVID-19 treatments provided (recommended, not recommended, or neither), and discharge to a skilled nursing facility (yes or no) or rehabilitation facility (yes or no). 'Recommended' treatment was defined as remdesivir with or without corticosteroids, while 'not recommended' treatment was defined as ivermectin or hydroxychloroquine, according to National Institutes of Health and US Centers for Disease Control and Prevention guidelines during the study period. Hospital characteristics included size (number of beds), teaching status (yes or no), geographical region (Midwest, Northeast, South, or West), urbanicity (rural or urban), profit status

(for-profit, public, or non-profit) and disproportionate share hospital index.[22]

Statistical analysis

Analyses were conducted using Stata V.16 (Cary, North Carolina), with a significance-level of alpha=0.05. Strengthening the Reporting of Observational Studies in Epidemiology guidelines were used throughout this report.

Characteristics of patients' index admission by quartile of spending in the 365 days starting on the date of the index admission were compared using non-parametric tests for trend.[23] The mean and SD of spending during the 365-day period were summarised per patient, by department and by treatment(s) provided during the index admission, and the non-parametric test for trend was used to test for differences by quartile of spending.

We fit a logistic model to estimate the association between select patient sociodemographic (age group, race and ethnicity, sex, primary insurance type and Elixhauser comorbidities) and inpatient admission (length of stay, ICU usage and treatments provided) characteristics and having high spending during the 365-day period. The model used robust standard errors, clustered by hospital, and included hospital-level and month-year fixed effects to control for unobservable differences in provider behaviour between hospitals and during different phases of the pandemic. A logistic model was used due to the binary outcome. Among patients with at least one prior inpatient admission between January 2019 and March 2020, the percentage of patients with select new clinical diagnoses during the 365-day period was summarised for those with the highest (quartile 4) and lowest (quartile 1) spending. Finally, several sensitivity analyses were conducted with each of the following adjustments: (1) substitution of hospital characteristics for hospital fixed effects, (2) use of a continuous measure of total unadjusted hospital spending as the outcome, (3) use of top quartile of hospital spending over 90 days starting on the date of index admission as the outcome, (4) exclusion of patients who died in-hospital following the index admission and (5) restriction to patients with a *primary* COVID-19 diagnosis during their index admission. For the analysis with a continuous outcome of total hospital spending, we used a generalised linear model with the outcome log transformed, otherwise specified as above.

Patient and public involvement

This study did not involve patients or the public.

RESULTS

Characteristics of sample

From April 2020 to June 2020, 73 606 adult patients had an inpatient hospital admission with a primary or secondary COVID-19 diagnosis (table 1). Overall, 73% of patients (n=53 900) were aged 50 years or older, and 51% were female (n=37 489). The largest number of patients were non-Hispanic white (37%, n=27 266), followed by non-Hispanic black (24%, n=17 979) and Hispanic (20%, n=14 863). Just under half of patients (45%, n=33 349) had Medicare insurance, while 27%

Table 1 Characteristics of the study sample of adult patients with an inpatient COVID-19 admission, April 2020–June 2020

	n=73 606 n (%)
Age group (years)	
18–34	7239 (10)
35–49	12 467 (17)
50–64	21 929 (30)
65–74	14 507 (20)
75–84	10 535 (14)
85+	6929 (9)
Race and ethnicity	
Hispanic (any race)	14 863 (20)
Non-Hispanic Asian	2327 (3)
Non-Hispanic black	17 979 (24)
Non-Hispanic white	27 266 (37)
Other or unknown	11 171 (15)
Sex	
Female	37 489 (51)
Male	36 117 (49)
Primary insurance type	
Commercial	19 770 (27)
Medicaid	14 347 (19)
Medicare	33 349 (45)
Other	3602 (5)
None (self-pay)	2538 (3)
Elixhauser comorbidities	
No comorbidities	8037 (11)
Any comorbidities	65 569 (89)
Number of comorbidities	
1	11 864 (16)
2–3	29 033 (39)
4+	24 672 (34)
Select specific comorbidities	
Chronic obstructive pulmonary disease	10 435 (14)
Diabetes	28 910 (39)
Hypertension	42 436 (58)
Obesity	17 914 (24)
Geographical region*	
Midwest	15 071 (20)
Northeast	28 162 (38)
South	23 735 (32)
West	6692 (9)

*Based on the location of the hospital attended for the index admission.

Table 2 Characteristics of patients' index COVID-19 admission, overall and by quartile of total unadjusted hospital spending in the 365 days starting on the date of index admission

		Total hospital spending over 365 days				
	Overall n=73 606 n (%)*	Quartile 1 n=18 406 n (%)*	Quartile 2 n=18 398 n (%)*	Quartile 3 n=18 395 n (%)*	Quartile 4 n=18 407 n (%)*	P value†
Length of stay, median (IQR)	6 (3–11)	2 (2–3)	5 (3–6)	8 (5–10)	16 (11–25)	<0.001
ICU usage	21 427 (29)	2497 (12)	3689 (17)	5484 (26)	9757 (46)	<0.001
Provided recommended treatment‡	15 136 (21)	3052 (20)	3651 (24)	4017 (27)	4416 (29)	<0.001
Provided not recommended treatment‡	24 921 (34)	4488 (18)	5595 (23)	6468 (26)	8370 (34)	<0.001
Discharged to skilled nursing facility	12 630 (17)	1447 (12)	2561 (20)	3747 (30)	4875 (39)	<0.001
Discharged to rehabilitation facility	1899 (3)	39 (2)	148 (8)	344 (18)	1368 (72)	<0.001

*Unless otherwise specified.
†Non-parametric test for trend.
‡Recommended treatment includes remdesivir with or without corticosteroids. Not recommended treatment includes ivermectin and/or hydroxychloroquine.
ICU, intensive care unit.

(n=19 770) had commercial insurance. Most patients (89%, n=65 569) had at least one Elixhauser comorbidity, with hypertension (58%, n=42 436) and diabetes (39%, n=28 910) being most common. Additionally, the largest number of patients attended hospitals in the Northeast (38%, n=28 162). Compared with all PHD hospitals, PHD hospitals with at least one patient included in the study sample (ie, adult admitted for COVID-19) were more likely to have 400 or more beds (33% vs 18%) and to be located in the Northeast (25% vs 15%) and less likely to be a teaching hospital (47% vs 72%) and located in the Midwest (16% vs 27%) (online supplemental e table 1).

Characteristics of the index COVID-19 admission

The median length of stay in the hospital during the index COVID-19 admission was 6 days (IQR=3–11) (table 2), and 29% of patients (n=21 427) received care in the ICU. About one-third of patients (34%, n=24 921) were provided a COVID-19 treatment that was not recommended (ie, ivermectin or hydroxychloroquine), while 21% (n=15 136) were provided a recommended treatment (ie, remdesivir with or without corticosteroids). Overall, 17% of patients (n=12 630) were discharged to a skilled nursing facility, and 3% (n=1899) were discharged to a rehabilitation facility.

Characteristics of the index admission differed by quartile of total unadjusted hospital spending in the 365 days starting on the date of index admission (all p<0.001). Compared with patients with the lowest spending (quartile 1), those with the highest spending (quartile 4) had a longer length of stay (median 16 vs 2 days), were more likely to have received care in the ICU (46% vs 12%), were more likely to have been provided recommended (29% vs 20%) and not recommended (34% vs 18%) treatments, and were more likely to have been discharged to skilled nursing (39% vs 12%) and rehabilitation (72% vs 2%) facilities.

Of note, 4% of patients (n=2708) died in-hospital following discharge from their index admission. The percentage of patients who died in-hospital following the index admission ranged from 10% (n=232) among those with the lowest spending to 40% (n=909) among those with the highest spending during the 365-day period (p<0.001).

Characteristics associated with high hospital spending

The mean total unadjusted hospital spending per patient in the 90 days starting on the date of index admission was US$28 712 (SD=US$48,583) and in the 365 days starting on the date of index admission was US$31 768 (SD=US$52 811) (table 3). Over the 365-day period, spending per patient was highest for inpatient services (mean=US$30 731, SD=US$52 174) and primarily driven by room and board, pharmacy, laboratory and respiratory services (online supplemental e table 2). The mean spending overall and by department and treatment provided during the index admission differed by quartile of spending in the 365 days starting on the date of index admission (all p<0.001). Mean overall spending per patient ranged from US$4849 (SD=US$1723) in quartile 1 to US$88 230 (SD=US$81 842) in quartile 4.

In multivariable analyses, most patient and index admission characteristics were associated with high spending (quartile 4 vs quartiles 1–3) in the 365 days starting on the date of index admission (table 4). Patients who received care in the ICU during the index admission had a higher predicted probability of high spending than those who did not (36% (95% CI 35% to 37%) vs 23% (95% CI 23% to 23%), p<0.001). Additionally, compared with patients who received neither COVID-19 treatment during the index admission (25% (95% CI 25% to 25%)), those who received a non-recommended treatment had a higher predicted probability of high spending (28% (95% CI 27% to 28%), p<0.001) and

Table 3 Summary of total unadjusted hospital spending, overall and by quartile of spending in the 365 days starting on the date of index admission

	Total hospital spending over 365 days					
	Overall n=73 606 Mean (SD)	Quartile 1 n=18 406 Mean (SD)	Quartile 2 n=18 398 Mean (SD)	Quartile 3 n=18 395 Mean (SD)	Quartile 4 n=18 407 Mean (SD)	P value*
Spending per patient						
First 90 days (US$)	28 712 (48 583)	4717 (1720)	10 673 (2499)	21 203 (6234)	78 575 (77 371)	<0.001
365 days (US$)	31 768 (52 811)	4849 (1723)	11 145 (2193)	22 812 (5242)	88 230 (81 842)	<0.001
Department						
Inpatient (US$)	30 731 (52 174)	4645 (1722)	10 644 (2481)	21 825 (5749)	85 778 (81 540)	<0.001
Outpatient (US$)	775 (5489)	99 (429)	312 (1116)	706 (2423)	1981 (10 538)	<0.001
Emergency department (US$)	262 (1668)	106 (353)	188 (626)	280 (1028)	472 (3079)	<0.001
Treatment(s) provided during index admission†						
Recommended (US$)	35 292 (57 364)	4964 (1706)	11 185 (2184)	22 814 (5249)	88 802 (85 132)	<0.001
Not recommended (US$)	40 339 (62 961)	4984 (1708)	11 246 (2190)	23 031 (5287)	95 934 (87 418)	<0.001
Neither (US$)	23 735 (39 424)	4757 (1727)	11 060 (2195)	22 631 (5195)	77 481 (69 561)	<0.001

*Non-parametric test for trend.
†Recommended treatment includes remdesivir with or without corticosteroids. Not recommended treatment includes ivermectin and/or hydroxychloroquine.

those who received a recommended treatment had a lower predicted probability of high spending (21% (95% CI 19% to 23%), p<0.001). Each additional day of hospitalisation during the index admission was also associated with a higher predicted probability of high spending (2% (95% CI 2% to 2%), p<0.001). Patients aged 35–49 years (25% (95% CI 25% to 26%), p=0.013), 50–64 years (26% (95% CI 26% to 27%), p<0.001), and 65–74 years (26% (95% CI 25% to 26%), p=0.004) were more likely to have high spending than those aged 18–34 years (24% (95% CI 23% to 25%)); however, the oldest age group (≥85 years) had a lower predicted probability of high spending relative to the youngest group (22% (95% CI 22% to 23%), p=0.023). Hispanic patients of any race (24% (95% CI 23% to 24%), p<0.001), non-Hispanic Asian patients (25% (95% CI 24% to 26%), p=0.011), patients of 'other' or unknown race and ethnicity (24% (95% CI 23% to 24%), p<0.001), and females (25% (95% CI 24% to 25%), p<0.001) were less likely to have high spending compared with non-Hispanic white (26% (95% CI 26% to 26%)) and male (26% (95% CI 25% to 26%)) patients, respectively. Finally, patients with Medicare (27% (95% CI 27% to 28%), p<0.001) and Medicaid (25% (95% CI 25% to 26%), p<0.001) insurance had a higher predicted probability of high spending compared with those with commercial insurance (22% (95% CI 21% to 22%)). Of 38 Elixhauser comorbidities included in the multivariable models, most were also associated with a higher predicted probability of high spending (online supplemental e table 3). In sensitivity analyses, the characteristics associated with high spending were generally similar (online supplemental e table 4, e table 5, e table 6, e table 7, and e table 8).

New clinical diagnoses following the index admission

Among the subset of 8251 patients with a previous inpatient admission between January 2019 and March 2020, compared with those with low spending in the 365 days starting on the date of index admission (quartile 1), those with high spending (quartile 4) were more likely to be diagnosed with 'other' nutritional or metabolic disorders (10% vs <1%), nervous system disorders that were neither hereditary nor degenerative (10% vs <1%), hypotension (9% vs <1%), septicaemia (9% vs <1%), urinary tract infections (9% vs <1%) and aplastic anaemia (9% vs <1%) (figure 1).

DISCUSSION

In this cohort study of over 73 000 patients hospitalised for COVID-19 between April 2020 and June 2020, patients incurred an average of US$28 712 in hospital spending within 90 days of admission to the hospital and an additional US$3056 over the remainder of the 365-day follow-up period. Most spending was for inpatient services. High spending over 365 days was associated with a longer length of stay in the hospital, receipt of care in the ICU, and receipt of non-recommended treatments (ie, hydroxychloroquine or ivermectin). In contrast, lower spending was associated with receipt of recommended

Table 4 Multivariable analyses to estimate the association between patient sociodemographic characteristics and index COVID-19 admission characteristics and subsequently being in quartile 4 (vs any other quartile) of total unadjusted hospital spending in the 365 days starting on the date of index admission

	n=73 606 Unadjusted predicted probability (95% CI)*	P value	n=73 606 Adjusted predicted probability (95% CI)†	P value
Patient sociodemographic characteristics				
Age group (years)				
18–34—Ref.	11% (10% to 13%)	–	24% (23% to 25%)	–
35–49	18% (17% to 20%)	<0.001	25% (25% to 26%)	0.013
50–64	27% (25% to 29%)	<0.001	26% (26% to 27%)	<0.001
65–74	32% (30% to 34%)	<0.001	26% (25% to 26%)	0.004
75–84	31% (28% to 33%)	<0.001	25% (24% to 25%)	0.118
85+	23% (20% to 26%)	<0.001	22% (22% to 23%)	0.023
Race and ethnicity				
Hispanic (any race)	21% (19% to 23%)	<0.001	24% (23% to 24%)	<0.001
Non-hispanic Asian	28% (24% to 32%)	0.091	25% (24% to 26%)	0.011
Non-hispanic black	25% (23% to 27%)	0.502	26% (26% to 27%)	0.583
Non-hispanic white—Ref.	25% (24% to 27%)	–	26% (26% to 26%)	–
Other or unknown	29% (23% to 36%)	0.170	24% (23% to 24%)	<0.001
Sex				
Female	22% (21% to 24%)	<0.001	25% (24% to 25%)	<0.001
Male—Ref.	28% (25% to 30%)	–	26% (25% to 26%)	–
Primary insurance type				
Commercial—Ref.	20% (18% to 21%)	–	22% (21% to 22%)	–
Medicaid	25% (22% to 27%)	<0.001	25% (25% to 26%)	<0.001
Medicare	30% (28% to 33%)	<0.001	27% (27% to 28%)	<0.001
Other	16% (14% to 18%)	<0.001	21% (20% to 22%)	0.163
None (self-pay)	14% (12% to 16%)	<0.001	22% (21% to 23%)	0.847
Index admission characteristics				
Length of stay (days)	3% (2% to 3%)	<0.001	2% (2% to 2%)	<0.001
ICU Usage				
No—Ref.	18% (15% to 20%)	–	23% (23% to 23%)	–
Yes	57% (54% to 60%)	<0.001	36% (35% to 37%)	<0.001
Treatment(s) provided‡				
Not recommended	38% (35% to 41%)	<0.001	28% (27% to 28%)	<0.001
Recommended	18% (14% to 22%)	0.148	21% (19% to 23%)	<0.001
Neither—Ref.	22% (19% to 24%)	–	25% (25% to 25%)	–

*Logistic model with robust standard errors and clustered by hospital.
†Logistic model with robust standard errors, clustered by hospital, and including hospital and month-year fixed effects (pseudo-R^2=0.51). Model includes terms for all characteristics in this table, as well as the 38 Elixhauser comorbidities (estimates for the comorbidity terms are available in online supplemental e table 3).
‡Recommended treatment includes remdesivir with or without corticosteroids. Not recommended treatment includes ivermectin and/or hydroxychloroquine.
ICU, intensive care unit; Ref, referent group.

treatments (ie, remdesivir with or without corticosteroids). New diagnoses associated with care following hospital discharge included metabolic, neurological and infectious conditions. Taken together, we found substantial hospital spending associated with COVID-19 among patients surviving hospitalisation to discharge.

Consistent with the intensity of care in the acute setting, we found that most hospital spending associated with COVID-19 illness requiring hospitalisation is incurred within 90 days of admission. On average, patients incurred just under US$30 000 in spending during this period, which is likely reflective of care received for acute

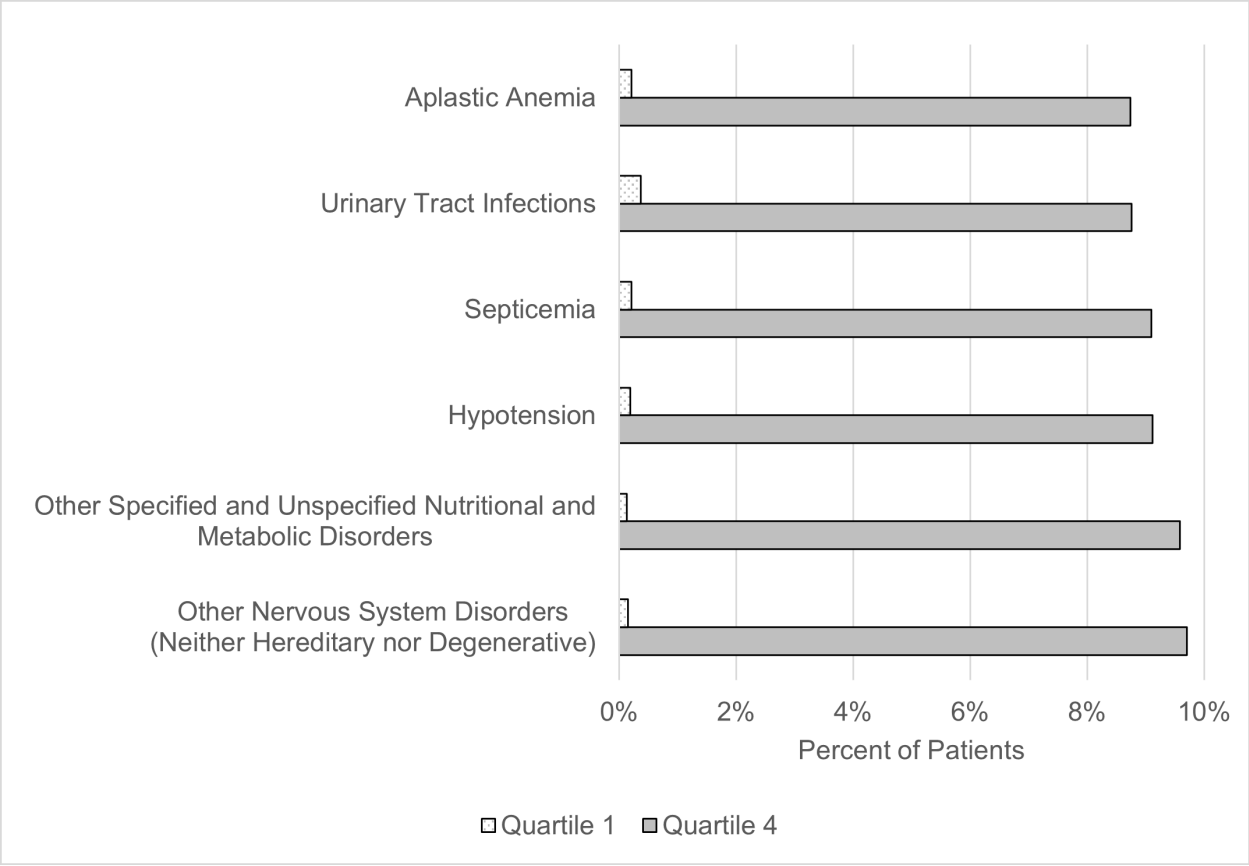

Figure 1 Per cent of patients with select new clinical diagnoses* in the 365 days following the index COVID-19 admission for quartile 4 versus quartile 1 of total Unadjusted hospital spending in the 365 days starting on the date of index admission, among patients with at least one hospital admission between January 2019 and March 2020. *New clinical diagnosis categories with the highest frequency in quartile 4 are displayed. Categories were defined using the Clinical Classifications Software Refined.

COVID-19 during the initial hospitalisation and immediately following discharge. Previous studies of the cost of COVID-19 hospitalisations have found a median cost of roughly US$11 300 to US$12 000 per patient in the USA from April to October/December 2020.[12 13] In the USA, the early phase of the pandemic has been associated with higher hospitalisation spending per patient.[11 12] The higher spending within 90 days of admission identified in the present study may be explained, in part, by the inclusion of postdischarge spending incurred within 90 days. As care after the public health emergency transitions into prepandemic models, such as value-based care, these findings provide important empirical foundations for the spending for a bundle of care associated with a COVID-19 hospitalisation episode.

We found substantial patient-level variation in hospital spending, suggesting varying treatment intensity across patients. Spending varied from just under US$5000 in the lowest quartile to nearly US$90 000 in the highest quartile. Consistent with prior studies, high spending was most strongly associated with complex care during the initial COVID-19 hospitalisation, including a longer length of stay and receipt of care in the ICU.[12–14 24] Patients with high spending were also much more likely to have been discharged from the hospital to a rehabilitation or skilled nursing facility.[12] Further research is needed to understand the relationship between spending variation and quality of COVID-19 care, as accountability for COVID-19 care transitions from public health to the medical and healthcare delivery system.

Notably, receipt of the non-recommended COVID-19 treatments hydroxychloroquine and/or ivermectin during the initial COVID-19 hospitalisation was associated with high hospital spending. This may be reflective of a 'Hail Mary' approach for the sickest patients or a broader marker of low-quality inpatient care for COVID-19, given the lack of evidence of their effectiveness at the time (and subsequent evidence of their ineffectiveness[25–27]). The finding of substantial utilisation of non-recommended treatment during this period warrants further study and has significant implications for the quality and value of care received by patients. Treatment with remdesivir with or without corticosteroids was associated with lower spending, consistent with studies demonstrating effectiveness of remdesivir for preventing disease progression and mortality among non-ventilated hospitalised patients with COVID-19[28] and of corticosteroids for preventing mortality among critically ill patients with COVID-19.[29 30]

We further identified that approximately 10% of the overall annual spending for patients hospitalised with COVID-19 and surviving discharge occurred after the initial 90-day period. This may represent, in part, ongoing care for postacute sequelae of COVID-19 or postintensive care syndrome. Prior studies suggest that more than 50% of patients hospitalised for COVID-19[2 3] and up to 75% of those who received care in the ICU[4] experience persistent symptoms 6–12 months following discharge. Among the subset of patients in the present study with a recent prior hospitalisation and high hospital spending over 365 days, the most common new clinical diagnoses following discharge from the COVID-19 hospitalisation were 'other' nutritional or metabolic disorders, nervous system disorders that were neither hereditary nor degenerative, hypotension, septicemia, urinary tract infections and aplastic anaemia. Some of these new diagnoses (eg, neurologic disorders) may be related to postacute sequelae of COVID-19, but further work is needed to understand COVID-19's chronic complications.

This study had several important limitations. First, the analysis included index admissions from the first 3 months of the pandemic, which allowed for a 1-year follow-up period but limits the generalisability to admissions from later periods of the pandemic. Additionally, we used the U07.1 ICD-10 code to identify hospitalisations for COVID-19, which may have missed some COVID-19 hospitalisations particularly early in the pandemic when there was more heterogeneity in the diagnosis codes assigned by providers. However, our approach was conservative in that hospitalisations with this ICD-10 code were likely to be true COVID-19 hospitalisations. Hospitals contributing data to the PHD were more likely to have less than 200 beds and to be teaching hospitals than all hospitals in the American Hospital Association, which may also limit generalisability. The PHD only includes information on symptoms and conditions that prompted use of healthcare services, and the analysis of new diagnoses following hospitalisation for COVID-19 is expected to underestimate the frequency of many conditions. We used hospital spending for the estimates of spending, and these estimates may not reflect spending for specific healthcare markets. Nonetheless, the study was strengthened by its large, national patient population.

Conclusions

In this national study of patients hospitalised with COVID-19 from April to June 2020, while the vast majority of hospital spending incurred over 1 year was for care within 90 days of admission to the hospital, approximately 10% of spending occurred in the period beyond the initial acute and postacute care period. Patients who received more complex care and/or COVID-19 treatments that were not recommended during the acute COVID-19 hospitalisation were associated with higher spending, while those who received recommended treatments during acute COVID-19 hospitalisation were associated with lower spending. Some patients with additional spending incurred following the first 90 days may be experiencing persistent symptoms of postacute sequelae of COVID-19 or postintensive care syndrome. These findings can inform future pandemic preparedness planning, including anticipation of long-term healthcare spending.

Author affiliations
[1]Office of the Dean, Brown University School of Public Health, Providence, Rhode Island, USA
[2]Department of Epidemiology, Brown University School of Public Health, Providence, Rhode Island, USA
[3]Department of Health Policy and Management, Harvard University T H Chan School of Public Health, Boston, Massachusetts, USA
[4]Department of Health Services, Policy and Practice, Brown University School of Public Health, Providence, Rhode Island, USA
[5]PINC AI Applied Sciences, Premier Inc, Charlotte, North Carolina, USA
[6]Emergency Medicine, Brown University Warren Alpert Medical School, Providence, Rhode Island, USA
[7]Department of Surgery, Brigham and Women's Hospital, Boston, Massachusetts, USA

Contributors Authors contributed to the manuscript (MS) in the following manner. Study concept: SN-D, FB and TCT. Study design: SN-D, FB and TCT. Data analysis: SN-D and MJS. Interpretation of results: all authors. Initial drafting of the MS: SN-D, LCC, MJS and CB. Critical revision of the MS: all authors. TCT accepts full responsibility for the work, had access to the data and controlled the decision to publish. Additionally, TCT affirms that the manuscript is an honest, accurate and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as originally planned have been explained. LCC attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

Funding This work was supported by funding from the Commonwealth Fund and the Hassenfeld Family Foundation. LCC was supported, in part, by the National Institutes of Health (grant R25MH083620).

Disclaimer The funders were not involved in the study design; collection, analysis, and interpretation of data; writing of the report; or decision to submit the article for publication.

Competing interests None declared.

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 was approved by the Harvard TH Chan School of Public Health Institutional Review Board (IRB21-1383).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available.

Author note This work was completed while SN-D was at the Brown University School of Public Health and CB was at the Harvard T.H. Chan School of Public Health. SN-D is now at the Stanford Institute for Economic Policy Research and the Meridian Collective in Palo Alto, California, USA. CB is now at the University of Colorado School of Medicine in Aurora, Colorado, USA. The content of this

manuscript is solely the responsibility of the authors and does not necessarily represent the official views of the Commonwealth Fund; Hassenfeld Family Foundation; National Institutes of Health; Brown University School of Public Health; Harvard T.H. Chan School of Public Health; Premier Inc.; Brigham and Women's Hospital; Stanford Institute for Economic Policy Research; Meridian Collective; or University of Colorado School of Medicine.

ORCID iDs
Laura C Chambers http://orcid.org/0000-0003-1802-6578
Scott A Rivkees http://orcid.org/0000-0001-9920-1109

REFERENCES

1 US Centers for Disease Control and Prevention. COVID data tracker. Available: https://covid.cdc.gov/covid-data-tracker/#datatracker-home [Accessed 1 Feb 2023].
2 Huang L, Yao Q, Gu X, *et al*. 1-year outcomes in hospital survivors with COVID-19: a longitudinal cohort study. *Lancet* 2021;398:747–58.
3 Huang C, Huang L, Wang Y, *et al*. 6-month consequences of COVID-19 in patients discharged from hospital: a cohort study. *Lancet* 2021;397:220–32.
4 Heesakkers H, van den Boogaard M, Zegers M. Clinical outcomes among patients with 1-year survival following intensive care unit treatment for COVID-19. *JAMA* 2022;327:2150–1.
5 O'Mahoney LL, Routen A, Gillies C, *et al*. The prevalence and long-term health effects of long covid among hospitalised and non-hospitalised populations: a systematic review and meta-analysis. *EClinicalMedicine* 2023;55:101762.
6 Perlis RH, Santillana M, Ognyanova K, *et al*. Prevalence and correlates of long COVID symptoms among US adults. *JAMA Netw Open* 2022;5:e2238804.
7 Petersen MS, Kristiansen MF, Hanusson KD, *et al*. Prevalence of long COVID in a national cohort: longitudinal measures from disease onset until 8 months' follow-up. *Int J Infect Dis* 2022;122:437–41.
8 Hartman M, Martin AB, Washington B, *et al*. The national health expenditure accounts team. national health care spending in 2020: growth driven by federal spending in response to the COVID-19 pandemic. *Health Affairs* 2022;41:13–25.
9 Cutler DM. The costs of long COVID. *JAMA Health Forum* 2022;3:e221809.
10 Chua K-P, Conti RM, Becker NV. Assessment of out-of-pocket spending for COVID-19 hospitalizations in the US in 2020. *JAMA Netw Open* 2021;4:e2129894.
11 Richards F, Kodjamanova P, Chen X, *et al*. Economic burden of COVID-19: a systematic review. *Clinicoecon Outcomes Res* 2022;14:293–307.
12 Ohsfeldt RL, Choong CK-C, Mc Collam PL, *et al*. Inpatient hospital costs for COVID-19 patients in the United States. *Adv Ther* 2021;38:5557–95.
13 Di Fusco M, Shea KM, Lin J, *et al*. Health outcomes and economic burden of hospitalized COVID-19 patients in the United States. *J Med Econ* 2021;24:308–17.
14 Carrera-Hueso FJ, Álvarez-Arroyo L, Poquet-Jornet JE, *et al*. Hospitalization budget impact during the COVID-19 pandemic in Spain. *Health Econ Rev* 2021;11:43.
15 Premier Applied Sciences. Premier healthcare database: data that informs and performs. Available: https://products.premierinc.com/downloads/PremierHealthcareDatabaseWhitepaper.pdf [Accessed 1 Feb 2023].
16 Cunningham JW, Vaduganathan M, Claggett BL, *et al*. Clinical outcomes in young US adults hospitalized with COVID-19. *JAMA Intern Med* 2020;181:379–81.
17 Molina RL, Tsai TC, Dai D, *et al*. Comparison of pregnancy and birth outcomes before vs during the COVID-19 pandemic. *JAMA Netw Open* 2022;5:e2226531.
18 Tsai TC, Bryan AF, Rosenthal N, *et al*. Variation in use of surgical care during the COVID-19 pandemic by surgical urgency and race and ethnicity. *JAMA Health Forum* 2021;2:e214214.
19 DeCuir J, Baggs J, Melgar M, *et al*. Identification and description of patients with multisystem inflammatory syndrome in adults associated with SARS-Cov-2 infection using the premier healthcare database. *Epidemiol Infect* 2022;150:e26.
20 Agency for Healthcare Research and Quality. Healthcare cost and utilization project: chronic condition indicator (CCI) for ICD-9-CM. Available: https://hcup-us.ahrq.gov/toolssoftware/chronic/chronic.jsp [Accessed 1 Feb 2023].
21 Elixhauser A, Steiner C, Harris DR, *et al*. Comorbidity measures for use with administrative data. *Med Care* 1998;36:8–27.
22 US Centers for Medicare and Medicaid Services. Disproportionate share hospital (DSH)
. Available: https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AcuteInpatientPPS/dsh [Accessed 1 Feb 2023].
23 Cuzick J. A Wilcoxon-type test for trend. *Stat Med* 1985;4:87–90.
24 Huang BZ, Creekmur B, Yoo MS, *et al*. Healthcare utilization among patients diagnosed with COVID-19 in a large integrated health system. *J Gen Intern Med* 2022;37:830–7.
25 Singh B, Ryan H, Kredo T, *et al*. Chloroquine or hydroxychloroquine for prevention and treatment of COVID-19. *Cochrane Database Syst Rev* 2021;2:CD013587.
26 Roman YM, Burela PA, Pasupuleti V, *et al*. Ivermectin for the treatment of Coronavirus disease 2019: A systematic review and meta-analysis of randomized controlled trials. *Clin Infect Dis* 2022;74:1022–1029.
27 Horby P, Mafham M, *et al*, RECOVERY Collaborative Group. Effect of hydroxychloroquine in hospitalized patients with COVID-19. *N Engl J Med* 2020;383:2030–2040.
28 Amstutz A, Speich B, Mentré F, *et al*. Effects of remdesivir in patients hospitalised with COVID-19: a systematic review and individual patient data meta-analysis of randomised controlled trials. *Lancet Respir Med* 2023;11:453–64.
29 Wagner C, Griesel M, Mikolajewska A, *et al*. Systemic corticosteroids for the treatment of COVID-19. *Cochrane Database Syst Rev* 2021;8:CD014963.
30 WHO Rapid Evidence Appraisal for COVID-19 Therapies (REACT) Working Group, Sterne JAC, Murthy S, *et al*. Association between administration of systemic corticosteroids and mortality among critically ill patients with COVID-19: a meta-analysis. *JAMA* 2020;324:1330–1341.