Adv Ther (2021) 38:5557–5595
https://doi.org/10.1007/s12325-021-01887-4

ORIGINAL RESEARCH

Inpatient Hospital Costs for COVID-19 Patients in the United States

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Received: May 5, 2021 / Accepted: August 4, 2021 / Published online: October 5, 2021
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ABSTRACT

Introduction: Reliable cost and resource use data for COVID-19 hospitalizations are crucial to better inform local healthcare resource decisions; however, available data are limited and vary significantly.

Methods: COVID-19 hospital admissions data from the Premier Healthcare Database were evaluated to estimate hospital costs, length of stay (LOS), and discharge status. Adult COVID-19 patients (ICD-10-CM: U07.1) hospitalized in the US from April 1 to December 31, 2020, were identified. Analyses were stratified by patient and hospital characteristics, levels of care during hospitalization, and discharge status. Factors associated with changes in costs, LOS, and discharge status were estimated using regression analyses. Monthly trends in costs, LOS, and discharge status were examined.

Results: Of the 247,590 hospitalized COVID-19 patients, 49% were women, 76% were aged ≥ 50, and 36% were admitted to intensive care units (ICU). Overall median hospital LOS, cost, and cost/day were 6 days, US$11,267, and $1772, respectively; overall median ICU LOS, cost, and cost/day were 5 days, $13,443, and $2902, respectively. Patients requiring mechanical ventilation had the highest hospital and ICU median costs ($47,454 and $41,510) and LOS (16 and 11 days), respectively. Overall, 14% of patients died in hospital and 52% were discharged home. Older age, Black and Caucasian race, hypertension and obesity, treatment with extracorporeal membrane oxygenation, and discharge to long-term care facilities were major drivers of costs, LOS, and risk of death. Admissions in December had significantly lower median hospital and ICU costs and LOS compared to April.

Conclusion: The burden from COVID-19 in terms of hospital and ICU costs and LOS has been substantial, though significant decreases in cost and LOS and increases in the share of hospital discharges to home were observed from April to December 2020. These estimates will be

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12325-021-01887-4.

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useful for inputs to economic models, disease burden forecasts, and local healthcare resource planning.

Keywords: COVID-19; Hospital costs; Intensive care unit (ICU); Length of stay; Post-acute care

Key Summary Points
Why carry out this study?
Published reports citing healthcare resource utilization and costs for COVID-19 hospitalization in the United States vary widely
Some reports also confuse hospital costs with hospital charges, and most were not from COVID-19 patient data
A comprehensive analysis of COVID-19 hospitalization costs is essential to identify underlying determinants and observed trends for this rapidly evolving pandemic
What was learned from the study?
Overall median hospital length of stay, cost, and cost/day were 6 days, $11,267, and $1772, respectively. Older age, comorbidities, and mechanical ventilation were major drivers of costs, hospital length of stay, and risk of death. A downward trend of cost and hospital stay was observed from April to December 2020
These results highlight the significant burden from COVID-19 in the US in terms of hospital costs and length of stay
These estimates will be useful for inputs to economic models, disease burden forecasts, and local healthcare resource decisions

INTRODUCTION

Coronavirus disease 2019 (COVID-19) is imposing a substantial burden on the United States (US) healthcare system [1]. As of July 2021, 33.8 million confirmed COVID-19 cases and 605,905 associated deaths have been reported by the Centers for Disease Control and Prevention in the US. [2]. Precautionary measures such as social distancing and quarantine to slow the spread of COVID-19 have impacted psychological health and inter-personal lives, while also leading to economic downturn and job losses, especially in socioeconomically disadvantaged communities [1, 3].

COVID-19 primarily affects the respiratory system, followed by cardiovascular, hepatic, renal, gastrointestinal, and central nervous systems. Pneumonia-related respiratory symptoms including breathlessness and respiratory failure are the common clinical manifestations of COVID-19 [4]. According to previous reports, among all hospitalized patients with COVID-19, approximately 14–30% developed acute respiratory distress syndrome, with an associated mortality rate of 45–75% [5, 6]. Approximately one-third of COVID-19 survivors who had severe or critical disease are likely to have long-term clinical and mental health complications with an increased risk of premature death [7]. The severity of the disease is positively correlated with age, males, and underlying comorbidities, including cardiovascular disease, chronic kidney disease, chronic lung disease, diabetes, obesity, and malignancy.

The US Food and Drug Administration recommends multiple therapies to reduce inflammation and repair damage to ailing lungs due to COVID-19. Such treatments include neutralizing antibodies (bamlanivimab, etesevimab, casirivimab, and imdevimab), and anti-inflammatory and antiviral therapies (baricitinib and remdesivir) [8]. However, all these medications are approved under emergency use authoriza-

tion and require more data to support their effectiveness in patients with severe disease. In addition, although an increasing number of patients are being vaccinated, questions related to dose and administrations are yet to be answered [9]. Therefore, supplemental oxygenation via mechanical ventilation (MV) or non-MV remains an essential part of the management of hospitalized COVID-19 patients with severe respiratory failure.

Published reports citing healthcare resource utilization and costs for COVID-19 hospitalization in the US vary widely between studies, and the majority were not derived from data from actual COVID-19 patients [10–12]. In addition, some reports conflate hospital costs with hospital charges [13]. A recent observational study reported descriptive data for COVID-19 hospitalization [14]; however, the underlying factors for the reported increases in hospitalization costs have not been assessed.

Due to the wide variation in estimates from multiple sources, a more comprehensive analysis of the healthcare resource utilization and costs associated with COVID-19 hospitalization is required. In addition, identifying important underlying determinants and examining observed trends is essential for this rapidly evolving pandemic. Here, we present estimates of COVID-19-related inpatient costs and length of stay (LOS), at both overall hospital and intensive care unit (ICU)-specific level, for various patient subgroups and investigate the factors influencing these estimates using a large and nationally representative hospital database.

METHODS

Data Source and Population

This observational study utilized inpatient hospital admissions and discharge records of adult patients with a diagnosis for COVID-19 from the Premier Healthcare Database (PHD) [15]. The PHD is a large patient-level information system that can be used for clinical and financial comparative analysis. It includes discharge records from more than 800 non-governmental, community, and academic hospitals across the US. The database represents about one in five of all-cause inpatient discharges in the US. The PHD records were de-identified to protect patients' privacy and are fully compliant with the US health information privacy requirements, including the Health Insurance Portability and Accountability Act of 1996. This is an observational study that uses previously collected data and does not impose any form of intervention, and was performed in accordance with the Helsinki Declaration of 1964 and its later amendments.

Adult patients (aged $\geq$ 18 years) who had at least one report of COVID-19 diagnosis [International Classification of Disease, Tenth Revision, Clinical Modification (ICD-10-CM) code: U07.1], and valid discharge status during the study period, April 1 to December 31, 2020, were included in this analysis. The diagnostic code U07.1 was shown to have high sensitivity (98.01%) and specificity (99.04%) to identify COVID-19 cases in real-world data since it has been widely adopted by hospitals in the US [16].

Outcomes and Measures

Total and daily hospital costs, total and daily ICU costs, hospital LOS, ICU LOS, and discharge status were the main outcomes of this study. Only the first hospitalization for each patient was included in this analysis (approximately 4% of patients had more than 1 hospitalization in the PHD).

Patient characteristics included sex, age, race, ethnicity, and comorbidities [asthma, autoimmune disease, chronic obstructive pulmonary disease (COPD), diabetes, hypertension, and obesity]. Hospital characteristics included geographic region, area of hospitalization (urban or rural), hospital status (community or academic), hospital size (based on number of beds), and insurance payer mix.

ICU admissions were identified based on recorded ICU Current Procedural Terminology, 4th Edition (CPT-4) codes or charge master codes. Total hospital and ICU costs were calculated as the sum of medical and medication costs accrued during the hospital or ICU stay. Daily hospital or ICU costs were calculated as

total hospital cost divided by LOS at the hospital or ICU, respectively.

The main outcomes were stratified based on subgroups including patient characteristics, hospital characteristics, levels of care according to the ordinal scale defined in the Adaptive COVID-19 Treatment Trial Ordinal Scale (ACTT OS) [17, 18], and 15 most frequent Medicare Severity Diagnosis-Related Groups (MS-DRG).

The level of care was estimated according to the ACTT OS scores based on oxygen procedures received by patients during hospitalization. Patients were categorized into five ACTT OS groups based on oxygen treatments: no supplemental oxygen (ACTT OS 3/4), supplemental oxygen (ACTT OS 5), non-invasive ventilation or high-flow oxygen (ACTT OS 6), invasive MV or extracorporeal membrane oxygenation (ECMO) (ACTT OS 7), and death (ACTT OS 8).

The underlying determinants or predictors for the differences in costs, LOS, and discharge status were analyzed using univariate and multivariate regression analyses with the following variables: patient characteristics, hospital characteristics, (level of care) ACTT OS, MS-DRG codes, month of discharge status, and month of hospitalization.

For patients with zero total hospital and ICU costs reported on the hospital record, no imputations were performed, thus these patients were not included in the cost analyses. In addition, costs were trimmed to reduce the impact of extremely low (below 1st percentile) or high costs (above 99th percentile), as done in other hospital cost studies [19].

Statistical Analysis

Descriptive analysis of the data is reported as frequency, mean, median, and standard deviation. To compare the costs and LOS within groups, adjusting for patient and hospital level characteristics, a multivariate log-linear regression was fitted including age groups, sex, race, ethnicity, geographic region, comorbidity, hospital type, urban status, payer type, ACTT OS, MS-DRG codes, discharge status, and admission month, while dependent variables (costs, LOS) were log-transformed. The least square (LS) means and LS means differences, along with 95% confidence intervals (CIs) and *P* values were presented. Discharge status within groups was compared, adjusting for patient- and hospital-level characteristics, by using a logistic regression fitted with covariates of age groups, sex, race, ethnicity, geographic region, comorbidity, hospital type, urban status, payer type, ACTT OS, MS-DRG codes, and admission month. Odds ratios (OR), CIs, and a *P* values were reported. A *P* value of ≤ 0.05 was considered as statistically significant. Multiple group comparisons were adjusted with a Bonferroni correction. A comparison of key outcomes (inpatient costs, LOS, hospital discharge status) by month was conducted. Sample selection and the creation of analytic variables were performed using the Instant Health Data platform (Panalgo, Boston, MA, USA). The regression models were estimated using SAS v.9.4 (SAS Institute, Cary, NC, USA).

RESULTS

From a total of 770,397 patients with a diagnosis of COVID-19 in the PHD database, 247,590 hospitalized patients were included in this study. Attrition of patients is presented in Fig. 1.

Overall, 49% of patients were women, 87% were aged above 40 years, and 60% were Caucasian. The most frequent comorbidity was hypertension, followed by diabetes, and obesity. About 90% of patients were hospitalized in urban areas and 48% patients were from the Southern region of the US. Almost two-thirds ($> 65\%$) of the patients had government (Medicare or Medicaid) insurance and 24% were commercially insured. In total, 198,806 patients were evaluated for hospital costs after excluding low- and high-cost outliers. The median total hospital costs were \$11,267 and hospital costs/day were \$1772. Among all hospitalized patients, 88,530 were admitted to ICU and 70,054 (with cost information) were included in the ICU cost analyses. Median ICU total costs were \$13,443 and costs/day were \$2902. Overall, the median LOS in hospital was 6 days and, among patients admitted to ICU, the median

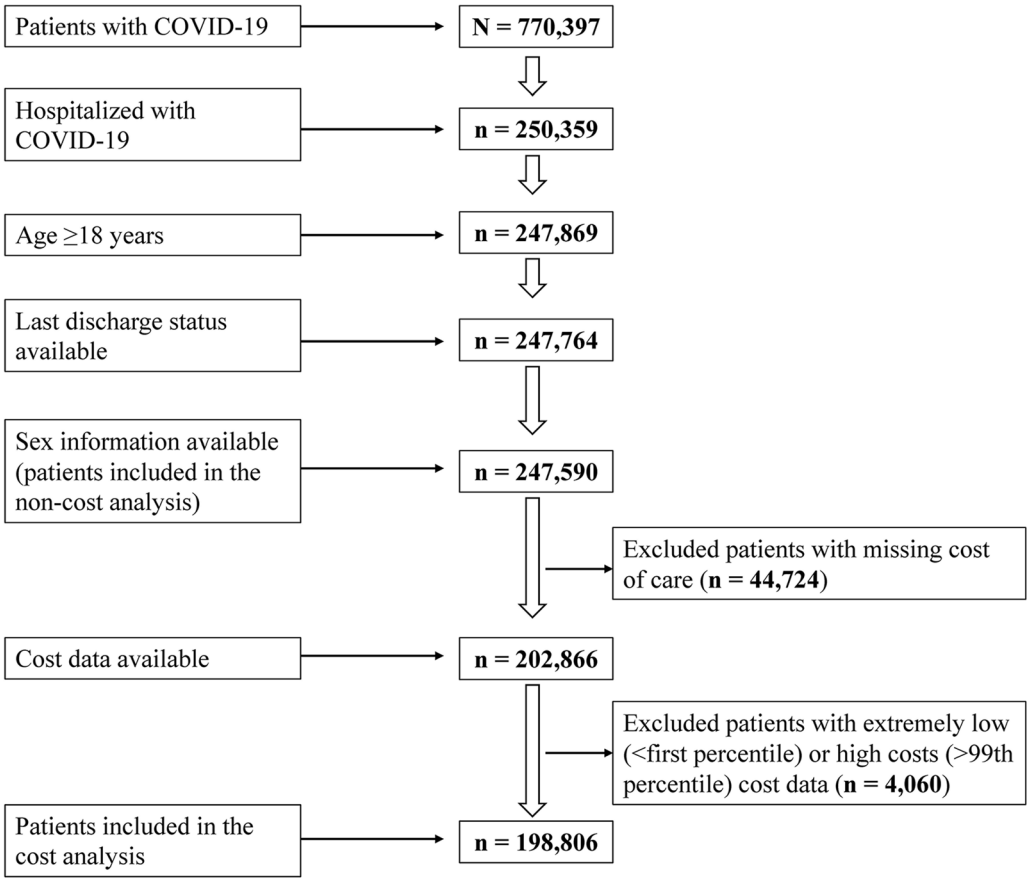


Fig. 1 Patient attrition and cohort selection

ICU LOS was 5 days (Fig. 2a, b; Tables S1a, S1b, S4).

Hospital Cost and Length of Stay by Patient Characteristics

Cost and LOS estimates stratified by patient characteristics are presented in Fig. 2a, b (hospital and ICU) and Tables S1a (hospital), and S1b (ICU). Among all hospitalized patients, the median cost was highest for men ($12,237), Asians ($12,785), patients aged 70–79 ($13,181), and those with COPD ($13,582). The median LOS generally was similar across patient demographic groups; the highest LOS (7 days) was for men, those aged > 60 years, and those with autoimmune disease, COPD, diabetes, hypertension, and obesity (Table S1a). Among patients admitted to ICU, the median costs were highest for men ($14,468), other race ($18,247), patients aged 60–69 ($16,540), and those with obesity ($16,330). The median ICU cost/day was comparable across the groups. The median ICU LOS was highest for patients with obesity (6 days) (Table S1b).

Hospital Cost and Length of Stay by Hospital Characteristics

Cost and LOS estimates stratified by hospital characteristics are presented in Fig. 3a, b (hospital and ICU) and Tables S2a (hospital) and S2b (ICU). The median total hospital costs and median hospital cost/day were highest for patients from the Northeast region ($14,497 and $2263, respectively). The highest median LOS (7 days) was for patients from the Western region, admitted to hospitals with over 500 beds, or with Medicare insurance (Table S2a). Among patients who were admitted to ICU, the

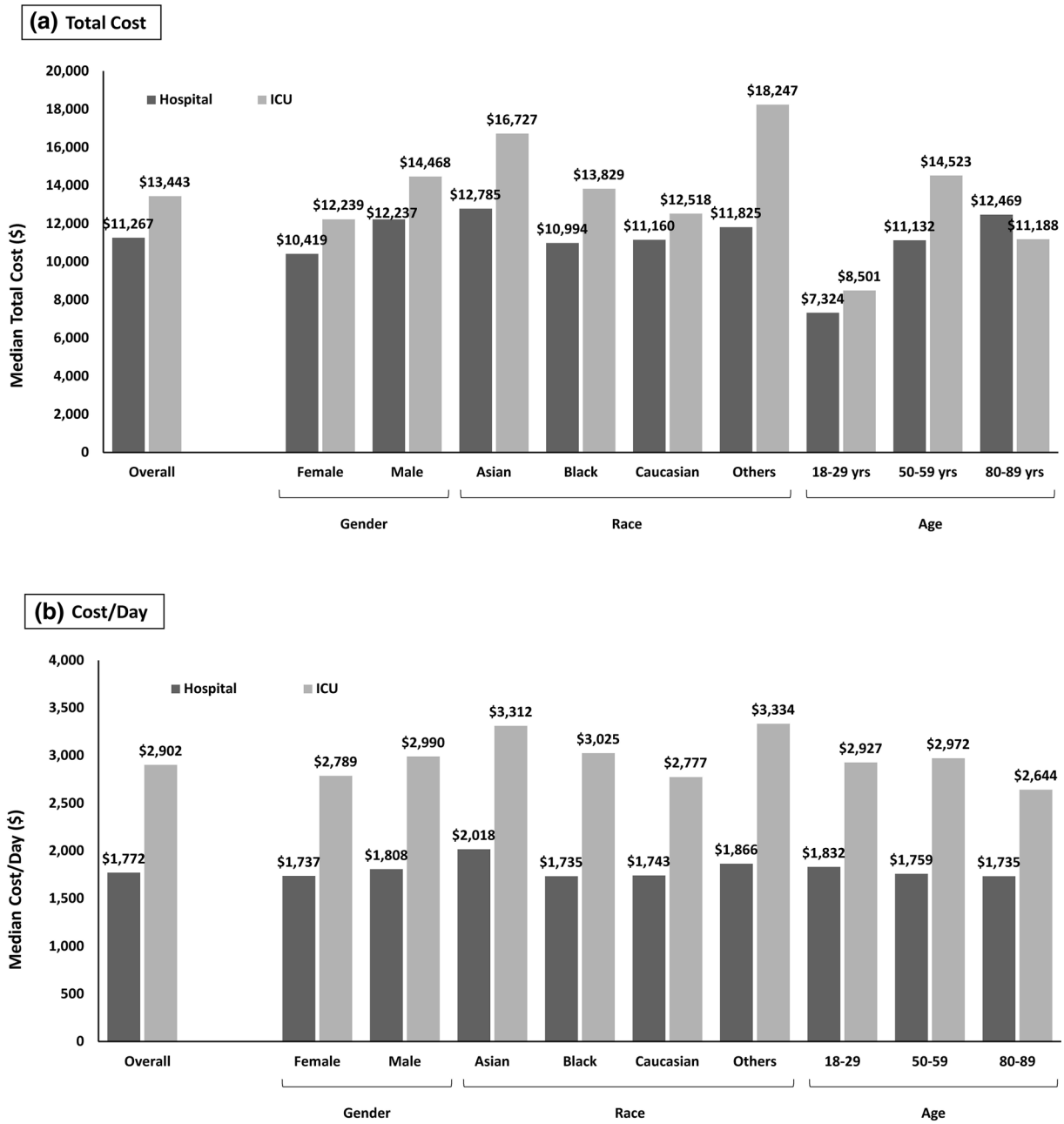


Fig. 2 COVID-19 hospital and ICU total costs (**a**) and costs/day (**b**) by patient characteristics; *ICU* intensive care unit

highest median costs and median cost/day were recorded in patients from the Northeast ($19,727, and $4136, respectively). The median LOS was 5 days for patients hospitalized from the Midwest, Northeast, and Western regions, in urban hospitals, academic and community hospitals, and hospitals with over 300 beds, and who had Medicare or Medicaid insurance (Table S2b).

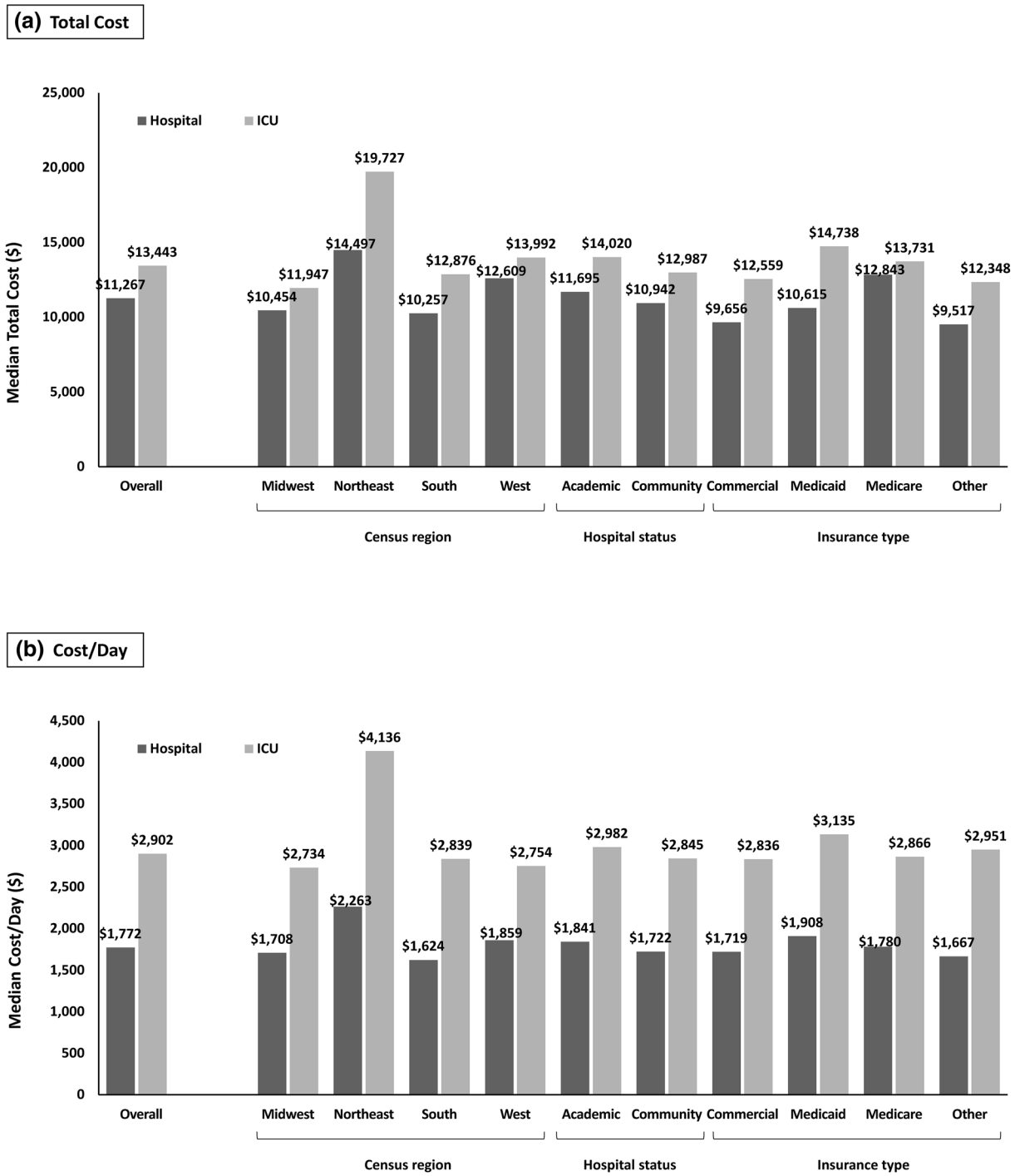


Fig. 3 COVID-19 hospital and ICU total costs (**a**) and costs/day (**b**) by hospital characteristics; *ICU* intensive care unit

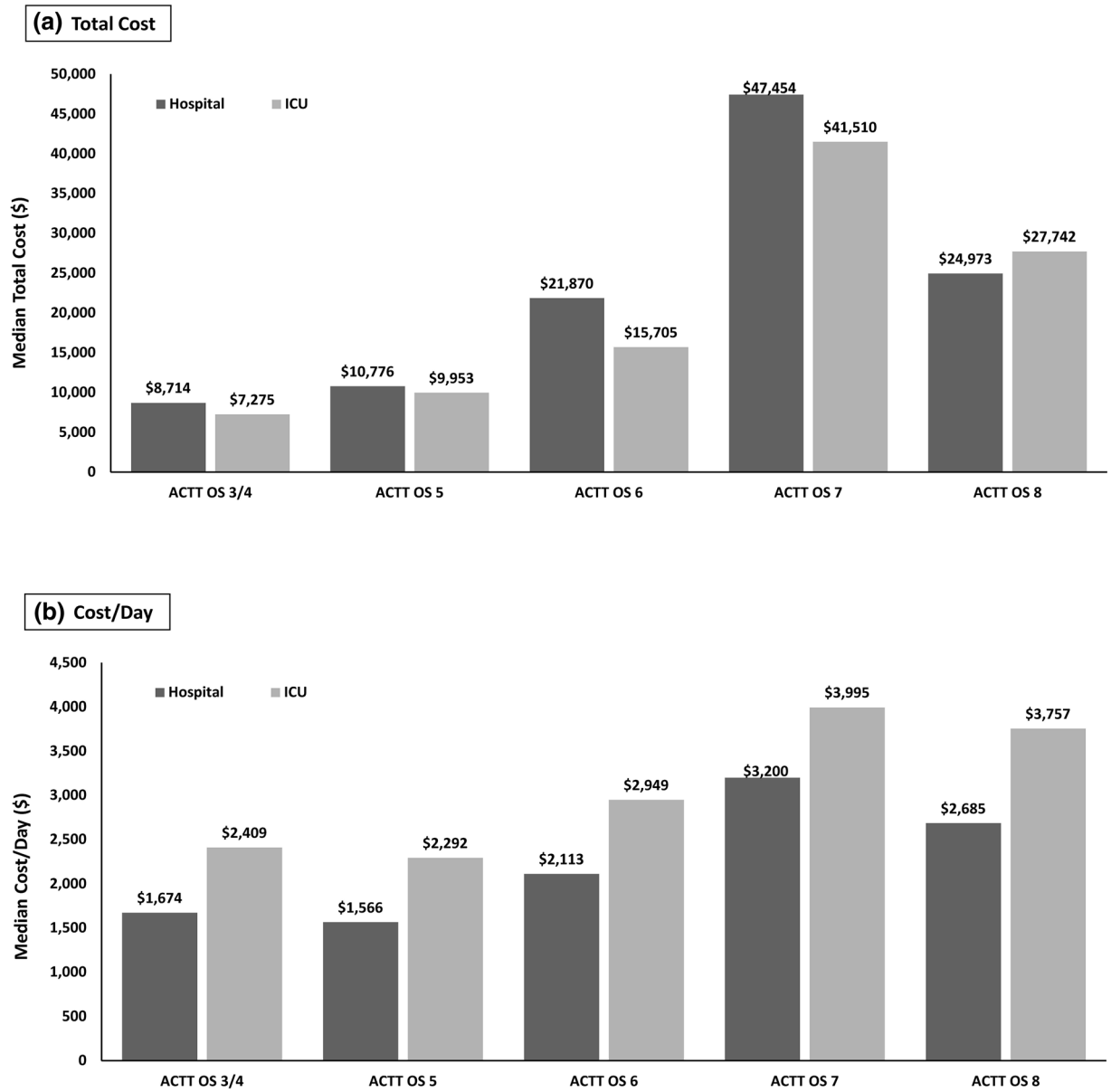


Fig. 4 COVID-19 hospital and ICU total costs (**a**) and costs/day (**b**) by level of care (ACTT OS). ACTT OS were estimated using the oxygen procedures received by patients during the hospitalization. ACTT OS 3/4 no supplemental oxygen, ACTT OS 5 supplemental oxygen, ACTT OS 6 non-invasive ventilation or high-flow oxygen, ACTT OS 7 ECMO using invasive mechanical ventilation, ACTT OS 8 death; ACTT OS Adaptive COVID-19 Treatment Trial ordinal scale

Hospital Cost and Length of Stay by ACTT OS Scores, and MS-DRG Codes

The main outcomes stratified based on the levels of care (ACTT OS) are presented in Fig. 4a, b (hospital and ICU) and Tables S3a (hospital) and S3b (ICU); and the most frequent MS-DRGs (9 respiratory, 3 sepsis, 2 renal failure, and 1 cardiovascular-related) are presented in Tables S3a (hospital) and S3b (ICU). Over half (n/N: 106,924/198,806 = 54%) of patients did not require supplemental oxygen (ACTT OS

Table 1 COVID-19 Discharge Status by Patient and Hospital Characteristics

Characteristic	Total	Home		Inpatient Rehabilitation Facility		Skilled Nursing Facility		Long-term Hospital		Hospice		Dead		Others	
		n(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population
Sex															
Female	121,165	64,416	53.2	5327	4.4	15,864	13.1	1398	1.2	1211	1.0	14,317	11.8	18,632	15.4
		(49.9)		(45.7)		(53.6)		(44.3)		(55.1)		(42.2)		(49.0)	
Male	126,425	64,630	51.1	6335	5.0	13,735	10.9	1759	1.4	986	0.8	19,600	15.5	19,380	15.3
		(50.1)		(54.3)		(46.4)		(55.7)		(44.9)		(57.8)		(51.0)	
Race															
Asian	5964	3543	59.4	229	3.8	444	7.4	52	0.9	39	0.7	804	13.5	853	14.3
		(2.9)		(2.1)		(1.5)		(1.7)		(1.8)		(2.5)		(2.3)	
Black	49,079	25,763	52.5	2296	4.7	6043	12.3	651	1.3	330	0.7	6032	12.3	7964	16.2
		(21.1)		(20.6)		(20.9)		(21.5)		(15.5)		(18.7)		(21.7)	
Caucasian	147,968	72,676	49.7	7235	4.9	19,906	13.6	1985	1.4	1606	1.1	21,074	14.4	23,486	16.0
		(59.6)		(64.8)		(68.9)		(65.6)		(75.4)		(65.1)		(64.0)	
Others	33,115	19,922	60.2	1400	4.2	2490	7.5	336	1.0	155	0.5	4441	13.4	4371	13.2
		(16.3)		(12.5)		(8.6)		(11.1)		(7.3)		(13.7)		(11.9)	
Ethnicity															
Hispanic	48,379	31,919	66.0	1620	3.3	2395	5.0	485	1.0	237	0.5	5658	11.7	6065	12.5
		(24.7)		(13.9)		(8.1)		(15.4)		(10.8)		(16.7)		(16.0)	
Not Hispanic	157,211	76,443	49.1	7956	5.1	21,441	13.8	2144	1.4	1645	1.1	21,499	13.8	26,083	16.8
		(59.2)		(68.2)		(72.4)		(67.9)		(74.9)		(63.4)		(68.6)	
Unknown	42,000	20,684	49.2	2086	5.0	5763	13.7	528	1.3	315	0.75	6760	16.1	5864	14.0
		(16.0)		(17.9)		(19.5)		(16.7)		(14.3)		(19.9)		(15.4)	

Table 1 continued

Characteristic	Total	Home		Inpatient Rehabilitation Facility		Skilled Nursing Facility		Long-term Hospital		Hospice		Dead		Others	
		n(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population
Age groups, years															
18–29	13,905	12,442 (9.6)	89.5	296 (2.5)	2.1	69 (0.2)	0.5	33 (1.1)	0.2	1 (0.1)	0.01	156 (0.5)	1.1	908 (2.4)	6.5
30–39	18,823	15,967 (12.4)	84.8	506 (4.3)	2.7	232 (0.8)	1.2	66 (2.1)	0.4	4 (0.2)	0.02	464 (1.4)	2.5	1584 (4.2)	8.4
40–49	26,536	20,697 (16.0)	78.0	899 (7.7)	3.4	678 (2.3)	2.6	208 (6.6)	0.8	29 (1.3)	0.11	1267 (3.7)	4.8	2758 (7.3)	10.4
50–59	41,841	28,241 (21.9)	67.5	1816 (15.6)	4.3	2414 (8.16)	5.8	484 (15.3)	1.2	72 (3.3)	0.17	3424 (10.1)	8.2	5390 (14.2)	12.9
60–69	52,120	26,808 (20.8)	51.4	2690 (23.1)	5.2	5807 (19.6)	11.1	960 (30.4)	1.8	235 (10.7)	0.45	7245 (21.4)	13.9	8375 (22.0)	16.1
70–79	49,608	17,226 (13.4)	34.7	2786 (23.9)	5.6	8693 (29.4)	17.5	855 (27.1)	1.7	536 (24.4)	1.08	9606 (28.3)	19.4	9906 (26.1)	20.0
80–89	43,402	7525 (5.8)	17.3	2583 (22.2)	6.0	11,314 (38.2)	26.1	535 (17.0)	1.2	1247 (56.8)	2.87	11,398 (33.6)	26.3	8800 (23.2)	20.3
≥ 90	1355	140 (0.1)	10.3	86 (0.7)	6.3	392 (1.3)	28.9	16 (0.5)	1.2	73 (3.3)	5.39	357 (1.1)	26.3	291 (0.8)	21.5
Comorbidities															
Asthma	25,065	15,056 (11.7)	60.1	995 (8.5)	4.0	2114 (7.1)	8.4	269 (8.5)	1.1	108 (4.9)	0.43	2453 (7.2)	9.8	4070 (10.7)	16.2
Autoimmune diseases	10,185	4569 (3.5)	44.9	513 (4.4)	5.0	1512 (5.1)	14.8	145 (4.6)	1.4	96 (4.4)	0.94	1516 (4.5)	14.9	1834 (4.8)	18.0

Table 1 continued

Characteristic	Total	Home		Inpatient Rehabilitation Facility		Skilled Nursing Facility		Long-term Hospital		Hospice		Dead		Others	
		n(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population
COPD	34,663	10,608	30.6	1958	5.6	7070	20.4	670	1.9	469	1.35	7227	20.8	6661	19.2
		(8.2)		(16.8)		(23.9)		(21.2)		(21.4)		(21.3)		(17.5)	
Diabetes	103,365	45,948	44.5	5317	5.1	14,511	14.0	1675	1.6	885	0.86	17,531	17.0	17,498	16.9
		(35.6)		(45.6)		(49.0)		(53.1)		(40.3)		(51.7)		(46.0)	
Hypertension	168,395	73,608	43.7	8840	5.2	25,648	15.2	2598	1.5	1825	1.08	28,172	16.7	29,529	17.5
		(57.0)		(75.8)		(86.7)		(82.3)		(83.1)		(83.1)		(77.7)	
Obesity	80,070	44,304	55.3	3640	4.5	7803	9.7	1305	1.6	349	0.44	10,651	13.3	12,018	15.0
		(34.3)		(31.2)		(26.4)		(41.3)		(15.9)		(31.4)		(31.6)	
Census region															
Midwest	55,883	28,394	50.8	2696	4.8	7470	13.4	796	1.4	512	0.92	7041	12.6	8974	16.1
		(22.0)		(23.1)		(25.2)		(25.2)		(23.3)		(20.8)		(23.6)	
Northeast	44,630	19,116	42.8	2244	5.0	7360	16.5	233	0.5	282	0.63	8319	18.6	7076	15.9
		(14.8)		(19.2)		(24.9)		(7.4)		(12.8)		(24.5)		(18.6)	
South	117,991	64,530	55.2	5777	4.9	11,895	10.2	1708	1.5	1146	0.98	14,844	12.7	18,091	15.5
		(50.0)		(49.5)		(40.2)		(54.1)		(52.2)		(43.8)		(47.6)	
West	29,086	17,006	58.5	945	3.2	2874	9.9	420	1.4	257	0.88	3713	12.8	3871	13.3
		(13.2)		(8.1)		(9.7)		(13.3)		(11.7)		(11.0)		(10.2)	
Rural/urban setting															
Rural	29,484	15,118	51.3	2318	7.9	3077	10.4	268	0.9	262	0.89	3775	12.8	4666	15.8
		(11.7)		(19.9)		(10.4)		(8.5)		(11.9)		(11.1)		(12.3)	
Urban	2,18,106	113,928	11.1	9344	9.1	26,522	25.9	2889	2.8	1935	1.89	30,142	29.5	33,346	32.6
		(88.3)		(80.1)		(89.6)		(91.5)		(88.1)		(88.9)		(87.7)	

Table 1 continued

Characteristic	Total	Home		Inpatient Rehabilitation Facility		Skilled Nursing Facility		Long-term Hospital		Hospice		Dead		Others	
		n(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population
Teaching status															
Academic	116,706	60,059 (46.5)	51.5	4685 (40.2)	4.0	15,156 (51.2)	13.0	1432 (45.4)	1.2	909 (41.4)	0.78	16,928 (49.9)	14.5	17,537 (46.1)	15.0
Community	129,596	68,987 (53.5)	53.2	6977 (59.8)	5.4	14,443 (48.8)	11.1	1725 (54.6)	1.3	1288 (58.6)	0.99	16,989 (50.1)	13.1	20,475 (53.9)	15.8
Hospital size															
0–99	14,264	7329 (5.7)	51.4	1692 (14.5)	11.9	1244 (4.2)	8.7	150 (4.8)	1.1	118 (5.4)	0.83	1175 (3.5)	8.2	2556 (6.7)	17.9
100–299	79,362	40,658 (31.5)	51.2	4376 (37.5)	5.5	9487 (32.1)	12.0	965 (30.6)	1.2	757 (34.5)	0.95	10,889 (32.1)	13.7	12,230 (32.2)	15.4
300–499	73,593	38,293 (29.7)	52.0	2759 (23.7)	3.7	9264 (31.3)	12.6	1090 (34.5)	1.5	663 (30.2)	0.90	10,746 (31.7)	14.6	10,778 (28.4)	14.6
≥ 500	80,371	42,766 (33.1)	53.2	2835 (24.3)	3.5	9604 (32.5)	11.9	952 (30.2)	1.2	659 (30.0)	0.82	11,107 (32.8)	13.8	12,448 (32.8)	15.5
Payor															
Commercial	60,373	45,924 (35.6)	76.1	2191 (18.8)	3.6	1337 (4.5)	2.2	598 (18.9)	1.0	94 (4.3)	0.16	3739 (11.0)	6.2	6490 (17.1)	10.7
Medicaid	36,793	25,168 (19.5)	68.4	1470 (12.6)	4.0	2345 (7.9)	6.4	265 (8.4)	0.7	96 (4.4)	0.26	2913 (8.6)	7.9	4536 (11.9)	12.3
Medicare	127,199	40,633 (31.5)	31.9	7287 (62.5)	5.7	25,359 (85.7)	19.9	2164 (68.6)	1.7	1923 (87.5)	1.51	25,416 (74.9)	20.0	24,417 (64.2)	19.2

Table 1 continued

Characteristic	Total	Home		Inpatient Rehabilitation Facility		Skilled Nursing Facility		Long-term Hospital		Hospice		Dead		Others	
		n(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population
Other	23,225	17,321 (13.4)	74.6	714 (6.1)	3.1	558 (1.9)	2.4	130 (4.1)	0.6	84 (3.8)	0.36	1849 (5.5)	8.0	2569 (6.8)	11.1

COPD chronic obstructive pulmonary disease

3/4), while 28% ($n = 54,772$) required supplemental oxygen (ACTT OS 5), 7% ($n = 13,705$) required non-invasive MV or high-flow oxygen (ACTT OS 6) and 12% ($n = 23,405$) required invasive MV or ECMO (ACTT OS 7). Hospital and ICU costs and LOS increased with the requirement of supplemental oxygen and the use of non-invasive to invasive MV. The highest median hospital costs were reported for ACTT OS 7 (required ECMO) ($47,454) (Fig. 4a, Table S3a).

Among patients who died in hospital (ACTT OS 8), the median hospital cost was $24,973 and median hospital cost/day was $2,685 (Fig. 4a; Table S3a), the median ICU cost was $27,742 and ICU cost/day was $3,757 (Fig. 4b; Table S3b), while the median hospital LOS was 10 days (Table S3a), and the median ICU LOS was 8 days (Table S3b).

The most frequent MS-DRG code was 177 [respiratory infections and inflammations with major complication or comorbidity (MCC)] (50.3%: 99,963 of 198,806 patients). Although infrequent, the median hospital cost and LOS were highest for MS-DRG code 4 (tracheostomy with MV > 96 h or principal diagnosis except face, mouth, and neck without major operating room procedure: $114,182, and 40 days, respectively) (Table S3a). Among patients who were admitted to ICU, the median cost and LOS were highest for MS-DRG code 4) ($114,674, and 33 days, respectively) (Table S3b).

Discharge Status by Patients and Hospital Characteristics, ACTT OS, and MS-DRG Codes

Discharge status stratified by patient and hospital characteristics is presented in Table 1. Discharges to home were similar by sex; however, males were more likely to be deceased at discharge (16%) compared with females (12%). The proportion of patients who died or were discharged to a skilled nursing facility was seen to increase with age. Death or discharge to a skilled nursing facility was common among older patients who were aged > 60 years (> 70%), with comorbid COPD (> 20%), from the Northeast region (> 17%), hospitalized in

Table 2 COVID-19 hospital discharge status by level of care and MS DRG

Characteristic	Total	Home		Inpatient Rehabilitation Facility		Skilled Nursing Facility		Long-term Hospital		Hospice		Dead		Others	
		n(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population
Level of Care*															
ACTT OS 3/4	1,32,843	82,221 (63.7)	61.9	5377 (46.1)	4.1	16,540 (55.9)	12.5	567 (18.0)	0.4	1181 (53.7)	0.9	6068 (17.9)	4.6	20,889 (55.0)	15.7
ACTT OS 5	67,462	37,709 (29.2)	55.9	2857 (24.5)	4.2	8999 (30.4)	13.3	676 (21.4)	1.0	725 (33.0)	1.1	5157 (15.2)	7.6	11,339 (29.8)	16.8
ACTT OS 6	17,123	6507 (5.0)	38.0	765 (6.6)	4.5	1660 (5.6)	9.7	418 (13.2)	2.4	196 (8.9)	1.1	4411 (13.0)	25.8	3166 (8.3)	18.5
ACTT OS 7	30,162	2609 (2.0)	8.7	2663 (22.8)	8.8	2400 (8.1)	8.0	1496 (47.4)	5.0	95 (4.3)	0.3	18,281 (53.9)	60.6	2618 (6.9)	8.7
MS-DRGs															
MS DRG: 177 Respiratory infections and inflammations with MCC	124,215	74,959 (72.1)	60.3	4598 (50.9)	3.7	14,067 (58.8)	11.3	936 (35.1)	0.8	1095 (59.9)	0.9	7638 (26.2)	6.1	20,922 (66.1)	16.8
MS DRG: 178 Respiratory infections and inflammations with CC	41,826	18,610 (17.9)	44.5	1911 (21.1)	4.6	5716 (23.9)	13.7	430 (16.1)	1.0	550 (30.1)	1.3	8016 (27.5)	19.2	6593 (20.8)	15.8
MS DRG: 179 Respiratory infections and inflammations without CC/MCC	8685	5225 (5.0)	60.2	414 (4.6)	4.8	1487 (6.2)	17.1	51 (1.9)	0.6	60 (3.3)	0.7	63 (0.2)	0.7	1385 (4.4)	15.9
MS DRG: 189 Pulmonary edema and respiratory failure	7937	520 (0.5)	6.6	513 (5.7)	6.5	733 (3.1)	9.2	235 (8.8)	3.0	24 (1.3)	0.3	5198 (17.9)	65.5	714 (2.3)	9.0
MS DRG: 190 Chronic obstructive pulmonary disease with MCC	6965	525 (0.5)	7.5	509 (5.6)	7.3	509 (2.1)	7.3	207 (7.8)	3.0	19 (1.0)	0.3	4600 (15.8)	66.0	596 (1.9)	8.6
MS DRG: 193 Simple pneumonia and pleurisy with MCC	4511	397 (0.4)	8.8	619 (6.9)	13.7	217 (0.9)	4.8	45 (1.7)	1.0	13 (0.7)	0.3	2900 (10.0)	64.3	320 (1.0)	7.1

Table 2 continued

Characteristic	Total	Home		Inpatient Rehabilitation Facility		Skilled Nursing Facility		Long-term Hospital		Hospice		Dead		Others	
		n(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population	*n*(%)	Stratum of Total population
MS DRG: 207 Respiratory system diagnosis with ventilator support > 96 h	3369	2450 (2.4)	72.7	126 (1.4)	3.7	340 (1.4)	10.1	19 (0.7)	0.6	8 (0.4)	0.2	27 (0.1)	0.8	399 (1.3)	11.8
MS DRG: 208 Respiratory system diagnosis with ventilator support ≤ 96 h	1836	57 (0.1)	3.1	197 (2.2)	10.7	222 (0.9)	12.1	718 (26.9)	39.1	2 (0.1)	0.1	515 (1.8)	28.1	125 (0.4)	6.8
MS DRG: 291 Heart failure and shock with MCC	1296	520 (0.5)	40.1	70 (0.8)	5.4	360 (1.5)	27.8	15 (0.6)	1.2	26 (1.4)	2.0	59 (0.2)	4.6	246 (0.8)	19.0
MS DRG: 4 Tracheostomy with MV > 96 h or PDX except face, mouth and neck without major O.R. procedure	850	367 (0.4)	43.2	40 (0.4)	4.7	151 (0.6)	17.8	6 (0.2)	0.7	17 (0.9)	2.0	46 (0.2)	5.4	223 (0.7)	26.2
MS DRG: 682 Renal failure with MCC	314	157 (0.2)	50.0	23 (0.3)	7.3	61 (0.3)	19.4	0	0.0	6 (0.3)	1.9	21 (0.1)	6.7	46 (0.2)	14.6
MS DRG: 683 Renal failure with CC	210	87 (0.1)	41.4	13 (0.1)	6.2	37 (0.2)	17.6	4 (0.2)	1.9	7 (0.4)	3.3	23 (0.1)	11.0	39 (0.1)	18.6
MS DRG: 870 Septicemia or severe sepsis with MV > 96 h	92	52 (0.1)	56.5	7 (0.1)	7.6	12 (0.1)	13.0	1 (0.04)	1.1	1 (0.1)	1.1	1 (0.0)	1.1	18 (0.1)	19.6
MS DRG: 871 Septicemia or severe sepsis without MV > 96 h with MCC	35	23 (0.02)	65.7	1 (0.01)	2.9	1 (0.0)	2.9	0	0.0	1 (0.1)	2.9	4 (0.0)	11.4	5 (0.0)	14.3
MS DRG: 872 Septicemia or severe sepsis without MV > 96 h without MCC	10	4 (0.0)	40.0	1 (0.0)	10.0	2 (0.0)	20.0	1 (0.04)	10.0	0	0.0	0	0.0	2 (0.0)	20.0

*255 patients could not be assigned an ACTT OS value

ACTT OS were estimated using the oxygen procedures received by patients during the hospitalization. ACTT OS ¾, no supplemental oxygen; ACTT OS 5, supplemental oxygen; ACTT OS 6: non-invasive ventilation or high-flow oxygen; ACTT OS 7, ECMO using invasive mechanical ventilation. CC, major complication or comorbidity; ECMO, extracorporeal membrane oxygenation; MCC, major complication or comorbidity; MS DRG, Medicare Severity Diagnosis Related Group; ACTT OS, Adaptive COVID-19 Treatment Trial Ordinal Scale; OR, operating room; PDX, principal diagnosis

Table 3 Predictors for COVID-19 hospitalization costs and length of stay—multivariate log-linear regression analysis

	Total hospital cost ($) (*N* = 190,175)			Hospital LOS (days) (*N* = 236,126)[a]			Hospital cost/day ($) (*N* = 190,175)		
Variables	**LS mean (95% CI)**	**LS mean difference (95% CI)**	***P*-value**	**LS mean (95% CI)**	**LS mean difference (95% CI)**	***P*-value**	**LS mean (95% CI)**	**LS mean difference (95% CI)**	***P*-value**
Sex									
Female	27,652	Reference		11	Reference		2600	Reference	
	(27,200, 28,112)			(11, 11)			(2573, 2626)		
Male	30,127	2474	< 0.0001	12	1	< 0.0001	2643	44	< 0.0001
	(29,621, 30,640)	(2280, 2669)		(12, 12)	(1, 1)		(2616, 2671)	(33, 55)	
Age groups									
18–29 years	26,157	Reference		10	Reference		2,986	Reference	
	(25,604, 26,721)			(9, 10)			(2946, 3026)		
30–39 years	27,108	952	0.0002	11	1	< 0.0001	2770	− 216	< 0.0001
	(26,584, 27,643)	(458, 1445)		(10, 11)	(1, 1)		(2736, 2804)	(− 249, − 183)	
40–49 years	29,252	3095	< 0.0001	12	2	< 0.0001	2645	− 341	< 0.0001
	(28,726, 29,787)	(2603, 3588)		(12, 12)	(2, 2)		(2615, 2675)	(− 372, − 310)	
50–59 years	30,623	4467	< 0.0001	12	3	< 0.0001	2616	− 370	< 0.0001
	(30,108, 31,148)	(3979, 4955)		(12, 13)	(3, 3)		(2589, 2644)	(− 400, − 339)	
60–69 years	31,353	5196	< 0.0001	13	3	< 0.0001	2616	− 370	< 0.0001
	(30,833, 31,881)	(4686, 5707)		(13, 13)	(3, 3)		(2589, 2643)	(− 401, − 339)	
70–79 years	30,524	4367	< 0.0001	13	3	< 0.0001	2544	− 442	< 0.0001
	(29,988, 31,069)	(3822, 4912)		(12, 13)	(3, 3)		(2516, 2572)	(− 475, − 409)	
80–89 years	28,775	2619	< 0.0001	12	3	< 0.0001	2481	− 504	< 0.0001
	(28,249, 29,311)	(2070, 3168)		(12, 12)	(2, 3)		(2453, 2510)	(− 539, − 470)	
≥ 90 years	27,535	1378	0.0409	12	2	< 0.0001	2359	− 627	< 0.0001
	(26,233, 28,901)	(57, 2701)		(12, 13)	(2, 3)		(2289, 2431)	(− 709, − 545)	

Table 3 continued

Variables	Total hospital cost ($) (*N* = 190,175)			Hospital LOS (days) (*N* = 236,126)[a]			Hospital cost/day ($) (*N* = 190,175)		
	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value
Census regions									
Midwest	26,163	Reference		11	Reference		2504	Reference	
	(25,704, 26,630)			(11, 11)			(2477, 2532)		
Northeast	33,446	7283	< 0.0001	12	1	< 0.0001	3154	649	< 0.0001
	(32,827, 34,077)	(6918, 7647)		(12, 12)	(1, 1)		(3117, 3190)	(628, 671)	
South	24,799	− 1364	< 0.0001	12	1	< 0.0001	2252	− 252	< 0.0001
	(24,389, 25,215)	(− 1601, − 1127)		(11, 12)	(1, 1)		(2229, 2276)	(− 266, − 238)	
West	31,981	5817	< 0.0001	13	2	< 0.0001	2654	150	< 0.0001
	(31,389, 32,583)	(5434, 6201)		(13, 13)	(2, 2)		(2623, 2685)	(128, 171)	
Urban									
Rural	27,817	Reference		11	Reference		2566	Reference	
	(27,313, 28,331)			(11, 12)			(2537, 2595)		
Urban	29,948	2131	< 0.0001	12	0	< 0.0001	2678	112	< 0.0001
	(29,469, 30,435)	(1816, 2446)		(12, 12)	(0, 1)		(2651, 2705)	(94, 129)	
Race									
Asian	30,942	Reference		12	Reference		2741	Reference	
	(30,140, 31,765)			(12, 12)			(2697, 2786)		
Black	28,070	− 2872	< 0.0001	12	− 1	< 0.0001	2570	− 171	< 0.0001
	(27,584, 28,564)	(− 3531, − 2214)		(11, 12)	(− 1, 0)		(2542, 2598)	(− 208, − 135)	
Caucasian	28,148	− 2794	< 0.0001	12	− 1	< 0.0001	2598	− 143	< 0.0001
	(27,716, 28,587)	(− 3433, − 2156)		(11, 12)	(− 1, 0)		(2574, 2623)	(− 179, − 107)	
Other	28,387	− 2555	< 0.0001	12	0	< 0.0001	2579	− 163	< 0.0001
	(27,900, 28,883)	(− 3243, − 1868)		(12, 12)	(− 1, 0)		(2551, 2606)	(− 201, − 125)	

Table 3 continued

Variables	Total hospital cost ($) (*N* = 190,175)			Hospital LOS (days) (*N* = 236,126)[a]			Hospital cost/day ($) (*N* = 190,175)		
	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value
Ethnicity									
Hispanic	31,367	Reference		12	Reference		2719	Reference	
	(30,791, 31,953)			(12, 12)			(2688, 2750)		
Not Hispanic	28,083	− 3284	< 0.0001	12	− 1	< 0.0001	2571	− 148	< 0.0001
	(27,631, 28,542)	(− 35,80, − 29,88)		(11, 12)	(− 1, − 1)		(2546, 2597)	(− 164, − 131)	
Unknown	27,296	− 4070	< 0.0001	11	− 1	< 0.0001	2,576	− 143	< 0.0001
	(26,819, 27,782)	(− 4423, − 3718)		(11, 11)	(− 1, − 1)		(2548, 2604)	(− 163, − 123)	
Payor									
Commercial	28,123	Reference		11	Reference		2599	Reference	
	(27,631, 28,624)			(11, 12)			(2571, 2628)		
Medicaid	30,344	2221	< 0.0001	12	1	< 0.0001	2690	91	< 0.0001
	(29,798, 30,900)	(1889, 2553)		(12, 12)	(1, 1)		(2660, 2720)	(72, 109)	
Medicare	28,339	216	0.1584	12	0	0.0175	2594	− 5	0.5394
	(27,868, 28,819)	(− 84, 517)		(11, 12)	(0, 0)		(2567, 2621)	(− 23, 12)	
Other	28,696	573	0.0021	12	0	0.0002	2603	3	0.7676
	(28,138, 29,266)	(208, 938)		(12, 12)	(0, 0)		(2571, 2634)	(− 18, 24)	
Comorbidities									
Asthma	28,441	Reference		12	Reference		2604	Reference	
(without)	(27,991, 28,898)			(11, 12)			(2578, 2630)		
Asthma	29,291	850	< 0.0001	12		0.0017	2639	35	0.0001
(with)	(28,754, 29,838)	(530, 1169)		(12, 12)			(2609, 2669)	(17, 53)	
Autoimmune diseases	28,143	Reference		11	Reference		2607	Reference	
(without)	(27,737, 28,554)			(11, 12)			(2584, 2630)		
Autoimmune diseases	29,601	1458	< 0.0001	12	0	< 0.0001	2635	29	0.0380
(with)	(28,972, 30,244)	(980, 1937)		(12, 12)	(0, 1)		(2601, 2671)	(2, 55)	

Table 3 continued

Variables	Total hospital cost ($) (*N* = 190,175)			Hospital LOS (days) (*N* = 236,126)[a]			Hospital cost/day ($) (*N* = 190,175)		
	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value
COPD	28,946	Reference		12	Reference		2605	Reference	
(without)	(28,484, 29,416)			(12, 12)			(2579, 2631)		
COPD	28,779	− 167	0.2468	12		< 0.0001	2637	32	< 0.0001
(with)	(28,266, 29,302)	(− 450, 116)		(11, 12)			(2608, 2667)	(16, 48)	
Hypertension	28,410	Reference		12	Reference		2614	Reference	
(without)	(27,921, 28,907)			(11, 12)			(2586, 2642)		
Hypertension	29,323	913	< 0.0001	12		< 0.0001	2628	14	0.0452
(with)	(28,844, 29,810)	(666, 1161)		(12, 12)			(2602, 2655)	(0, 28)	
Diabetes	27,932	Reference		11	Reference		2604	Reference	
(without)	(27,471, 28,401)			(11, 12)			(2577, 2631)		
Diabetes	29,824	1892	< 0.0001	12	1	< 0.0001	2639	35	< 0.0001
(with)	(29,326, 30,331)	(1684, 2100)		(12, 12)	(0, 1)		(2612, 2667)	(24, 47)	
Obesity	27,802	Reference		11	Reference		2632	Reference	
(without)	(27,345, 28,268)			(11, 11)			(2605, 2659)		
Obesity	29,964	2161	< 0.0001	12	1	< 0.0001	2610	− 22	0.0005
(with)	(29,459, 30,477)	(1943, 2379)		(12, 12)	(1, 1)		(2583, 2638)	(− 34, − 9)	
Levels of care									
ACTT OS 3/4	16,442	Reference		8	Reference		2220	Reference	
	(16,169, 16,719)			(7, 8)			(2197, 2244)		
ACTT OS 5	19,706	3264	< 0.0001	10	2	< 0.0001	2117	− 103	< 0.0001
	(19,369, 20,048)	(3121, 3407)		(9, 10)	(2, 2)		(2094, 2140)	(− 114, − 93)	
ACTT OS 6	35,139	18,698	< 0.0001	13	6	< 0.0001	2708	488	< 0.0001
	(34,441, 35,851)	(18,348, 19,048)		(13, 14)	(6, 6)		(2675, 2742)	(467, 509)	

Table 3 continued

Variables	Total hospital cost ($) (*N* = 190,175)			Hospital LOS (days) (*N* = 236,126)[a]			Hospital cost/day ($) (*N* = 190,175)		
	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value
ACTT OS 7	60,958	44,517	< 0.0001	19	12	< 0.0001	3709	1488	< 0.0001
	(59,815, 62,123)	(44,019, 45,017)		(19, 20)	(12, 12)		(3665, 3753)	(1464, 1513)	
Teaching status									
Academic	28,539	Reference		12	Reference		2629	Reference	
	(28,058, 29,029)			(11, 12)			(2601, 2656)		
Community	29,190	651	< 0.0001	12		< 0.0001	2614	− 15	0.0260
	(28,708, 29,680)	(421, 881)		(12, 12)			(2587, 2641)	(− 28, − 2)	
Hospital size									
0–99 beds	29,997	Reference		11	Reference		3068	Reference	
	(29,367, 30,639)			(10, 11)			(3028, 3109)		
100–299 beds	27,346	− 2651	< 0.0001	11	1	< 0.0001	2521	− 547	< 0.0001
	(26,889, 27,810)	(− 3104, − 2198)		(11, 12)	(1, 1)		(2495, 2548)	(− 574, − 520)	
300–499 beds	28,123	− 1873	< 0.0001	12	2	< 0.0001	2430	− 638	< 0.0001
	(27,640, 28,615)	(− 2352, − 1395)		(12, 12)	(2, 2)		(2404, 2456)	(− 666, − 610)	
500 + beds	30,083	87	0.7377	13	2	< 0.0001	2511	− 557	< 0.0001
	(29,569, 30,607)	(− 422, 596)		(13, 13)	(2, 2)		(2485, 2538)	(− 586, − 528)	
Discharge status									
Home	18,939	Reference		8	Reference		2402	Reference	
	(18,647, 19,235)			(8, 8)			(2379, 2425)		
Dead	25,057	6118	< 0.0001	9	1	< 0.0001	2938	536	< 0.0001
	(24,627, 25,494)	(5,836, 6400)		(9, 9)	(1, 1)		(2906, 2970)	(514, 558)	
Hospice	32,552	13,613	< 0.0001	13	5	< 0.0001	2611	209	< 0.0001
	(31,351, 33,798)	(12,711, 14,520)		(13, 14)	(5, 6)		(2551, 2672)	(154, 264)	
Inpatient Rehabilitation Facility	27,571	8633	< 0.0001	11	3	< 0.0001	2671	269	< 0.0001
	(26,991, 28,165)	(8248, 9019)		(11, 11)	(3, 3)		(2636, 2706)	(242, 295)	

Table 3 continued

Variables	Total hospital cost ($) (*N* = 190,175)			Hospital LOS (days) (*N* = 236,126)[a]			Hospital cost/day ($) (*N* = 190,175)		
	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value
Long– term Hospital Care	43,049	24,110	< 0.0001	18	9	< 0.0001	2628	226	< 0.0001
	(41,631, 44,514)	(23,153, 25,073)		(17, 18)	(9, 10)		(2574, 2683)	(178, 274)	
Others	27,987	9049	< 0.0001	11	3	< 0.0001	2651	249	< 0.0001
	(27,518, 28,465)	(8,813, 9285)		(11, 11)	(3, 3)		(2623, 2679)	(233, 265)	
Skilled Nursing Facility	32,520	13,581	< 0.0001	14	6	< 0.0001	2480	79	< 0.0001
	(31,943, 33,107)	(13,283, 13,879)		(14, 14)	(6, 6)		(2453, 2508)	(61, 96)	
Admission month									
April	33,495	Reference		13	Reference		2638	Reference	
	(32,914, 34,087)			(13, 13)			(2610, 2667)		
May	34,549	1054	< 0.0001	13	0	0.0887	2737	99	< 0.0001
	(33,912, 35,199)	(613, 1496)		(13, 13)	(0, 0)		(2706, 2769)	(77, 120)	
June	31,804	− 1691	< 0.0001	13	0	0.7278	2576	− 62	< 0.0001
	(31,214, 32,406)	(− 2135, − 1247)		(13, 13)	(0, 0)		(2546, 2606)	(− 84, − 40)	
July	29,697	− 3799	< 0.0001	12	− 1	< 0.0001	2519	− 119	< 0.0001
	(29,181, 30,222)	(− 4175, − 3422)		(12, 13)	(− 1, − 1)		(2492, 2547)	(− 139, − 100)	
August	30,511	− 2984	< 0.0001	12	− 1	< 0.0001	2696	58	< 0.0001
	(29,958, 31,074)	(− 3405, − 2564)		(12, 12)	(− 1, − 1)		(2666, 2727)	(36, 80)	
September	30,480	− 3016	< 0.0001	12	− 1	< 0.0001	2781	142	< 0.0001
	(29,887, 31,084)	(− 3493, − 2539)		(12, 12)	(− 1, − 1)		(2747, 2815)	(117, 167)	
October	28,271	− 5224	< 0.0001	12	− 2	< 0.0001	2625	− 14	0.2356
	(27,741, 28,811)	(− 5652, − 4797)		(11, 12)	(− 2, − 1)		(2594, 2656)	(− 37, 9)	
November	24,783	− 8713	< 0.0001	10	− 3	< 0.0001	2524	− 114	< 0.0001
	(24,315, 25,260)	(− 9117, − 8309)		(10, 11)	(− 3, − 3)		(2495, 2554)	(− 136, − 92)	

Table 3 continued

Variables	Total hospital cost ($) (*N* = 190,175)			Hospital LOS (days) (*N* = 236,126)[a]			Hospital cost/day ($) (*N* = 190,175)		
	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value
December	19,520	− 13,976	< 0.0001	8	− 5	< 0.0001	2510	− 128	< 0.0001
	(18,824, 20,241)	(− 14,876, − 13,080)		(8, 9)	(− 5, − 5)		(2454, 2567)	(-— 182, − 74)	

[a] Ns are for patients with cost data and above minimum cost threshold trim. ACTT OS were estimated using the oxygen procedures received by patients during the hospitalization. ACTT OS 3/4, no supplemental oxygen; ACTT OS 5, supplemental oxygen; ACTT OS 6, non-invasive ventilation or high-flow oxygen; ACTT OS 7, ECMO using invasive mechanical ventilation. COPD, chronic obstructive pulmonary disease; ECMO, extracorporeal membrane oxygenation; LOS, length of stay; LS, least square; ACTT OS, Adaptive COVID-19 Treatment Trial Ordinal Scale

urban areas (> 25%), and covered by Medicare insurance (∼ 20%). Overall, 52% (129,046/247,590) of patients were discharged home, 12% (25,599/247,590) were discharged to a skilled nursing facility, and 13.7% (33,917/247,590) died in hospital (Table S5).

Discharge status stratified by levels of care and MS-DRG groups is presented in Table 2. With the increase in ACTT OS, home discharge decreased while discharge due to death increased. While discharge home was most frequent for ACTT OS 3/4 (62%), discharge due to death was more common in ACTT OS 7 (61%). Among patients stratified based on MS-DRG codes, discharge due to death was more frequent for MS-DRG codes 189, 190, 193 (pulmonary edema and respiratory failure, COPD with MCC, and simple pneumonia and pleurisy with MCC, respectively; > 65%).

Determinants of Costs and Length of Stay

Determinants of hospital and ICU costs and LOS are presented in Tables 3 (hospital) and 4 (ICU), and Table S3 (descriptive analysis of cost versus month of admission). Hospital costs for males were significantly higher compared to females [least square mean difference (△) $2474; $P < 0.0001$], while costs versus patients aged 18–29 years ranged from △ $952 for age 30–39 years to △ $5196 for age 60–69; both $P < 0.001$). The mean cost was significantly higher in patients from the Northeast (△ $7283) and West (△ $5817) compared with the Midwest ($P < 0.0001$). Patients hospitalized in urban areas accrued higher mean costs (△ $2131) compared with rural areas ($P < 0.0001$).

By race/ethnicity, mean costs were significantly lower in Blacks and Caucasians (− △ $2872 and − △ $2794, respectively) versus Asians (all $P < 0.0001$). Non-Hispanics had a lower mean cost (− △ $3284) compared with Hispanics ($P < 0.0001$).

Among patients with comorbid conditions, mean cost was higher in obese patients (△ $2161) and in diabetic patients (△ $1892) versus those without obesity or diabetes (both $P < 0.0001$), respectively. Overall cost increased with the intensity of oxygen care (e.g., invasive

Table 4 Predictors for COVID-19 ICU costs and length of stay—multivariate log-linear regression analysis

	Total ICU Cost ($) (*N* = 67,256)			ICU LOS (Days) (*N* = 84,779)[a]			ICU Cost/Day ($) (*N* = 67,256)		
Variables	**LS mean (95% CI)**	**LS mean difference (95% CI)**	***P*-value**	**LS mean (95% CI)**	**LS mean difference (95% CI)**	***P*-value**	**LS mean (95% CI)**	**LS mean difference (95% CI)**	***P*-value**
Sex									
Female	24,014	Reference		7	Reference		3913	Reference	
	(23,304, 24,745)			(7, 7)			(3835, 3991)		
Male	25,911	1897	< 0.0001	7	0	< 0.0001	3992	79	< 0.0001
	(25,129, 26,718)	(1590, 2205)		(7, 8)	(0, 0)		(3912, 4074)	(47, 112)	
Age groups									
18–29 years	23,554	Reference		6	Reference		4665	Reference	
	(22,563, 24,589)			(6, 6)			(4533, 4800)		
30–39 years	24,625	1070	0.0331	7	1	< 0.0001	4232	− 433	< 0.0001
	(23,736, 25,547)	(86, 2056)		(7, 7)	(1, 1)		(4129, 4336)	(− 554, − 312)	
40–49 years	25,169	1615	0.0006	7	1	< 0.0001	4089	− 576	< 0.0001
	(24,360, 26,005)	(687, 2543)		(7, 7)	(1, 2)		(4001, 4179)	(− 687, − 464)	
50–59 years	27,274	3720	< 0.0001	8	2	< 0.0001	4027	− 638	< 0.0001
	(26,462, 28,110)	(2785, 4656)		(8, 8)	(2, 2)		(3947, 4108)	(− 745, − 531)	
60–69 years	27,721	4167	< 0.0001	8	2	< 0.0001	3953	− 712	< 0.0001
	(26,910, 28,555)	(3205, 5129)		(8, 8)	(2, 2)		(3876, 4031)	(− 820, − 604)	
70–79 years	26,981	3427	< 0.0001	8	2	< 0.0001	3821	− 844	< 0.0001
	(26,145, 27,844)	(2426, 4429)		(8, 8)	(2, 2)		(3742, 3902)	(− 956, − 731)	
80–89 years	23,661	107	0.8292	7	1	< 0.0001	3606	− 1,059	< 0.0001
	(22,892, 24,456)	(− 867, 1,081)		(7, 8)	(1, 2)		(3527, 3686)	(− 1173, − 945)	
≥ 90 years	21,275	− 2279	0.0442	7	1	< 0.0001	3363	− 1,302	< 0.0001
	(19,335, 23,409)	(− 4505, − 59)		(7, 8)	(1, 2)		(3155, 3584)	(− 1568, − 1037)	

Table 4 continued

Variables	Total ICU Cost ($) (*N* = 67,256)			ICU LOS (Days) (*N* = 84,779)[a]			ICU Cost/Day ($) (*N* = 67,256)		
	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value
Census regions									
Midwest	22,931	Reference		7	Reference		3438	Reference	
	(22,207, 23,679)			(7, 8)			(3366, 3512)		
Northeast	27,038	4107	< 0.0001	6	− 1	< 0.0001	5575	2,136	< 0.0001
	(26,108, 28,002)	(3506, 4709)		(6, 7)	(− 1, − 1)		(5446, 5707)	(2,062, 2,210)	
South	22,474	− 458	0.0177	7	0	< 0.0001	3499	61	0.0018
	(21,802, 23,166)	(− 836, − 79)		(7, 7)	(0, 0)		(3429, 3571)	(23, 99)	
West	27,786	4855	< 0.0001	8	1	< 0.0001	3637	199	< 0.0001
	(26,874, 28,729)	(4261, 5450)		(8, 8)	(0, 1)		(3558, 3718)	(146, 252)	
Urban									
Rural	23,522	Reference		7	Reference		3774	Reference	
	(22,756, 24,313)			(7, 7)			(3692, 3858)		
Urban	26,453	2932	< 0.0001	7	0	< 0.0001	4138	364	< 0.0001
	(25,690, 27,239)	(2450, 3413)		(7, 8)	(0, 1)		(4059, 4220)	(313, 415)	
Race									
Asian	27,620	Reference		8	Reference		4067	Reference	
	(26,302, 29,004)			(7, 8)			(3937, 4201)		
Black	23,101	− 4519	< 0.0001	7	− 1	< 0.0001	3799	− 268	< 0.0001
	(22,379, 23,847)	(− 5584, − 3455)		(7, 7)	(− 1, 0)		(3720, 3880)	(− 378, − 158)	
Caucasian	23,459	− 4161	< 0.0001	7	0	0.0006	3760	− 307	< 0.0001
	(22,817, 24,120)	(− 5200, − 3124)		(7, 7)	(− 1, 0)		(3692, 3831)	(− 412, − 201)	
Other	25,866	− 1754	0.0032	7	0	0.0885	4198	131	0.0318
	(25,063, 26,695)	(− 2921, − 587)		(7, 8)	(− 1, 0)		(4111, 4287)	(11, 251)	

Table 4 continued

Variables	Total ICU Cost ($) (*N* = 67,256)			ICU LOS (Days) (*N* = 84,779)[a]			ICU Cost/Day ($) (*N* = 67,256)		
	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value
Ethnicity									
Hispanic	27,080	Reference		8	Reference		3933	Reference	
	(26,182, 28,009)			(8, 8)			(3846, 4022)		
Not Hispanic	23,772	− 3308	< 0.0001	7	− 1	< 0.0001	4003	70	0.0036
	(23,081, 24,484)	(− 3764, − 2853)		(6, 7)	(− 1, − 1)		(3925, 4082)	(23, 117)	
Unknown	24,110	− 2970	< 0.0001	7	0	< 0.0001	3921	− 12	0.6868
	(23,349, 24,897)	(− 3537, − 2403)		(7, 8)	(− 1, 0)		(3839, 4005)	(− 68, 45)	
Payor									
Commercial	25,219	Reference		7	Reference		3894	Reference	
	(24,422, 26,041)			(7, 8)			(3812, 3978)		
Medicaid	26,376	1158	< 0.0001	8	0	< 0.0001	4055	161	< 0.0001
	(25,520, 27,261)	(614, 1,701)		(7, 8)	(0, 0)		(3967, 4144)	(105, 216)	
Medicare	23,161	−2058	< 0.0001	7	-1	< 0.0001	3849	-45	0.0718
	(22,468, 23,875)	(-−2,516, -1600)		(7, 7)	(-1, 0)		(3772, 3927)	(-94, 4)	
Other	25,131	-− 88	0.7740	7	0	0.0416	4014	120	0.0002
	(24,249, 26,045)	(−686, 511)		(7, 7)	(0, 0)		(3920, 4111)	(58, 183)	
Comorbidities									
Asthma	24,460	Reference		7	Reference		3969	Reference	
(without)	(23,764, 25,176)			(7, 7)			(3894, 4046)		
Asthma	25,439	979	0.0002	7	0	< 0.0001	3935	− 34	0.2108
(with)	(24,594, 26,313)	(471, 1488)		(7, 8)	(0, 0)		(3848, 4024)	(− 88, 19)	
Autoimmune diseases	24,583	Reference		7	Reference		3964	Reference	
(without)	(23,939, 25,244)			(7, 7)			(3895, 4035)		

Table 4 continued

Variables	Total ICU Cost ($) (*N* = 67,256)			ICU LOS (Days) (*N* = 84,779)[a]			ICU Cost/Day ($) (*N* = 67,256)		
	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value
Autoimmune diseases	25,312	729	0.0524	7	0	0.0858	3940	− 24	0.5429
(with)	(24,351, 26,310)	(− 8, 1466)		(7, 8)	(0, 0)		(3840, 4043)	(− 102, 54)	
COPD	25,493	Reference		7	Reference		3973	Reference	
(without)	(24,756, 26,251)			(7, 8)			(3897, 4051)		
COPD	24,408	− 1084	< 0.0001	7	0	< 0.0001	3931	− 42	0.0631
(with)	(23,631, 25,211)	(− 1503, − 666)		(7, 7)	(0, 0)		(3848, 4017)	(− 86, 2)	
Hypertension	24,814	Reference		7	Reference		3954	Reference	
(without)	(24,044, 25,609)			(7, 7)			(3872, 4038)		
Hypertension	25,076	262	0.1852	7	0	0.0669	3950	− 4	0.8560
(with)	(24,338, 25,837)	(− 126, 651)		(7, 7)	(0, 0)		(3872, 4030)	(− 45, 38)	
Diabetes	24,531	Reference		7	Reference		3962	Reference	
(without)	(23,799, 25,284)			(7, 7)			(3883, 4042)		
Diabetes	25,366	835	< 0.0001	7	0	< 0.0001	3942	− 20	0.2499
(with)	(24,604, 26,151)	(518, 1152)		(7, 8)	(0, 0)		(3863, 4023)	(− 53, 14)	
Obesity	23,725	Reference		7	Reference		4020	Reference	
(without)	(23,021, 24,451)			(7, 7)			(3941, 4102)		
Obesity	26,227	2502	< 0.0001	8	1	< 0.0001	3885	− 135	< 0.0001
(with)	(25,432, 27,046)	(2169, 2835)		(7, 8)	(1, 1)		(3806, 3965)	(− 170, − 100)	
Levels of care									
ACTT OS 3/4	14,119	Reference		4	Reference		3568	Reference	
	(13,686, 14,567)			(4, 5)			(3494, 3643)		
ACTT OS 5	17,967	3847	< 0.0001	6	2	< 0.0001	3345	− 223	< 0.0001
	(17,408, 18,544)	(3591, 4104)		(6, 6)	(1, 2)		(3275, 3416)	(− 260, − 186)	

Table 4 continued

Variables	Total ICU Cost ($) (*N* = 67,256)			ICU LOS (Days) (*N* = 84,779)[a]			ICU Cost/Day ($) (*N* = 67,256)		
	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value
ACTT OS 6	26,868	12,749	< 0.0001	7	3	< 0.0001	4142	574	< 0.0001
	(25,964, 27,804)	(12,305, 13,194)		(7, 8)	(3, 3)		(4048, 4237)	(518, 630)	
ACTT OS 7	56,804	42,685	< 0.0001	14	9	< 0.0001	4936	1368	< 0.0001
	(55,039, 58,625)	(42,032, 43,341)		(13, 14)	(9, 9)		(4834, 5040)	(1316, 1421)	
Teaching status									
Academic	25,390	Reference		7	Reference		4106	Reference	
	(24,618, 26,187)			(7, 7)			(4023, 4191)		
Community	24,507	− 883	< 0.0001	7	0	0.0006	3804	− 302	< 0.0001
	(23,778, 25,257)	(− 1235, − 532)		(7, 8)	(0, 0)		(3728, 3881)	(− 339, − 265)	
Hospital size									
0–99 beds	29,747	Reference		7	Reference		5039	Reference	
	(28,569, 30,973)			(6, 7)			(4906, 5176)		
100–299 beds	23,956	− 5791	< 0.0001	7	1	< 0.0001	3809	− 1230	< 0.0001
	(23,237, 24,697)	(− 6627, − 4957)		(7, 7)	(0, 1)		(3733, 3887)	(− 1322, − 1138)	
300–499 beds	22,906	− 6841	< 0.0001	7	1	< 0.0001	3560	− 1479	< 0.0001
	(22,203, 23,632)	(− 7689, − 5995)		(7, 8)	(1, 1)		(3486, 3634)	(− 1572, − 1387)	
500 + beds	23,719	− 6028	< 0.0001	8	1	< 0.0001	3570	− 1469	< 0.0001
	(22,995, 24,465)	(− 6910, − 5149)		(8, 8)	(1, 1)		(3497, 3645)	(− 1563, − 1374)	
Discharge status									
Home	17,190	Reference		5	Reference		3610	Reference	
	(16,702, 17,692)			(5, 5)			(3541, 3680)		
Dead	23,639	6449	< 0.0001	6	1	< 0.0001	4371	762	< 0.0001
	(22,932, 24,367)	(6045, 6854)		(6, 6)	(1, 1)		(4283, 4461)	(708, 815)	

Table 4 continued

Variables	Total ICU Cost ($) (*N* = 67,256)			ICU LOS (Days) (*N* = 84,779)[a]			ICU Cost/Day ($) (*N* = 67,256)		
	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value
Hospice	25,840	8650	< 0.0001	7	2	< 0.0001	4024	414	< 0.0001
	(24,156, 27,642)	(7303, 10,006)		(7, 8)	(2, 3)		(3848, 4209)	(255, 574)	
Inpatient Rehabilitation Facility	24,041	6851	< 0.0001	7	2	< 0.0001	4185	575	< 0.0001
	(23,161, 24,955)	(6270, 7435)		(7, 7)	(1, 2)		(4083, 4289)	(501, 649)	
Long-term Hospital Care	38,707	21,517	< 0.0001	12	7	< 0.0001	3693	83	0.0955
	(36,927, 40,573)	(20,398, 22,645)		(12, 13)	(7, 7)		(3579, 3810)	(− 15, 180)	
Others	24,082	6892	< 0.0001	7	2	< 0.0001	4018	408	< 0.0001
	(23,343, 24,844)	(6499, 7285)		(7, 7)	(1, 2)		(3935, 4102)	(359, 456)	
Skilled Nursing Facility	25,539	8349	< 0.0001	8	3	< 0.0001	3820	210	< 0.0001
	(24,709, 26,398)	(7884, 8816)		(8, 8)	(2, 3)		(3737, 3905)	(156, 264)	
Admission month									
April	27,736	Reference		8	Reference		3945	Reference	
	(26,876, 28,624)			(8, 8)			(3863, 4029)		
May	29,746	2010	< 0.0001	8	0	0.0004	4040	94	0.0029
	(28,782, 30,743)	(1342, 2679)		(8, 9)	(0, 1)		(3952, 4129)	(32, 156)	
June	27,088	− 648	0.0500	8	0	0.1825	3883	− 62	0.0489
	(26,206, 27,999)	(− 1297, 0)		(8, 8)	(0, 0)		(3798, 3969)	(− 124, 0)	
July	25,275	− 2461	< 0.0001	8	0	< 0.0001	3738	− 207	< 0.0001
	(24,497, 26,077)	(− 3019, − 1904)		(7, 8)	(− 1, 0)		(3661, 3817)	(− 261, − 153)	
August	26,921	− 815	0.0136	8	− 1	< 0.0001	4122	177	< 0.0001
	(26,049, 27,822)	(− 1463, − 168)		(7, 8)	(− 1, 0)		(4033, 4214)	(113, 241)	
September	26,891	− 845	0.0248	7	− 1	< 0.0001	4264	319	< 0.0001
	(25,951, 27,865)	(− 1584, − 107)		(7, 8)	(− 1, − 1)		(4165, 4366)	(245, 393)	

Table 4 continued

Variables	Total ICU Cost ($) (*N* = 67,256)			ICU LOS (Days) (*N* = 84,779)[a]			ICU Cost/Day ($) (*N* = 67,256)		
	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value	LS mean (95% CI)	LS mean difference (95% CI)	*P*-value
October	25,000	− 2736	< 0.0001	7	− 1	< 0.0001	3945	0	0.9916
	(24,158, 25,871)	(− 3405, − 2068)		(7, 7)	(− 1, − 1)		(3856, 4036)	(− 67, 67)	
November	21,754	− 5983	< 0.0001	7	− 2	< 0.0001	3710	− 235	< 0.0001
	(21,003, 22,531)	(− 6631, − 5335)		(6, 7)	(− 2, − 1)		(3625, 3797)	(− 302, − 169)	
December	16,814	− 10,922	< 0.0001	5	− 3	< 0.0001	3952	6	0.9465
	(15,589, 18,137)	(− 12,531, − 9326)		(5, 5)	(− 3, − 3)		(3758, 4156)	(− 183, 196)	

MV). Patients who received the highest level of care (ACTT OS 7) had a higher mean hospital cost (△ $44,517) and longer mean LOS (△ 12 days) compared with patients who did not receive oxygen during the hospital stay (all $P < 0.0001$). Patients discharged to long-term hospital care were associated with a significantly higher mean hospital cost (△ $24,110) compared with patients discharged home ($P < 0.0001$). Compared with patients hospitalized in April 2020, for patients hospitalized in May 2020 the cost was significantly higher (△ $1054, $P < 0.0001$), while the costs of hospitalization in all months from June to December were significantly lower (all $P < 0.0001$) (Table 3). Further, a descriptive analysis showed a decreasing trend in median hospital and ICU costs from April 2020 ($14,412, and $19,034, respectively) to December 2020 ($6967, and $6657, respectively). The median hospital and ICU LOS was decreased from April 2020 (7 days and 6 days, respectively) to December 2020 (4 days and 3 days, respectively) (Table S6).

Among patients admitted to ICU, the mean cost and LOS also increased with the following regressors: male sex, older age, Asian race (vs. Blacks and Caucasians), Hispanic ethnicity (vs. non-Hispanics), Medicaid insurance (vs. Commercial insurance), asthma, diabetes and obesity (without respective comorbidities), levels of care (vs. ACTT OS 3/4), hospital size (> 99 vs. < 99 beds), and all discharge categories (vs. home discharge). Mean ICU cost/day differences versus April 2020 ranged from △ $319 (September) to − △ $235 (November) (Table 4).

Determinants of Discharge Status

Multivariable logistic regression analyses on predictors of discharge status are provided in Table 5, Fig. 5a and b (discharge status versus month of admission), and Table S7 (descriptive data discharge status versus month of admission). The odds to be discharged to home decreased with age, (for age 70–79, the OR was 0.156 and for age 80–89, the OR was 0.054 relative to patients aged 18–29), and by ACTT OS level (for ACTT OS 6, the OR was 0.383 and for ACTT OS 7, the OR was 0.04 relative to ACTT OS

Table 5 Predictors for discharge status of COVID-19 hospitalization—multivariate logistic regression analysis (N = 236,126)

Variables	Home discharge		Skilled nursing home discharge		Inpatient rehab discharge		Hospice discharge		Long-term care discharge		Death outcome		Other discharge	
	Odds ratio (95% CI)	*P*-value	Odds ratio (95% CI)	*P*-value	Odds ratio (95% CI)	*P*-value	Odds ratio (95% CI)	*P*-value	Odds ratio (CI)	*P*-value	Odds ratio (CI)	*P*-value	Odds ratio (CI)	*P*-value
Sex														
Male vs Female	0.959 (0.939, 0.979)	< 0.0001	0.867 (0.844, 0.891)	< 0.0001	1.107 (1.064, 1.152)	< 0.0001	0.864 (0.791, 0.944)	0.0012	1.033 (0.958, 1.114)	0.3968	1.223 (1.186, 1.261)	< 0.0001	1.039 (1.015, 1.064)	0.0012
Age groups vs Age group 18–29 years														
30–39 years	0.763 (0.674, 0.864)	< 0.0001	2.554 (1.647, 3.960)	< 0.0001	1.220 (0.957, 1.554)	0.2934	1.695 (0.037, 77.768)	1	1.053 (0.530, 2.092)	1	1.653 (1.191, 2.295)	< .0001	1.305 (1.134, 1.501)	< 0.0001
40–49 years	0.582 (0.518, 0.653)	< 0.0001	5.268 (3.513, 7.902)	< 0.0001	1.401 (1.118, 1.757)	< 0.0001	18.312 (0.759, 441.88)	0.1213	1.828 (0.998, 3.349)	0.0519	2.446 (1.808, 3.309)	< .0001	1.619 (1.420, 1.846)	< 0.0001
50–59 years	0.391 (0.350, 0.437)	< 0.0001	10.460 (7.060, 15.498)	< 0.0001	1.676 (1.351, 2.078)	< 0.0001	30.932 (1.325, 722.19)	0.0187	2.207 (1.229, 3.964)	0.0007	3.746 (2.797, 5.016)	< .0001	1.998 (1.762, 2.265)	< 0.0001
60–69 years	0.266 (0.238, 0.298)	< 0.0001	13.704 (9.253, 20.297)	< 0.0001	1.765 (1.420, 2.195)	< 0.0001	73.001 (3.163, 1684.9)	0.0005	2.679 (1.491, 4.813)	< .0001	6.233 (4.658, 8.342)	< .0001	2.365 (2.083, 2.685)	< 0.0001
70–79 years	0.156 (0.139, 0.175)	< 0.0001	17.105 (11.531, 25.372)	< 0.0001	1.793 (1.430, 2.249)	< 0.0001	146.34 (6.332, 3382.0)	< 0.0001	2.231 (1.228, 4.054)	0.0008	11.681 (8.696, 15.691)	< .0001	2.821 (2.473, 3.219)	< 0.0001
80–89 years	0.054 (0.048, 0.061)	< 0.0001	25.550 (17.222, 37.905)	< 0.0001	1.980 (1.575, 2.490)	< 0.0001	361.20 (15.641, 8341.0)	< 0.0001	2.011 (1.097, 3.684)	0.0088	31.075 (23.104, 41.795)	< .0001	2.813 (2.461, 3.216)	< 0.0001

Table 5 continued

Variables	Home discharge		Skilled nursing home discharge		Inpatient rehab discharge		Hospice discharge		Long-term care discharge		Death outcome		Other discharge	
	Odds ratio (95% CI)	*P*-value	Odds ratio (95% CI)	*P*-value	Odds ratio (95% CI)	*P*-value	Odds ratio (95% CI)	*P*-value	Odds ratio (CI)	*P*-value	Odds ratio (CI)	*P*-value	Odds ratio (CI)	*P*-value
≥ 90 years	0.024	< 0.0001	34.459	< 0.0001	2.259	< 0.0001	623.01	< 0.0001	2.187	0.4995	51.788	< .0001	2.739	< 0.0001
	(0.017, 0.032)		(22.235, 53.403)		(1.484, 3.439)		(26.351, 14,730)		(0.779, 6.138)		(36.028, 74.443)		(2.140, 3.506)	
Census region vs Midwest														
Northeast	0.688	< 0.0001	1.229	< 0.0001	0.930	0.1949	0.773	0.0127	0.383	< 0.0001	1.533	< 0.0001	1.092	< 0.0001
	(0.656, 0.722)		(1.161, 1.301)		(0.850, 1.017)		(0.619, 0.964)		(0.308, 0.476)		(1.433, 1.641)		(1.035, 1.152)	
South	0.995	1	0.915	< 0.0001	1.106	0.001	1.238	0.002	1.033	1	0.998	1	1.002	1
	(0.958, 1.033)		(0.872, 0.961)		(1.030, 1.187)		(1.058, 1.450)		(0.907, 1.176)		(0.943, 1.056)		(0.961, 1.045)	
West	1.032	0.7951	0.980	1	0.663	< 0.0001	1.479	< 0.0001	1.139	0.4247	1.245	< 0.0001	0.937	0.0372
	(0.977, 1.091)		(0.911, 1.054)		(0.592, 0.743)		(1.174, 1.863)		(0.942, 1.378)		(1.146, 1.351)		(0.880, 0.998)	
Urban/rural settings														
Urban vs Rural	0.871	< 0.0001	1.149	< 0.0001	0.811	< 0.0001	1.151	0.0555	1.648	< 0.0001	0.977	0.355	1.096	< 0.0001
	(0.842, 0.901)		(1.098, 1.203)		(0.767, 0.858)		(0.997, 1.329)		(1.438, 1.889)		(0.930, 1.026)		(1.056, 1.138)	
Race vs Asian														
Black	0.659	< 0.0001	1.763	< 0.0001	1.085	1	1.227	1	1.368	0.2099	0.980	1	1.089	0.2068
	(0.600, 0.725)		(1.529, 2.034)		(0.897, 1.313)		(0.775, 1.943)		(0.924, 2.023)		(0.851, 1.129)		(0.979, 1.210)	
Caucasian	0.662	< 0.0001	1.847	< 0.0001	1.163	0.1866	1.318	0.5834	1.497	0.0313	1.106	0.3027	0.972	1
	(0.604, 0.726)		(1.607, 2.123)		(0.967, 1.399)		(0.849, 2.046)		(1.023, 2.193)		(0.965, 1.267)		(0.877, 1.077)	

Table 5 continued

Variables	Home discharge		Skilled nursing home discharge		Inpatient rehab discharge		Hospice discharge		Long-term care discharge		Death outcome		Other discharge	
	Odds ratio (95% CI)	*P*-value	Odds ratio (95% CI)	*P*-value	Odds ratio (95% CI)	*P*-value	Odds ratio (95% CI)	*P*-value	Odds ratio (CI)	*P*-value	Odds ratio (CI)	*P*-value	Odds ratio (CI)	*P*-value
Other	0.776 (0.703, 0.857)	< 0.0001	1.386 (1.193, 1.612)	< 0.0001	1.235 (1.013, 1.505)	0.0293	1.210 (0.742, 1.971)	1	1.411 (0.941, 2.117)	0.1503	0.982 (0.848, 1.137)	1	1.031 (0.922, 1.152)	1
Ethnicity vs Hispanic														
Not Hispanic	0.680 (0.653, 0.707)	< 0.0001	1.859 (1.747, 1.979)	< 0.0001	1.391 (1.284, 1.507)	< 0.0001	1.368 (1.130, 1.656)	0.0003	1.263 (1.096, 1.455)	0.0002	0.949 (0.895, 1.005)	0.0892	1.079 (1.032, 1.128)	0.0001
Unknown	0.703 (0.671, 0.737)	< 0.0001	1.911 (1.783, 2.048)	< 0.0001	1.503 (1.371, 1.648)	< 0.0001	1.105 (0.877, 1.392)	0.9095	1.154 (0.969, 1.375)	0.1485	0.962 (0.899, 1.030)	0.5321	0.980 (0.929, 1.034)	1
Payor vs commercial insurance														
Medicaid	0.551 (0.524, 0.579)	< 0.0001	3.601 (3.269, 3.967)	< 0.0001	1.324 (1.201, 1.461)	< 0.0001	2.196 (1.471, 3.278)	< 0.0001	0.831 (0.675, 1.022)	0.1108	1.349 (1.234, 1.475)	< 0.0001	1.336 (1.260, 1.416)	< 0.0001
Medicare	0.368 (0.353, 0.384)	< 0.0001	4.621 (4.246, 5.029)	< 0.0001	1.298 (1.191, 1.414)	< 0.0001	1.995 (1.446, 2.752)	< 0.0001	1.377 (1.180, 1.608)	< 0.0001	1.747 (1.625, 1.879)	< 0.0001	1.384 (1.315, 1.457)	< 0.0001
Other	0.855 (0.806, 0.907)	< 0.0001	1.273 (1.108, 1.463)	< 0.0001	0.890 (0.788, 1.005)	0.0697	2.039 (1.347, 3.086)	< 0.0001	0.568 (0.434, 0.743)	< 0.0001	1.426 (1.289, 1.578)	< 0.0001	1.107 (1.034, 1.185)	0.0005

Table 5 continued

Variables	Home discharge		Skilled nursing home discharge		Inpatient rehab discharge		Hospice discharge		Long-term care discharge		Death outcome		Other discharge	
	Odds ratio (95% CI)	*P*-value	Odds ratio (95% CI)	*P*-value	Odds ratio (95% CI)	*P*-value	Odds ratio (95% CI)	*P*-value	Odds ratio (CI)	*P*-value	Odds ratio (CI)	*P*-value	Odds ratio (CI)	*P*-value
Comorbidities with vs without														
Asthma	1.173	< 0.0001	0.763	< .0001	0.918	0.0153	0.693	0.0003	0.888	0.0762	0.805	< 0.0001	1.154	< 0.0001
	(1.133, 1.214)		(0.726, 0.802)		(0.856, 0.984)		(0.569, 0.846)		(0.779, 1.013)		(0.761, 0.851)		(1.112, 1.198)	
Autoimmune diseases	0.862	< 0.0001	1.057	0.0731	1.002	0.9701	0.955	0.6709	0.994	0.9478	1.107	0.0049	1.107	0.0002
	(0.820, 0.906)		(0.995, 1.122)		(0.911, 1.101)		(0.774, 1.179)		(0.837, 1.181)		(1.031, 1.188)		(1.049, 1.167)	
COPD	0.688	< 0.0001	1.296	< .0001	0.980	0.4500	1.093	0.101	1.080	0.1017	1.156	< 0.0001	1.064	< 0.0001
	(0.668, 0.708)		(1.255, 1.338)		(0.929, 1.033)		(0.983, 1.216)		(0.985, 1.184)		(1.113, 1.200)		(1.031, 1.097)	
Diabetes	0.804	< 0.0001	1.187	< .0001	1.048	0.0257	0.955	0.3268	1.034	0.4000	1.106	< 0.0001	1.072	< 0.0001
	(0.786, 0.822)		(1.154, 1.220)		(1.006, 1.093)		(0.871, 1.047)		(0.957, 1.117)		(1.072, 1.142)		(1.047, 1.099)	
Hypertension	0.821	< 0.0001	1.320	< .0001	1.042	0.1205	0.880	0.0396	1.184	0.0017	1.069	0.0019	1.146	< 0.0001
	(0.799, 0.843)		(1.268, 1.374)		(0.989, 1.098)		(0.779, 0.994)		(1.066, 1.316)		(1.025, 1.115)		(1.111, 1.183)	
Obesity	1.010	0.4304	1.001	0.95	0.969	0.1686	0.703	< .0001	1.157	0.0004	0.975	0.1522	1.056	< 0.0001
	(0.986, 1.034)		(0.970, 1.033)		(0.927, 1.013)		(0.622, 0.795)		(1.068, 1.253)		(0.941, 1.010)		(1.028, 1.084)	
Levels of Care (ACTT OS) vs ACTT OS 3/4														
ACTT OS 5	0.846	< 0.0001	0.963	0.0953	0.970	1	1.001	1	1.984	< 0.0001	1.796	< 0.0001	0.997	1
	(0.820, 0.873)		(0.924, 1.004)		(0.908, 1.035)		(0.879, 1.141)		(1.697, 2.320)		(1.698, 1.900)		(0.963, 1.034)	

Table 5 continued

Variables	Home discharge		Skilled nursing home discharge		Inpatient rehab discharge		Hospice discharge		Long-term care discharge		Death outcome		Other discharge	
	Odds ratio (95% CI)	*P*-value	Odds ratio (95% CI)	*P*-value	Odds ratio (95% CI)	*P*-value	Odds ratio (95% CI)	*P*-value	Odds ratio (CI)	*P*-value	Odds ratio (CI)	*P*-value	Odds ratio (CI)	*P*-value
ACTT OS 6	0.383	< 0.0001	0.586	< 0.0001	0.961	1	0.997	1	4.792	< 0.0001	8.170	< 0.0001	1.040	0.4609
	(0.363, 0.404)		(0.543, 0.633)		(0.862, 1.071)		(0.806, 1.235)		(4.008, 5.729)		(7.647, 8.729)		(0.981, 1.102)	
ACTT OS 7	0.040	< 0.0001	0.485	< 0.0001	2.190	< 0.0001	0.378	< 0.0001	10.112	< 0.0001	54.098	< 0.0001	0.449	< 0.0001
	(0.037, 0.042)		(0.455, 0.517)		(2.042, 2.349)		(0.283, 0.506)		(8.799, 11.621)		(51.016, 57.367)		(0.422, 0.477)	
Teaching status vs Academic														
Community	0.965	0.0045	0.927	< 0.0001	1.046	0.0705	1.089	0.1041	0.969	0.4664	1.072	0.0001	1.049	0.0005
	(0.942, 0.989)		(0.898, 0.956)		(0.996, 1.098)		(0.983, 1.207)		(0.889, 1.055)		(1.035, 1.111)		(1.021, 1.078)	
Hospital size vs 0–99 beds														
100–299 beds	1.185	< 0.0001	1.384	< 0.0001	0.441	< 0.0001	1.291	0.1018	0.906	1	1.485	< 0.0001	0.856	< 0.0001
	(1.112, 1.263)		(1.262, 1.518)		(0.403, 0.482)		(0.974, 1.712)		(0.699, 1.174)		(1.334, 1.653)		(0.800, 0.917)	
300–499 beds	1.320	< 0.0001	1.412	< 0.0001	0.289	< 0.0001	1.268	0.2017	1.019	1	1.649	< 0.0001	0.802	< 0.0001
	(1.235, 1.411)		(1.283, 1.554)		(0.261, 0.319)		(0.944, 1.703)		(0.781, 1.329)		(1.476, 1.843)		(0.746, 0.862)	
500 + beds	1.300	< 0.0001	1.394	< 0.0001	0.285	< 0.0001	1.317	0.1027	0.877	1	1.557	< 0.0001	0.885	< 0.0001
	(1.213, 1.392)		(1.263, 1.538)		(0.257, 0.318)		(0.971, 1.787)		(0.666, 1.154)		(1.389, 1.745)		(0.822, 0.954)	

ACTT OS were estimated using the oxygen procedures received by patients during the hospitalization. ACTT OS 3/4: no supplemental oxygen; ACTT OS 5: supplemental oxygen; ACTT OS 6: non-invasive ventilation or high-flow oxygen; ACTT OS 7: ECMO using invasive mechanical ventilation. COPD, chronic obstructive pulmonary disease; ECMO, extracorporeal membrane oxygenation; ACTT OS, Adaptive COVID-19 Treatment Trial Ordinal Scale

3/4 level), while the odds of death increased in age and by ACTT OS levels. Requirement of supplemental oxygen including ECMO (ACTT OS 5 to 7) increased the odds of discharge to long-term care facilities [for ECMO OR (95% CI): 10.112 (8.799–11.621) compared to ACTT OS 3/4] (Table 5).

The odds of home discharge were higher from June to December, compared to April, with the highest odds of home discharge in December [OR (95% CI): 2.221 (1.950–2.529)]. In addition, the odds of death were lower from May to December, compared to April, with the lowest odds of death in December [OR (95% CI): 0.411 (0.328–0.514)] (Fig. 5a, b). Further, a descriptive analysis showed that discharge status varied with the month of hospital admissions. Overall, the proportion of specialty care (other than home) discharge decreased from April to December 2020. Maximum death was reported in the month of April, which decreased to the month of December, while the proportion of patients discharged home increased from 41 to 61%, discharge to a skilled nursing facility decreased from 15.3% to 9.4%, and deaths decreased from 21.8 to 7.3% by December 2020 (Table S7).

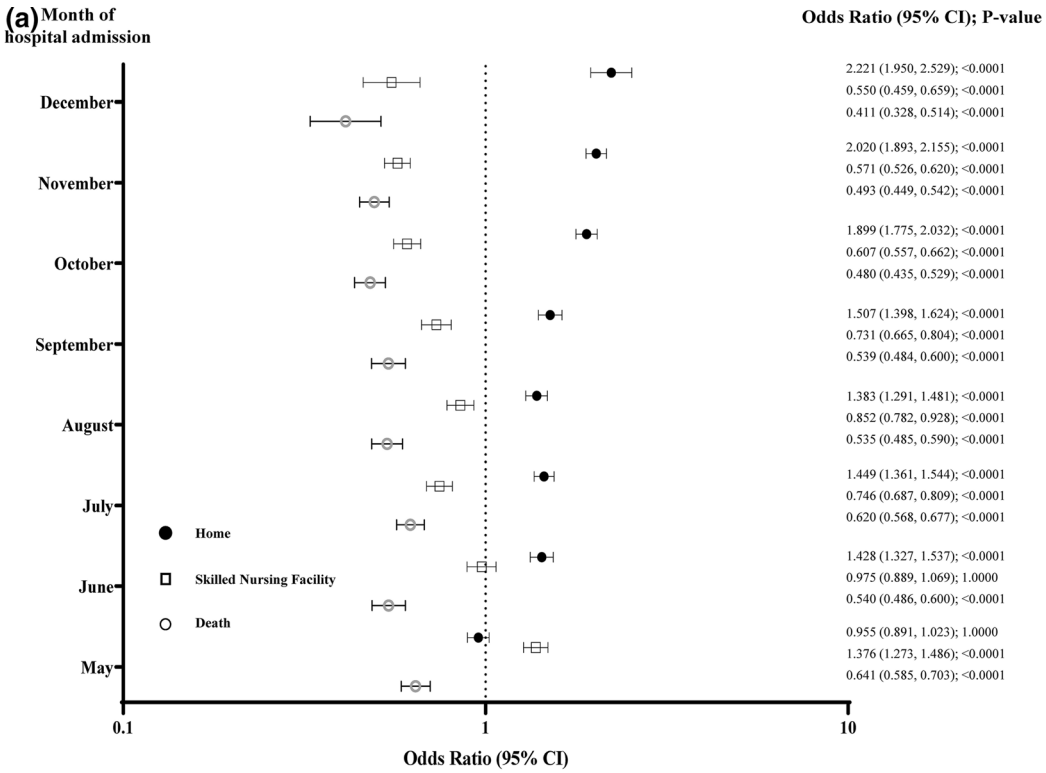
DISCUSSION

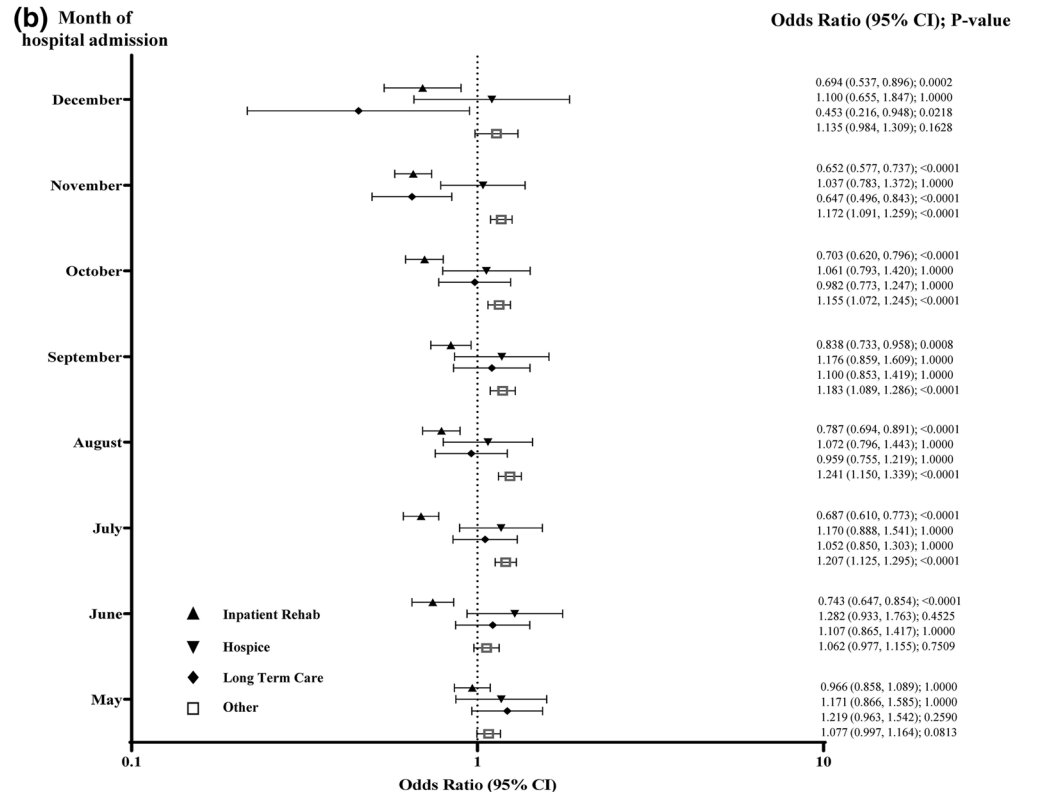
Demographics and clinical characteristics of patients analyzed in this study are consistent with previous studies on hospitalized COVID-19 patients identified from the PHD, with some differences [14, 20, 21]. Our results revealed that COVID-19 imposes a substantial burden on hospitals and patients, resulting in high costs, LOS, and ICU use, a large proportion of patients requiring post-acute care, and significant mortality among several patient subgroups. Previous studies that reported the cost of hospitalization in patients with COVID-19 were mostly based on assumptions or non-COVID-19 cost data reported with respect to related disease conditions such as pneumonia [10, 19].

To the best of our knowledge, the only study that reported hospital charges and costs data for COVID-19 patients was conducted by Di Fusco et al. [14] and studied 173,942 patients hospitalized with COVID-19 identified from the PHD during April 1 to October 31, 2020. Results from that study showed that 22% of all patients were admitted to the ICU and 16.9% received invasive MV. Consistent with our study, Di Fusco et al. also reported that the median hospital LOS was 5 days and median hospital costs were $12,046. The hospital LOS and costs increased up to 15 days in patients who used invasive MV in ICU admission. They also reported that government insurance and severity of disease were associated with increased LOS and costs [14]. However, unlike previous studies, more patients were admitted to ICU in our study (10–19% vs. ~ 36% in our study, respectively) [6, 14, 20, 21].

Although there are some similarities with the study conducted by Di Fusco et al., the present study is unique in several ways. Firstly, our study is the first to report adjusted results using multivariate log-linear and logistic regression analyses to identify the major drivers of costs, LOS, and discharge status. In addition, we have stratified cost, LOS, and discharge data based on ACTT OS scores and MS-DRG codes. Furthermore, our study provides important new results by month to show significant time trends in costs and outcomes.

Treatments that can reduce time to recovery and limit progression of disease towards requiring higher levels of oxygen support (invasive/non-invasive MV) may lead to better outcomes for patients, as well as conserving scarce resources for hospitals. The multivariate analyses further confirmed the trend observed in the descriptive analysis. The log-linear regression showed that age, comorbidity, Northeast region, and Medicare insurance, along with requirement of supplemental oxygen including ECMO via invasive MV, and discharge of patients to long-term care facilities or death were the major drivers of costs and LOS. The multivariable logistic regression showed that major factors for discharge due to death were higher age and ACTT OS 7. The OR for death was 11.6 for patients aged 70–79 versus those aged 18–29 years. Similarly, the OR for death was 54.1 for patients with ACTT OS of 7. Overall, teaching status and the size of hospitals had little impact on cost and discharge status.


(a) Month of hospital admission
Odds Ratio (95% CI); P-value
December
November
October
September
August
July
June
May
Home
Skilled Nursing Facility
Death
2.221 (1.950, 2.529); <0.0001
0.550 (0.459, 0.659); <0.0001
0.411 (0.328, 0.514); <0.0001
2.020 (1.893, 2.155); <0.0001
0.571 (0.526, 0.620); <0.0001
0.493 (0.449, 0.542); <0.0001
1.899 (1.775, 2.032); <0.0001
0.607 (0.557, 0.662); <0.0001
0.480 (0.435, 0.529); <0.0001
1.507 (1.398, 1.624); <0.0001
0.731 (0.665, 0.804); <0.0001
0.539 (0.484, 0.600); <0.0001
1.383 (1.291, 1.481); <0.0001
0.852 (0.782, 0.928); <0.0001
0.535 (0.485, 0.590); <0.0001
1.449 (1.361, 1.544); <0.0001
0.746 (0.687, 0.809); <0.0001
0.620 (0.568, 0.677); <0.0001
1.428 (1.327, 1.537); <0.0001
0.975 (0.889, 1.069); 1.0000
0.540 (0.486, 0.600); <0.0001
0.955 (0.891, 1.023); 1.0000
1.376 (1.273, 1.486); <0.0001
0.641 (0.585, 0.703); <0.0001
0.1
1
10
Odds Ratio (95% CI)


(b) Month of hospital admission
Odds Ratio (95% CI); P-value
December
November
October
September
August
July
June
May
Inpatient Rehab
Hospice
Long Term Care
Other
0.694 (0.537, 0.896); 0.0002
1.100 (0.655, 1.847); 1.0000
0.453 (0.216, 0.948); 0.0218
1.135 (0.984, 1.309); 0.1628
0.652 (0.577, 0.737); <0.0001
1.037 (0.783, 1.372); 1.0000
0.647 (0.496, 0.843); <0.0001
1.172 (1.091, 1.259); <0.0001
0.703 (0.620, 0.796); <0.0001
1.061 (0.793, 1.420); 1.0000
0.982 (0.773, 1.247); 1.0000
1.155 (1.072, 1.245); <0.0001
0.838 (0.733, 0.958); 0.0008
1.176 (0.859, 1.609); 1.0000
1.100 (0.853, 1.419); 1.0000
1.183 (1.089, 1.286); <0.0001
0.787 (0.694, 0.891); <0.0001
1.072 (0.796, 1.443); 1.0000
0.959 (0.755, 1.219); 1.0000
1.241 (1.150, 1.339); <0.0001
0.687 (0.610, 0.773); <0.0001
1.170 (0.888, 1.541); 1.0000
1.052 (0.850, 1.303); 1.0000
1.207 (1.125, 1.295); <0.0001
0.743 (0.647, 0.854); <0.0001
1.282 (0.933, 1.763); 0.4525
1.107 (0.865, 1.417); 1.0000
1.062 (0.977, 1.155); 0.7509
0.966 (0.858, 1.089); 1.0000
1.171 (0.866, 1.585); 1.0000
1.219 (0.963, 1.542); 0.2590
1.077 (0.997, 1.164); 0.0813
0.1
1
10
Odds Ratio (95% CI)

◀**Fig. 5** **a** Discharge status (home, skilled nursing facility, and death) of COVID-19 from hospital by month of admission. **b** Discharge status (inpatient rehab, hospice, long-term care, and other) of COVID-19 from hospital by month of admission. CI confidence interval, OR odds ratio

We also observed a downward trend of LOS, cost, discharge to post-acute care, and discharge due to death from April to December 2020. Over this time period, there was almost a 50% reduction in median hospital costs. The median LOS and median ICU LOS both fell by 3 days over the study period, while the median ICU costs decreased by 35%. Discharge status improved from April to December 2020 with an increase of home discharge by 20%, whereas discharge due to death fell by 14%. A recent report also showed that in-hospital mortality, LOS, and use of mechanical ventilation in patients with COVID-19 decreased from March/April to September/November 2020 (mortality fell from 19 to 11%, LOS fell from 10.7 to 7.5 days, and use of mechanical ventilation fell from 23.3 to 13.9% of patients) [22]. The trend of decrease in mortality and cost from our analyses may be associated with improved understanding of the pathophysiology of COVID-19 with time and the associated availability and implementation of newer treatment protocols, including increased use of medications such as glucocorticoids and remdesivir [22].

The results of our study suggest that reducing time to recovery by only one hospital day may save $2118 per patient/day on average, and, if applied to the 198,806 patients in our cost analysis alone, the cost savings would exceed $421 million. Reducing ICU LOS by one day would save $3586 per patient/day on average, and over $251 million based on the 70,054 ICU patients in our cost analysis. In addition, efficacious therapies could reduce the burden on post-acute care facilities. These data will be useful as inputs for cost-effectiveness models to evaluate the potential impacts of COVID-19 prevention and treatment efforts.

Although the present study has multiple strengths, including a large sample size, robust analyses, and predictor model of inpatient hospitalization costs and trends, it has several limitations which can be expected from any observational study; hence, results of this study should be interpreted with caution. Apart from the possibility of coding errors, these results may not be generalizable to other populations beyond those identified in the PHD. In addition, private for-profit hospitals are underrepresented in the study sample. Moreover, indirect costs and rehospitalizations were not assessed, although previous research has shown that 9% of COVID-19 survivors required readmission during the early phase of this pandemic [20]. Overall, ~ 18% of the patients did not have cost information due to incomplete financial reconciliation and a resultant delay in submission of hospital cost data to the PHD system. For this reason, incomplete cost information was more common among patients hospitalized later in the study period. Furthermore, a subset of patients with cost data outside the 1st and 99th percentiles were excluded in the cost analysis to reduce skewness in cost data.

Therefore, further studies are warranted in other care settings and databases. Nevertheless, results of this study provide important insights into the economic burden and changes over time associated with COVID-19 in the US.

CONCLUSIONS

Results of this study showed that the total median length of stay in hospital was 6 days and the median total hospital cost was $11,267. The median length of stay in ICU was 5 days and median total ICU cost was $13,443. This study is the first comprehensive analysis of healthcare resource use and hospital costs due to COVID-19 cases in the United States, using a large, nationally representative hospital database. These estimates will be useful for inputs to economic models, disease burden forecasts, and local healthcare resource decisions.

ACKNOWLEDGEMENTS

Funding. This study was funded by Eli Lilly and Company. The Journal's Rapid Service Fees were funded by Eli Lilly and Company.

Medical Writing, Editorial, and Other Assistance. Authors would like to acknowledge Siew Hoong Wong-Jacobson, Mingyang Shan, Xian Zhou, Diane Haldane and David R Nelson for their contributions in statistical analyses. Medical writing and editorial support were provided by Santanu Bhadra, PhD, full-time employees of Eli Lilly Services India Private Limited, Bengaluru, India.

Authorship. All named authors meet the International Committee of Medical Journal Editors (ICMJE) criteria for authorship for this article, take responsibility for the integrity of the work as a whole.

Authorship Contributions. Robert L. Ohsfeldt, Casey Kar-Chan Choong, Patrick L Mc Collam, Hamed Abedtash, Kari A. Kelton and Russel Burge all made substantial contributions to conception, interpretation of data, drafting the manuscript, and revising it critically for important intellectual content, and have given their approval for this version of manuscript to be published.

Disclosures. Robert L. Ohsfeldt is a consultant to Medical Decision Modeling Inc. for projects sponsored by various pharmaceutical companies. He received grants or contracts from Texas Dept of Human Health Services, Texas A&M University as co-principal investigator, and Blue Cross/Blue Shield of Texas, Texas A&M University as principal investigator. Casey Kar-Chan Choong, Patrick L Mc Collam, Hamed Abedtash, and Russel Burge are employees and shareholders of Eli Lilly and Company. Kari A. Kelton is an employee of Medical Decision Modeling Inc. which was contracted to perform consulting work for Eli Lilly and Company.

Compliance with Ethics Guidelines. This is an observational study that uses previously collected data and does not impose any form of intervention, and was performed in accordance with the Helsinki Declaration of 1964 and its later amendments. Data have been deidentified to protect subject privacy and to be fully compliant with the US patient confidentiality requirements, including the Health Insurance Portability and Accountability Act of 1996, and did not require institutional review board waiver or approval.

Data Availability. The datasets generated and/or analyzed during the current study are not publicly available due to individual data privacy but may be available from the corresponding author on reasonable request.

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