

Article

Clinical Outcomes and Hospital Resource Utilization Among Hospitalized Patients with Diabetes Mellitus and COVID-19 Infection: Insights from United States National Inpatient Sample, 2020–2022

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Abstract

Background: Diabetes mellitus (DM) is highly prevalent in the United States and increases the risk of severe illness in patients with COVID-19. We compared outcomes among adult COVID-19 hospitalizations with and without DM. **Methods:** We compared the National Inpatient Sample (2020–2022), using multivariate regression to adjust for potential confounders. **Results:** Among 5,934,565 hospitalizations for COVID-19, 2,155,978 (36.3%) had concomitant DM. The DM group had higher unadjusted in-hospital mortality (13.5% vs. 10.1%) and was associated with higher mortality after adjustment (aOR 1.17; 95% CI, 1.15–1.19; $p < 0.001$). DM was also independently associated with higher odds of acute respiratory failure (46.1% vs. 42.3%; aOR 1.12; 95% CI, 1.11–1.13; $p < 0.001$), greater use of invasive mechanical ventilation (aOR 1.35; 95% CI, 1.33–1.37; $p < 0.001$) and non-invasive ventilation (NIV; aOR 1.42; 95% CI, 1.40–1.45; $p < 0.001$). COVID-19 hospitalizations with DM also had higher rates of acute respiratory distress syndrome, acute kidney injury, renal replacement therapy, sepsis, septic shock, and vasopressor use, along with longer length of hospital stay and higher total hospitalization charges. In-hospital mortality among COVID-19 hospitalizations with DM was lower in 2022 than in 2020 and 2021. **Conclusions:** DM was associated with higher in-hospital mortality and greater respiratory, renal, and hemodynamic complications and hospital resource utilization.

Keywords: diabetes mellitus; COVID-19; National Inpatient Sample; in-hospital mortality; sepsis; septic shock; acute respiratory failure; acute kidney injury; mechanical ventilation; healthcare resource utilization



Academic Editor: Boris N. Mankovsky

Received: 6 August 2026

Revised: 11 September 2026

Accepted: 17 September 2026

Published: 20 September 2026

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1. Introduction

COVID-19, caused by SARS-CoV-2, was declared a pandemic by the World Health Organization in March 2020 [1]. Over the subsequent three years, the United States experi-

enced multiple waves of infection, resulting in millions of hospitalizations and substantial mortality [2]. COVID-19 management and the broader pandemic landscape evolved considerably between 2020 and 2022 [3].

Diabetes mellitus (DM) is highly prevalent in the United States, affecting a substantial proportion of adults and increasing the risk for both cardiovascular and kidney disease [4]. According to the Centers for Disease Control and Prevention (CDC), approximately 40.1 million Americans, or 12% of the population, have diabetes, including 29.1 million with diagnosed diabetes [4]. During the early stages of the pandemic, DM was a frequent comorbidity among hospitalized COVID-19 patients and was associated with adverse outcomes [5–7]. Chronic hyperglycemia has been associated with impaired immune function and systemic inflammation [7,8]. Furthermore, DM frequently coexists with obesity, hypertension, chronic kidney disease, and cardiovascular disease; conditions independently linked to adverse COVID-19 outcomes, making it challenging to isolate the specific contribution of diabetes from the broader cardiometabolic risk profile [5,6,9].

Early studies identified DM as an independent predictor of severe COVID-19 outcomes; however, these findings were largely based on limited data collected while hospital protocols were rapidly evolving [5–7]. The widespread adoption of new treatments and vaccinations after 2020 substantially altered the clinical landscape [3,10]. Consequently, it remains uncertain whether DM continued to independently influence in-hospital mortality as the pandemic progressed.

The National Inpatient Sample (NIS), maintained by the Agency for Healthcare Research and Quality, is the largest publicly available all-payer inpatient database in the United States and enables large-scale analysis across multiple years of the pandemic [11]. Using the 2020–2022 NIS, our primary objective was to evaluate the association between DM and in-hospital mortality among adult COVID-19 hospitalizations after multivariable adjustment. Secondary objectives were to evaluate the association of DM with respiratory, renal, and hemodynamic complications, critical care interventions, length of hospital stay, and total hospital charges. We also examined descriptive annual patterns in in-hospital mortality among COVID-19 hospitalizations with DM and the proportional distribution of COVID-19 hospitalizations with and without DM across the 2020–2022 study years.

2. Methods

2.1. Study Design and Data Source

A retrospective cohort study was conducted using the National Inpatient Sample (NIS) database that covered the study period from 1 January 2020, to 31 December 2022. The NIS is an all-payer, hospitalization-level database developed as part of the Healthcare Cost and Utilization Project (HCUP). It contains a stratified sample of discharges from U.S. hospitals and provides discharge-level weights that allow generation of nationally representative estimates of hospitalizations.

2.2. Study Population

Adult hospitalizations (age ≥ 18 years) with COVID-19 were identified using the ICD-10-CM diagnosis code U07.1. Diabetes mellitus was identified using ICD-10-CM codes E10 (type 1 diabetes mellitus), E11 (type 2 diabetes mellitus), and E13 (other specified diabetes mellitus). These categories were selected to capture type 1, type 2, and other specified forms of diabetes within the overall DM cohort. Diabetes subtypes were not analyzed separately because the primary objective was to evaluate the association of DM as an overall comorbidity with outcomes among COVID-19 hospitalizations. The study cohort was stratified into COVID-19 hospitalizations with DM and COVID-19 hospitalizations without DM.

2.3. Outcomes and Variables

The primary outcome was in-hospital mortality. Secondary outcomes included invasive mechanical ventilation (IMV), non-invasive ventilation (NIV), vasopressor use, acute respiratory failure, acute kidney injury (AKI), sepsis, septic shock, acute respiratory distress syndrome (ARDS), renal replacement therapy (RRT), extracorporeal membrane oxygenation (ECMO), length of hospital stay (LOS) in days, and total charges in United States Dollars (USD). We also descriptively examined annual in-hospital mortality among COVID-19 hospitalizations with DM and the proportional distribution of COVID-19 hospitalizations with and without DM across the 2020–2022 study years. Demographic variables included age, sex, race, median household income quartile, and primary insurance payer. Comorbidity burden was assessed using a modified Charlson Comorbidity Index (CCI), calculated after excluding the diabetes-related component to avoid potential over-adjustment because DM was the primary exposure of interest. The modified CCI was included in the multivariable models to account for the potential confounding effect of overall comorbidity burden while avoiding adjustment for the primary exposure itself. The modified CCI was categorized as 0, 1, 2, and ≥ 3 . Hospital-level characteristics included geographic region, hospital location/teaching status, and hospital bed size. The ICD-10-CM diagnosis codes and ICD-10-PCS procedure codes used to define the study population and clinical outcomes are provided in Supplementary Table S1.

2.4. Statistical Analysis

All data analyses were conducted using Stata/BE version 17.0 (StataCorp LLC, College Station, TX, USA). NIS discharge weights were applied to generate nationally representative estimates. The NIS survey design was specified in Stata using discharge weights (DISCWT), hospital-level clusters (HOSP_NIS), and NIS sampling strata (NIS_STRATUM). All descriptive analyses and regression models were conducted using Stata survey (svy) procedures with the same survey design specifications. Subpopulation analyses were used to restrict analyses to adult COVID-19 hospitalizations while preserving the NIS survey design. To compare groups, we used survey-weighted linear regression with adjusted Wald tests, while categorical/dichotomous variables were reported as weighted percentages and evaluated using the Rao–Scott corrected chi-square test.

Survey-weighted univariable analyses were initially performed to compare clinical outcomes between adult COVID-19 hospitalizations with DM and those without DM. Multivariable logistic regression analyses were then used to calculate adjusted odds ratios (aORs) for mortality, IMV, NIV, acute respiratory failure, sepsis, septic shock, AKI, RRT, ARDS, ECMO, and vasopressor use, while adjusted mean differences (aMDs) for LOS and total hospital charges were estimated using multivariable linear regression. Across all multivariable models, we adjusted for age, sex, race, median household income quartile, insurance status, modified CCI excluding the diabetes-related component, hospital region, hospital location/teaching status, hospital bed size, and calendar year, with calendar year modeled as a categorical covariate to account for temporal differences across the 2020–2022 study period. A sensitivity analysis was performed for the primary mortality outcome using the conventional CCI, which includes diabetes, while retaining the same covariates and survey design specifications as the primary model using the modified CCI. Linear regression was used for LOS and total hospital charges to estimate adjusted mean differences on their original clinically interpretable scales. Examination of residual distributions and diagnostic plots demonstrated right-skewness for both outcomes, particularly total hospital charges. Therefore, additional survey-weighted sensitivity analyses were performed using log-transformed LOS and total hospital charges to assess the robustness of the primary findings. A p -value < 0.05 was considered statistically significant.

3. Results

A nationally weighted estimate of 5,934,565 adult COVID-19 hospitalizations was identified in the 2020–2022 National Inpatient Sample (NIS). Hospitalizations were categorized according to the presence or absence of diabetes mellitus (DM). Of these, an estimated 3,778,587 hospitalizations (63.7%) were without DM, whereas 2,155,978 hospitalizations (36.3%) had concomitant DM (Figure 1).

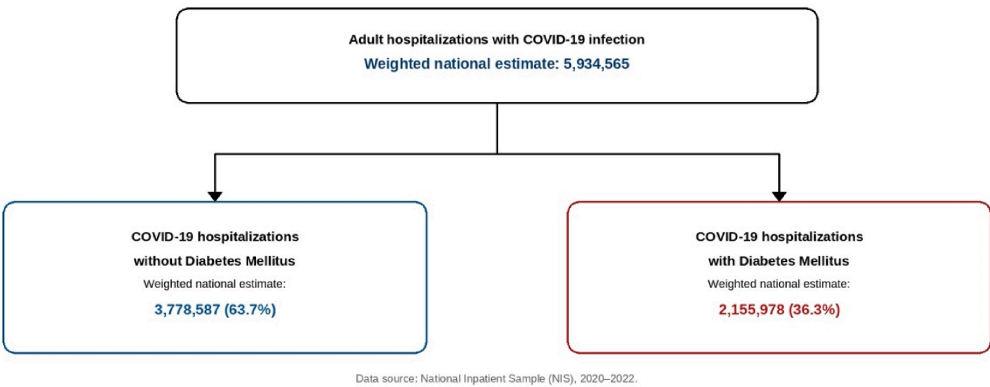


Figure 1. Study cohort flowchart showing weighted national estimates of adult COVID-19 hospitalizations with and without diabetes mellitus in the 2020–2022 National Inpatient Sample.

Baseline demographic and hospital characteristics are summarized in Table 1. COVID-19 hospitalizations with DM involved older individuals than hospitalizations without DM (mean age, 66.0 vs. 60.8 years). Females comprised a slight majority of hospitalizations without DM (50.9%), whereas males constituted the majority of hospitalizations with DM (53.7%). White individuals constituted the largest racial group in both the non-DM and DM groups (63.0% and 54.5%, respectively). Black and Hispanic individuals were equally represented in the non-DM group (15.1% each), whereas Black individuals were slightly more represented than Hispanic individuals in the DM group (19.5% vs. 18.1%). The largest proportion of hospitalizations with DM involved individuals in the lowest household income quartile (35.2% vs. 30.5%), while the highest income quartile had the lowest representation (15.1% vs. 19.0%). Medicare was the most common primary payer in both groups and was more frequently represented among hospitalizations with DM (60.9% vs. 49.1%). Other insurance categories were less frequently represented among hospitalizations with DM.

Table 1. Demographic and Clinical Characteristics of COVID-19 Hospitalizations, Stratified by Diabetes Mellitus Status.

Variable	COVID-19 Infection Without DM (n = 3,778,587)	COVID-19 Infection with DM (n = 2,155,978)	p-Value
Age, mean (years)	60.8	66.0	<0.001
Sex			<0.001
Male	49.1%	53.7%	
Female	50.9%	46.3%	
Race			<0.001
White	63.0%	54.5%	
Black	15.1%	19.5%	
Hispanic	15.1%	18.1%	
Asian/Pacific Islander	2.6%	3.4%	
Native American	0.7%	1.0%	
Other	3.4%	3.4%	
National Income Quartile			<0.001

Table 1. Cont.

Variable	COVID-19 Infection Without DM (n = 3,778,587)	COVID-19 Infection with DM (n = 2,155,978)	p-Value
\$1–\$38,999	30.5%	35.2%	<0.001
\$39,000–\$47,999	26.6%	27.3%	
\$48,000–\$62,999	23.9%	22.4%	
>\$63,000	19.0%	15.1%	
Insurance			
Medicare	49.1%	60.9%	<0.001
Medicaid	17.1%	13.6%	
Private	29.6%	22.5%	
Uninsured	4.1%	3.0%	
Modified Charlson Comorbidity Index			<0.001
0	44.6%	36.6%	
1	22.7%	16.2%	
2	13.6%	16.9%	
≥3	19.1%	30.3%	
Hospital Region			<0.001
Northeast	18.5%	17.1%	
Mid-West	21.2%	21.1%	
South	41.3%	42.5%	
West	19.0%	19.3%	0.043
Hospital Location & Teaching Status			
Rural	10.6%	10.7%	
Urban, Non-Teaching	18.8%	19.1%	
Urban, Teaching	70.6%	70.2%	0.01
Hospital Bed Size			
Small	25.5%	25.0%	
Medium	29.1%	29.4%	
Large	45.4%	45.6%	<0.001
Hospital Division			
New England	4.2%	3.6%	
Middle Atlantic	14.4%	13.6%	
East North Central	14.8%	15.3%	
West North Central	6.4%	5.8%	
South Atlantic	21.9%	22.0%	
East South Central	6.6%	6.8%	
West South Central	12.8%	13.7%	
Mountain	6.9%	6.2%	
Pacific	12.0%	13.0%	

NIS = National Inpatient Sample; DM = Diabetes Mellitus; COVID-19 = Coronavirus Disease 2019.

A modified Charlson Comorbidity Index (CCI) of 0 was the most common category in both groups (36.6% vs. 44.6%), whereas a modified CCI ≥ 3 was more frequently observed among hospitalizations with DM than among those without DM (30.3% vs. 19.1%). Most hospitalizations occurred in the Southern region in both groups (42.5% vs. 41.3%), with the South Atlantic division accounting for the largest proportion. Most hospitalizations in both groups occurred at urban teaching hospitals (70.2% vs. 70.6%) and large hospitals (45.6% vs. 45.4%).

3.1. Clinical Outcomes and Resource Utilization

Compared with COVID-19 hospitalizations without DM, hospitalizations with concomitant DM had worse unadjusted clinical outcomes across most measured parameters ($p < 0.001$; Figures 2–4). After multivariable adjustment for potential confounding variables, including the modified Charlson comorbidity index, DM was associated with increased odds of in-hospital mortality and several major clinical complications and critical care interventions (Figure 5).

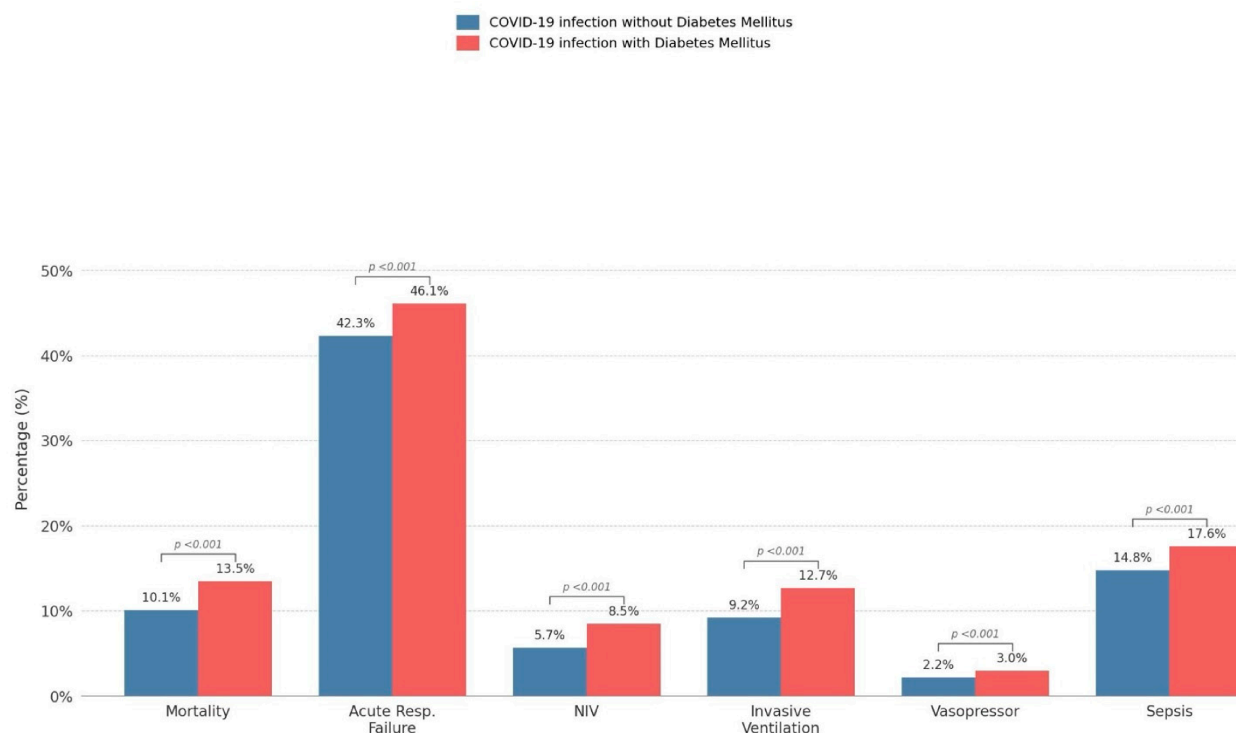


Figure 2. Clinical outcomes comparing mortality, acute respiratory failure, non-invasive ventilation, invasive ventilation, vasopressor use, and sepsis in COVID-19 hospitalizations with and without diabetes mellitus.

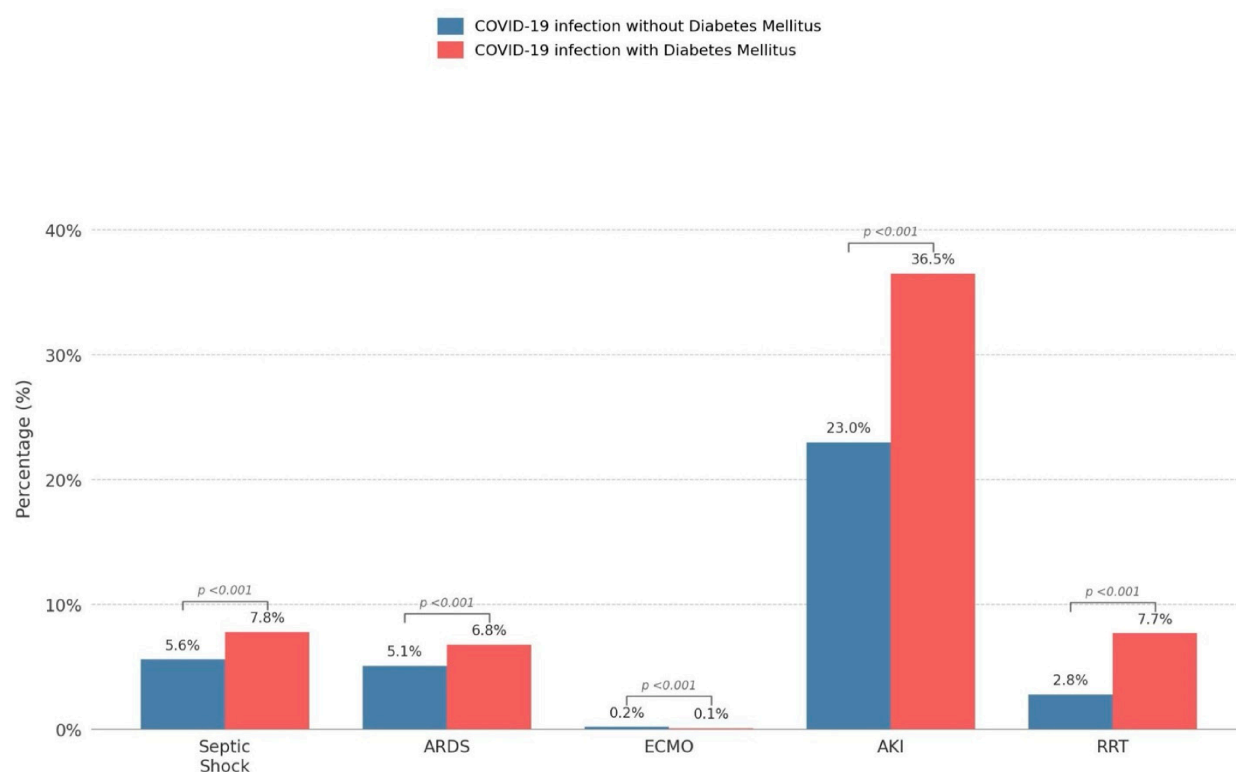


Figure 3. Clinical outcomes comparing septic shock, acute respiratory distress syndrome, extracorporeal membrane oxygenation, acute kidney injury, and renal replacement therapy in COVID-19 hospitalizations with and without diabetes mellitus.

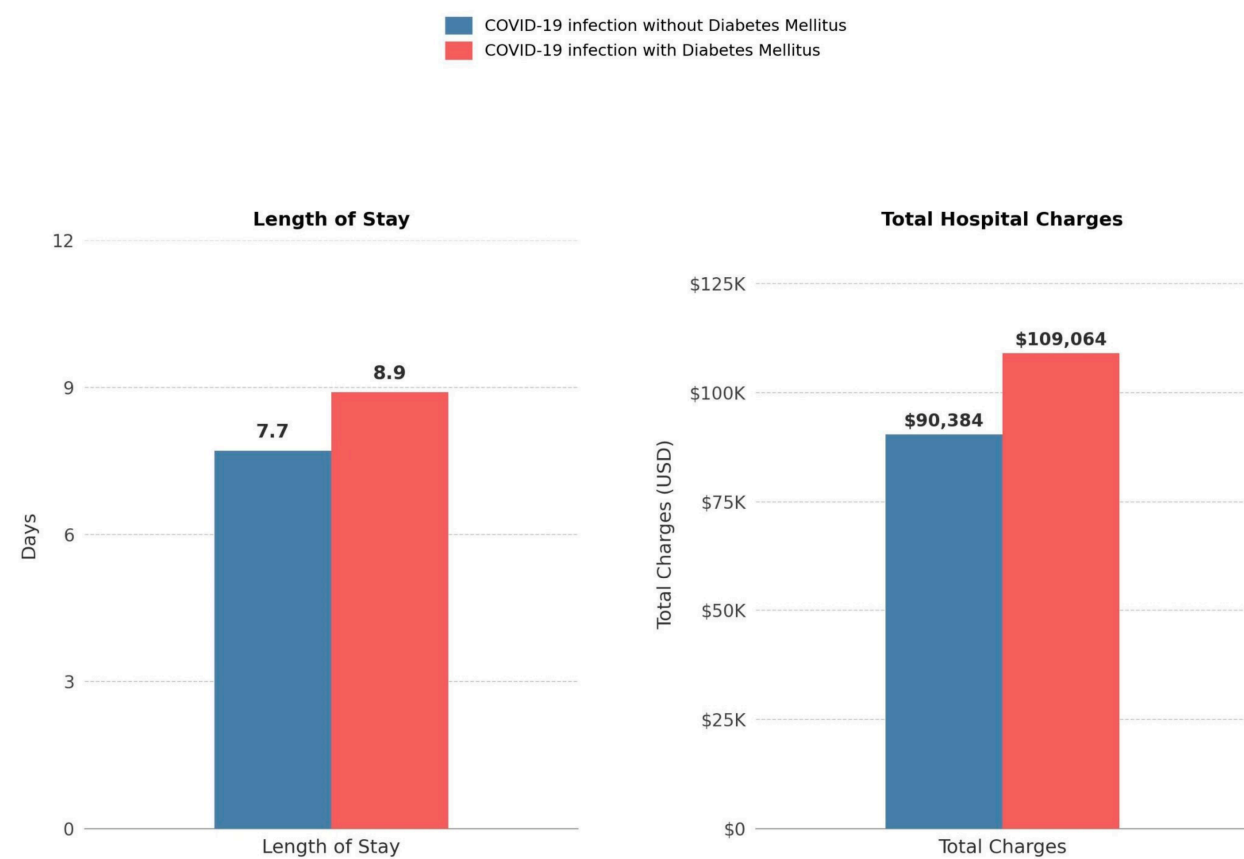


Figure 4. Unadjusted mean hospital length of stay and total hospital charges among COVID-19 hospitalizations with and without diabetes mellitus.

AKI occurred in 36.5% of COVID-19 hospitalizations with DM compared with 23.0% of hospitalizations without DM and was significantly associated with DM after adjustment (aOR 1.60; 95% CI, 1.59–1.62; $p < 0.001$). RRT was required more frequently among COVID-19 hospitalizations with DM than among those without DM (7.7% vs. 2.8%), with more than twofold higher adjusted odds (aOR 2.53; 95% CI, 2.47–2.59; $p < 0.001$).

Acute respiratory failure occurred more frequently among COVID-19 hospitalizations with DM than among those without DM (46.1% vs. 42.3%), and DM remained independently associated with acute respiratory failure after adjustment (aOR 1.12; 95% CI, 1.11–1.13; $p < 0.001$). COVID-19 hospitalizations with DM also had greater use of both non-invasive ventilation (8.5% vs. 5.7%; aOR 1.42; 95% CI, 1.40–1.45; $p < 0.001$) and invasive mechanical ventilation (12.7% vs. 9.2%; aOR 1.35; 95% CI, 1.33–1.37; $p < 0.001$). Similarly, ARDS occurred more frequently in the DM group (6.8% vs. 5.1%) and remained independently associated with DM (aOR 1.34; 95% CI, 1.32–1.37; $p < 0.001$). Sepsis was more frequent among COVID-19 hospitalizations with DM (17.6% vs. 14.8%) and was independently associated with DM (aOR 1.14; 95% CI, 1.13–1.16; $p < 0.001$). Septic shock was also more common in the DM group (7.8% vs. 5.6%; aOR 1.24; 95% CI, 1.22–1.26; $p < 0.001$), as was vasopressor use (3.0% vs. 2.2%; aOR 1.26; 95% CI, 1.22–1.30; $p < 0.001$). ECMO utilization remained low in both groups (0.1% vs. 0.2%) and was not significantly associated with DM after adjustment (aOR 0.92; 95% CI, 0.81–1.04; $p = 0.16$).

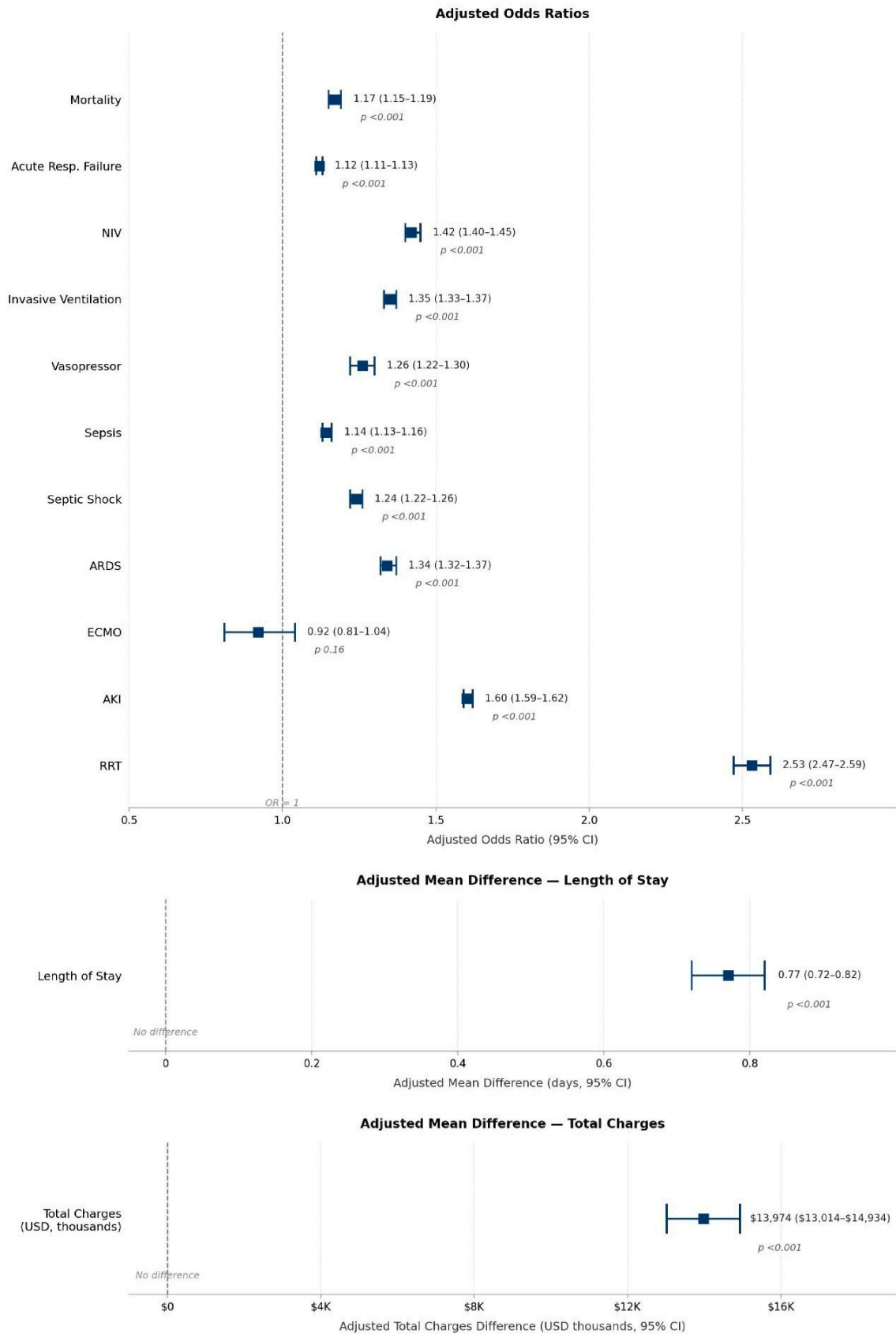


Figure 5. Forest plot depicting adjusted odds ratios for clinical outcomes and adjusted mean differences in hospital length of stay and total hospital charges among COVID-19 hospitalizations with diabetes mellitus.

All-cause in-hospital mortality was higher among COVID-19 hospitalizations with DM than among those without DM (13.5% vs. 10.1%). Multivariable analysis using the modified Charlson comorbidity index demonstrated that DM was independently associated with increased in-hospital mortality, with 17% higher adjusted odds of death (aOR 1.17; 95% CI, 1.15–1.19; $p < 0.001$). In the sensitivity analysis using the conventional CCI, which includes diabetes, the adjusted association between DM and in-hospital mortality was aOR 0.93 (95% CI, 0.92–0.95; $p < 0.001$), compared with aOR 1.17 (95% CI, 1.15–1.19; $p < 0.001$) in the primary model using the modified CCI excluding diabetes. Thus, inclusion of the diabetes component in the conventional CCI materially altered both the magnitude and direction of the estimated association. The length of hospital stay was slightly longer among COVID-19 hospitalizations with DM than among those without DM (8.9 vs. 7.7 days; aMD, 0.77 days; 95% CI, 0.72–0.82; $p < 0.001$). Although statistically significant, the magnitude of this adjusted difference was small. Total hospital charges were also higher among COVID-19 hospitalizations with DM (\$109,064 vs. \$90,384; aMD, \$13,974; 95% CI, \$13,014–\$14,934; $p < 0.001$). In sensitivity analyses using log-transformed outcomes, the findings remained consistent, with DM associated with an estimated 11.6% longer hospital stay (95% CI, 11.2–12.1%; $p < 0.001$) and 17.4% higher total hospital charges (95% CI, 16.8–18.0%; $p < 0.001$).

3.2. Temporal Patterns Among COVID-19 Hospitalizations with DM

An observed temporal pattern of lower in-hospital mortality was noted among COVID-19 hospitalizations with DM from 2020 to 2022. Among COVID-19 hospitalizations with DM within each respective year, in-hospital mortality was 15.8% in 2020, 15.7% in 2021, and 8.4% in 2022 (Figure 6).

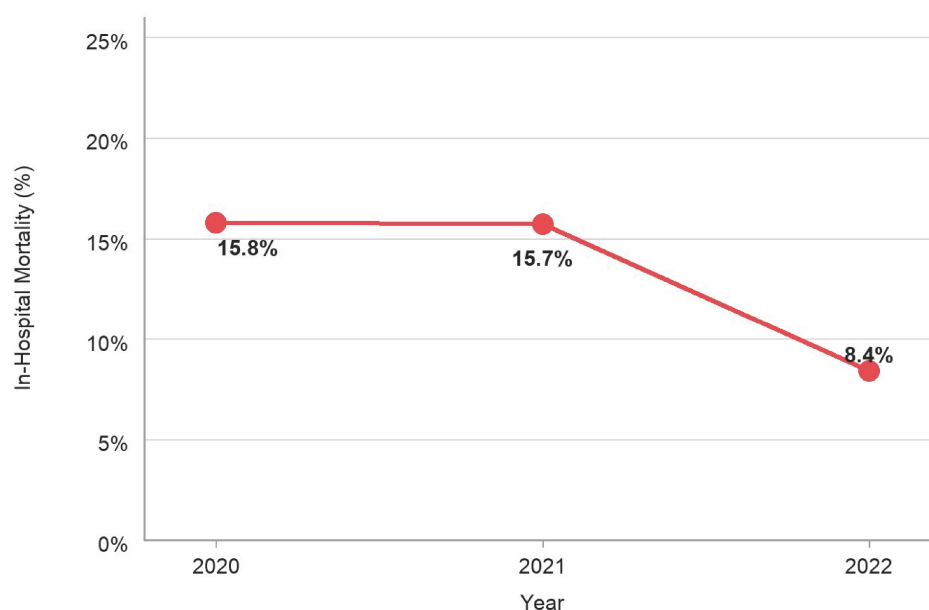


Figure 6. Observed annual in-hospital mortality among COVID-19 hospitalizations with diabetes mellitus, 2020–2022.

The proportional distribution of COVID-19 hospitalizations across the study years was also examined. Among COVID-19 hospitalizations without DM during the 2020–2022 study period, 26.4% occurred in 2020, 40.9% in 2021, and 32.7% in 2022. Among COVID-19 hospitalizations with DM, 30.7% occurred in 2020, 39.0% in 2021, and 30.3% in 2022 (Figure 7).

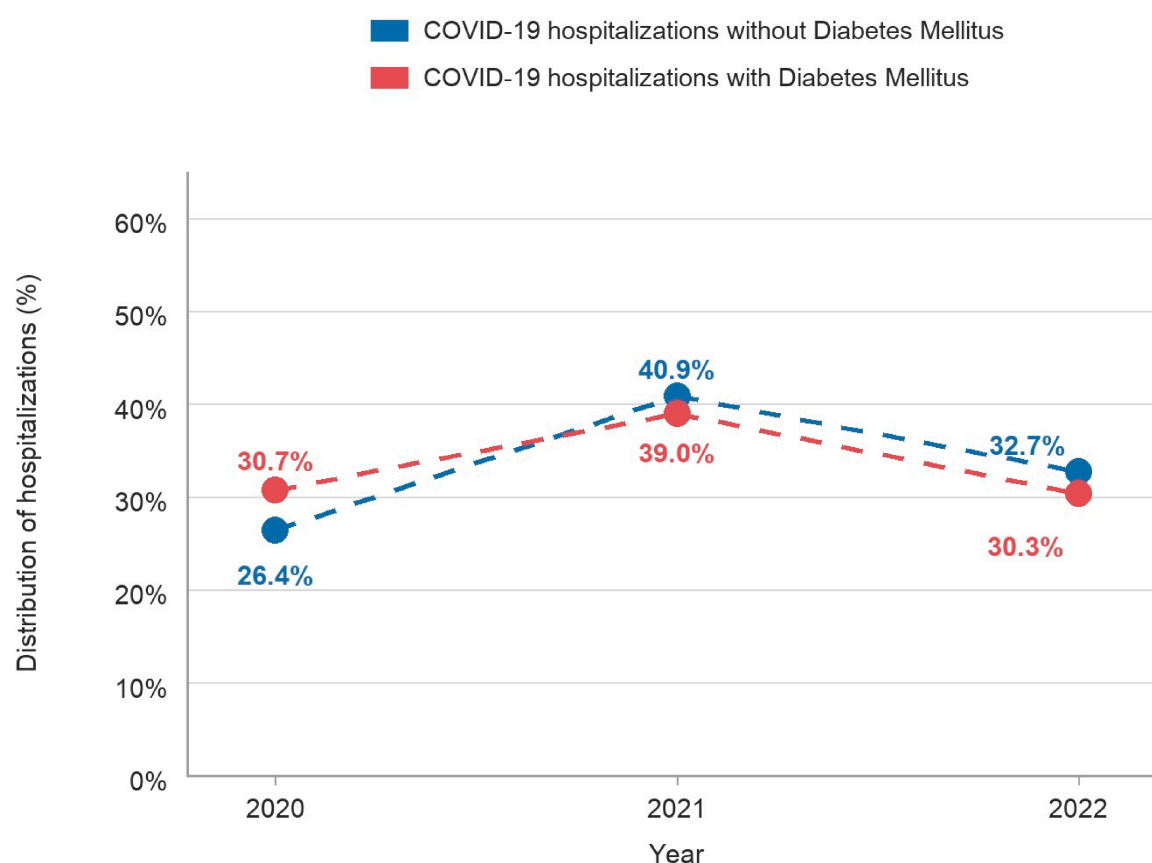


Figure 7. Distribution of COVID-19 hospitalizations with and without diabetes mellitus from 2020 to 2022.

4. Discussion

In this national study of adult COVID-19 hospitalizations in the United States between 2020 and 2022, diabetes mellitus was common and was associated with a more complicated hospital course. Of 5,934,565 adult COVID-19 hospitalizations, 2,155,978 had diabetes mellitus, accounting for more than one-third of the study population. COVID-19 hospitalizations with diabetes were more likely to involve older age, male sex, and a greater burden of comorbid illness, and they were more frequently represented among racial and socioeconomic groups that were heavily affected during the pandemic. These differences are important because age and comorbidity burden may contribute to the observed relationship between DM and COVID-19 outcomes and were therefore accounted for in the multivariable analyses.

On unadjusted analysis, COVID-19 hospitalizations with diabetes had worse outcomes than those without diabetes. Mortality was higher in the diabetes group, at 13.5% compared with 10.1% in hospitalizations without diabetes. COVID-19 hospitalizations with diabetes also had higher rates of non-invasive ventilation, invasive mechanical ventilation, vasopressor use, septic shock, acute respiratory distress syndrome, acute kidney injury, renal replacement therapy, and longer length of stay. After adjusting for demographic characteristics, income, insurance status, hospital factors, and comorbidities, diabetes remained independently associated with higher in-hospital mortality. The adjusted odds ratio for mortality was 1.17, with a 95% confidence interval of 1.15–1.19. The difference between the crude and adjusted mortality estimates suggests that measured demographic, socioeconomic, comorbidity, and hospital-level characteristics contributed to the observed association between DM and mortality. After adjustment for these factors, including the modified CCI excluding the diabetes-related component, DM remained associated with higher odds of in-hospital mortality. Notably, the mortality association was sensitive to

the method used to account for comorbidity burden. In the sensitivity model using the conventional CCI, which includes diabetes, the association changed from an aOR of 1.17 to 0.93. This finding highlights the potential for overadjustment when an exposure of interest is itself incorporated into a composite comorbidity index and supports our use of the modified CCI excluding diabetes in the primary analysis. This finding is consistent with prior studies reporting diabetes as an independent predictor of death in patients with COVID-19 [7,12–20]. Several factors may provide context for the observed findings. Our study includes hospitalizations through 2022 and therefore captures later phases of the pandemic. The observed lower mortality in 2022 occurred during a period of substantial changes in the COVID-19 pandemic, including advances in clinical management, increasing vaccination uptake and population immunity, and changes in circulating SARS-CoV-2 variants [3,21–24]. These factors may provide context for the observed temporal pattern; however, treatment, vaccination status, prior infection or immunity, and viral variant data were not available in the NIS, and the factors underlying the year-to-year differences cannot be determined from the present analysis. Diabetes frequently coexists with other major risk factors, including chronic kidney disease, obesity, cardiovascular disease, hypertension, and older age. After adjustment for the measured demographic, comorbidity, socioeconomic, and hospital-level characteristics, DM remained independently associated with higher odds of in-hospital mortality.

In addition to higher adjusted mortality, diabetes remained strongly associated with several important complications. COVID-19 hospitalizations with diabetes had higher adjusted odds of needing non-invasive ventilation and invasive mechanical ventilation. They also had higher adjusted odds of acute respiratory distress syndrome. These findings suggest that diabetes was associated with greater pulmonary disease severity among COVID-19 hospitalizations. Several biologically plausible mechanisms described in prior studies may help contextualize the observed associations between DM and adverse outcomes in COVID-19. Chronic hyperglycemia is known to impair immune function and is associated with endothelial dysfunction, inflammation, and a prothrombotic state [7,12,16]. These abnormalities may worsen the inflammatory lung injury and vascular damage seen in severe COVID-19. In addition, many patients with diabetes have obesity, cardiovascular disease, or reduced physiologic reserve, which may make respiratory decompensation more likely during acute infection [12,17,18]. These potential biological pathways, however, could not be directly evaluated using the available NIS data.

Kidney-related complications were also more frequent among COVID-19 hospitalizations with diabetes. Diabetes was associated with higher adjusted odds of acute kidney injury and renal replacement therapy. This finding is clinically expected, as diabetes is one of the leading causes of chronic kidney disease and may leave patients more vulnerable to kidney injury during acute illness. In COVID-19 infection, this risk may be further increased by hypoxemia, systemic inflammation, hemodynamic instability, sepsis, nephrotoxic medications, and critical illness [25,26].

COVID-19 hospitalizations with diabetes also had higher adjusted odds of sepsis, septic shock, and vasopressor use, although the magnitude of these associations was modest. Similarly, although DM was associated with a statistically significant adjusted increase in hospital length of stay of 0.77 days, the absolute difference was relatively small.

An observed temporal pattern of lower in-hospital mortality was noted among COVID-19 hospitalizations with DM, with mortality of 15.8% in 2020, 15.7% in 2021, and 8.4% in 2022. The lower mortality observed in 2022 occurred during a period of substantial changes in the pandemic, including advances in clinical management, increasing vaccination uptake and population immunity, and changes in circulating SARS-CoV-2 variants [3,22,23]. These factors may provide context for the observed pattern; however,

treatment, vaccination status, prior infection or immunity, and viral variant data were not available in the NIS, and the factors underlying the year-to-year differences cannot be determined from the present analysis. COVID-19 hospitalizations with diabetes continued to have high rates of complications and resource use despite the lower observed mortality in 2022.

This study adds to the current literature in several ways. Prior studies have included single-center cohorts, regional data, or early pandemic time periods [7,12–18]. In contrast, our study used a large national inpatient database and included three years of hospitalizations, allowing us to examine outcomes across different phases of the pandemic [11]. This broader timeframe is important because COVID-19 care changed significantly between 2020 and 2022. Our findings suggest that diabetes remained independently associated with higher in-hospital mortality and may also be understood as a marker of complicated hospitalization and organ-support needs.

From a clinical standpoint, our findings demonstrate that DM remains associated with adverse outcomes among COVID-19 hospitalizations. DM was independently associated with higher in-hospital mortality and higher odds of respiratory failure, ARDS, AKI, RRT, sepsis, and septic shock, as well as longer hospital stays and higher total hospital charges. These findings highlight the greater hospital resource utilization associated with DM among individuals hospitalized with COVID-19 and support further investigation into factors that may improve outcomes in this population.

Limitations

This study has several limitations. First, the NIS is an administrative database and depends on ICD-10-CM diagnosis and procedure codes. Because of this, coding errors, undercoding, or misclassification of COVID-19 infection, diabetes mellitus, comorbidities and clinical outcomes may have occurred [11]. Second, the NIS database does not contain laboratory or clinical data, including blood glucose levels, HbA1c, BMI, oxygen requirements, diabetes duration, type and severity and medication use. Consequently, these potentially important clinical factors could not be incorporated into the multivariable analyses, and residual confounding related to unmeasured differences in metabolic control, disease severity, and treatment cannot be excluded.

Third, the NIS provides hospitalization-level data rather than patient-level longitudinal data. As a result, repeat admissions by the same patient cannot be identified. The database also does not capture post-discharge outcomes, including 30-day mortality, readmission, long COVID symptoms, persistent kidney dysfunction, or functional recovery [11]. Therefore, our findings are limited to outcomes occurring during hospitalization and should not be interpreted as longitudinal patient-level outcomes. Fourth, important COVID-19-specific variables are not available, including vaccination status, prior infection, SARS-CoV-2 variant type, antiviral use, corticosteroid exposure, monoclonal antibody treatment, and timing of therapy. Because these factors changed substantially during the 2020–2022 study period, their absence limits interpretation of the observed year-to-year differences in mortality. Fifth, although type 1, type 2, and other specified forms of diabetes were included to comprehensively capture the diabetes population, these subtypes have distinct clinical characteristics and risk profiles and were not analyzed separately. Future studies evaluating outcomes according to individual diabetes subtypes may provide additional insights.

Finally, because this was a retrospective observational study, causality cannot be established. The associations seen in this study should be interpreted as relationships between diabetes status and hospital outcomes, not as proof that diabetes directly caused these complications.

5. Conclusions

In this United States National Inpatient Sample analysis of adult COVID-19 hospitalizations from 2020 to 2022, DM was associated with higher odds of in-hospital mortality, acute respiratory distress syndrome, vasopressor use, sepsis, septic shock, acute kidney injury, and renal replacement therapy, as well as greater use of respiratory support and hospital resource utilization. In-hospital mortality among COVID-19 hospitalizations with DM was lower in 2022 than in 2020 and 2021; however, the factors underlying this temporal pattern cannot be determined from the present NIS analysis.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/diabetology7090184/s1>. Table S1: ICD-10-CM diagnosis and ICD-10-PCS procedure codes used to define the study population and clinical outcomes.

Author Contributions: Conceptualization, A.A.; methodology, A.A. and P.D.; validation, A.A., D.D. and V.S.V.; formal analysis, A.A. and D.K.; data curation, A.A., P.D. and J.M.; writing—original draft preparation, A.A., D.K., V.S.V., P.D., D.D., M.K. and J.M.; writing—review and editing, A.A., D.K., V.S.V., P.D., D.D., M.K. and J.M.; visualization, A.A., D.K., V.S.V., P.D., D.D., M.K. and J.M.; supervision, A.A., D.D. and P.D.; project administration, A.A., D.K. and P.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: All data were obtained through a request to the Online Healthcare Cost and Utilization Project (HCUP) Central Distributor, which administers the database (certificate HCUP-28M71GVP5). We followed all AHRQ guidelines (<https://hcup-us.ahrq.gov/db/publishing.jsp>, accessed on 15 March 2026) and were exempt from IRB review as the National Inpatient Sample is a publicly available, deidentified dataset.

Informed Consent Statement: Patient consent was waived due to the study analyzing secondary data from the NIS database; patients and the public were not involved directly. And all data in the NIS database are de-identified.

Data Availability Statement: The datasets analyzed during the current study are available from the Healthcare Cost and Utilization Project (HCUP) National Inpatient Sample (NIS) database and can be obtained as requested.

Conflicts of Interest: The authors declare no conflicts of interest.

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