Trends and Demographic Disparities in Diabetes Hospital Admissions: Analyses of Serial Cross-Sectional National and State Data, 2008–2017

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EPIDEMIOLOGY/HEALTH SERVICES RESEARCH

OBJECTIVE

To analyze national and state-specific trends in diabetes-related hospital admissions and determine whether disparities in rates of admission exist between demographic groups and geographically dispersed states.

RESEARCH DESIGN AND METHODS

We conducted serial cross-sectional analyses of the National Inpatient Sample (2008, 2011, 2014, and 2016) and State Inpatient Databases for Arizona, Florida, Kentucky, Iowa, Maryland, Nebraska, New Jersey, New York, North Carolina, Utah, and Vermont for 2008, 2011, 2014, and 2016/2017 among adult patients with type 1 and type 2 diabetes–related ICD codes (ICD-9 [250.XX] or ICD-10 [E10.XXX, E11.XXX, and E13.XXX]. We measured hospitalization rates for people with diabetes (all-cause hospitalizations) and for admissions with a primary diagnosis of diabetes or diabetes-related complications (diabetes-specific hospitalizations) per 10,000 people per year.

RESULTS

Nationally, all-cause and diabetes-specific hospitalizations declined by 3.1% (95% CI −5.5, −0.7) and 19.1% (95% CI −21.6, −16.6), respectively, over 2008 to 2016. The analysis of individual states showed that diabetes-specific admissions in individuals ≥65 years old declined during this time (16.3–48.8% decrease) but increased among patients 18–29 years old (10.5–81.5% increase) and that rural diabetes-specific admissions decreased in just over half of the included states (15.2–69.2% decrease). There were no differences in changes in admission rates among different racial/ethnic groups.

CONCLUSIONS

Overall, rates of diabetes-related hospitalizations decreased over 2008 to 2016/2017, but there were large state-level differences across subgroups of patients. The rise in diabetes hospitalizations among young adults is a cause for concern. These state- and subpopulation-level differences highlight the need for state-level policies and interventions to address disparities in diabetes health care use.

An estimated 34.2 million individuals in the U.S. have diabetes (1). Between 2012 and 2017, the total inflation-adjusted costs of diabetes increased from $261 billion

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to $327 billion (2). Moreover, in 2017, 24.8% of inpatient days nationally were among individuals with diabetes, and 13.9% of total inpatient days could be attributed to diabetes (2). As health care expenditures nationally continue to increase (3), understanding and reducing diabetes-related admissions is an area of focus for health care professionals, payers, and policy makers.

Although data on national trends in diabetes-related inpatient hospitalizations are useful, they may not reveal differences in rates of diabetes-related care across subpopulations. Previous work has shown that racial and ethnic minorities are more likely to have diabetes and that their diabetes is more likely to be uncontrolled (4,5). Additionally, among Medicare beneficiaries with diabetes, Hispanic patients experience higher rates of hospital admissions for diabetes compared with non-Hispanic White patients (6).

Examinations of disparities in diabetes-related hospitalizations by age, sex, and rural/urban status have been more limited. Diabetes is highly prevalent in older adults, with 2012 estimates placing the prevalence of diabetes between 22 and 33% among adults >65 years old (7). Older adults are more likely to experience complications from diabetes, may be more prone to hypoglycemia, and have more hospitalizations overall (7); however, recent investigations into the impact of age on the rate of diabetes-specific hospitalizations have not been performed. Similarly, while biological sex has a well-described effect on diabetes incidence and complications (8), few studies have focused on disparities in the need for hospitalizations for diabetes by sex. One study, published in 2010, found that diabetes-associated hospitalizations were increasing among younger women and older men (9). Regarding urban/rural disparities, a study describing emergency department–initiated diabetes-related hospitalizations between 2009 and 2014 found that residents of nonmetropolitan areas were 10% more likely to have a hospitalization for diabetes than were residents of metropolitan areas (10). When these demographic and geographic risk factors for hospitalization for diabetes overlap, the rates of hospitalization may increase even further.

The prevalence of diabetes also varies greatly from state to state. In 2016, Alabama had the highest prevalence of adults with diabetes (13.2%) and Colorado the lowest (6.2%) (11). This variability across the country highlights the need for state-level analyses of diabetes-related hospital admissions. We analyzed both national and state-specific trends in diabetes-related hospital admissions to explore whether subnational trends differ and examine if there were disparities in rates of hospital admissions for diabetes and among patients with diabetes between demographic groups.

RESEARCH DESIGN AND METHODS

Data Sources

We pooled annual cross-sectional administrative hospital data from the Agency for Healthcare Research and Quality's (AHRQ) Healthcare Cost and Utilization Project (HCUP) (12). To determine the count of diabetes-related inpatient stays both nationally and within states, we used the National Inpatient Sample (NIS) and the State Inpatient Databases (SID), respectively.

The NIS approximates a 20% stratified sample of discharges from participating hospitals and are weighted to provide nationally representative estimates; it is the largest all-payer inpatient discharge record database for the U.S. (13). Until 2011, the NIS was constructed annually by including 100% of the discharges from 20% of U.S. hospitals. Starting in 2012, AHRQ redesigned the NIS as a 20% national patient-level sample. We used trend weights provided by HCUP, which facilitate trend analysis and maintain comparability of rates generated from data sets prior to and post–sampling change. We used the NIS from 2008, 2011, 2014, and 2016. Data for the NIS were available only through 2016 at the time of the analysis.

The SID are state-level records that capture all inpatient care provided in nonfederal hospitals within an individual state (14). Like the NIS, the unit of observation is a discharge, not an individual. We analyzed SID data for 11 states: Arizona, Utah, Nebraska, Iowa, Kentucky, North Carolina, Maryland, New York, New Jersey, Vermont, and Florida. These states were chosen as they provide geographic and demographic variation as well as varying diabetes prevalence (11) to reflect between-state differences in diabetes-related hospital admissions; practically, they also had complete data available across key variables of interest. We used SID data from 2008, 2011, 2014, and 2016/2017 (based on data availability at the time of analysis). Data for New York and Vermont were available through 2016; the remaining data are reported through 2017.

We used data from the American Community Survey (ACS) to estimate population denominators for demographic and insurance subgroups for state and national populations for our rate calculations (15). The ACS is an annual survey conducted by the U.S. Census Bureau, which samples an average of 2.15 million households each year and includes information about participants' demographic characteristics and is designed to generate national and state-level estimates (15,16). Denominator estimates generated using the ACS data were survey weighted using the Survey and Tidyr packages in R (17,18).

Study Population: Identifying Diabetes-Related Inpatient Stays

We selected NIS and SID discharge records (Supplementary Appendix 1) for adult patients with the presence of ICD codes indicative of diabetes (ICD-9 [250.XX] or ICD-10 [E10.XXX, E11.XXX, and E13.XXX]) (19). We did not include cases of gestational or secondary diabetes; both type 1 and type 2 diabetes were included. We did not differentiate patients with type 1 versus type 2 diabetes because it was not a main focus of this analysis, and it is challenging to differentiate type 1 and type 2 diabetes in administrative data sets. We only examined discharge records for adult patients because rates of hospitalizations for children <18 years old with diabetes are low (20), in part due to the many years it takes to develop micro- and macrovascular complications of diabetes.

Outcomes: Inpatient Utilization by Individuals With Diabetes

We distinguished inpatient stays by individuals with diabetes for any reason ("all-cause diabetes inpatient stays") from inpatient stays by individuals with diabetes for diabetes-specific complications ("diabetes-specific inpatient stays"). The "all-cause diabetes" criterion captures patients that may have an inpatient stay for nondiabetes-related reasons but were coded with a diabetes diagnosis on their discharge record. "Diabetes-specific inpatient stays" were defined by presence of a diabetes-specific condition (short-term diabetes complications [e.g., ketoacidosis and hyperosmolarity], long-term diabetes complications [e.g., renal and eye complications], uncontrolled diabetes, limb ulcers/inflammation, and lower-extremity amputations). Definitions of diabetes-specific conditions were derived from AHRQ's list of ambulatory care–sensitive conditions (21,22); these complications are those identified by AHRQ as preventable with high-quality primary care. The complete code list is included in Supplementary Appendix 2.

Demographic and Insurance Status Subgroups

Subgroup-specific numerators were stratified by age (18–29, 30–44, 45–64, 65–74, and ≥75 years), sex, race/ethnicity (White non-Hispanic, Black non-Hispanic, or Hispanic), rural/urban, and insurance (Medicaid, Medicare, private, and uninsured). National estimates were also stratified by region (Midwest, Northeast, South, and West) but not by race/ethnicity because of high missingness of the race variable in the NIS and no existing method to impute missing race variables in the NIS. We excluded race from certain state-level analyses due to inconsistent coding (2008 for Florida, Arizona, Iowa, and North Carolina; 2011 for Arizona), counts of events/population ≤10 or relative SE ≥30% (Vermont, all years), or not provided (Nebraska, all years) (23). Rural/urban stratification in New Jersey was not reported, as denominator population estimates were ≤10 for all years.

We selected complete records for all analytic variables with <1% missing for both the national and state data sets. Individual SID year data sets with missingness >1% for any of the analytic variables were imputed using the Mice package in R, while individual NIS year data sets were imputed via hot-deck imputation using the VIM package in R (24–26). Full description of missing data methods is provided in Supplementary Appendix 1.

This study was reviewed and deemed exempt by the Emory University Institutional Review Board.

Statistical Methodology: Calculating National and State-Specific Rates

Numerators, Denominators, and Measures of Uncertainty

The numerator counts of inpatient stays calculated using NIS data were survey-weighted to adjust for complex survey design. We calculated SEs and variance for survey-weighted estimates using Taylor series linearization methodology provided in the Survey package for R (27).

Counts of diabetes-related inpatient stays generated using SID data were aggregated by state, as the SID data sets represent a complete census of inpatient stays in each state. We assumed a Poisson distribution for purpose of count variance estimation, as the parameter of interest was counts of diabetes-related inpatient stays (28).

The denominator population figures calculated using the ACS data were weighted using survey weights provided by the data source. Population estimates were aggregated both nationally and by state and represent the total U.S. adult population. This methodology has been applied elsewhere in the literature (29).

HCUP provides race/ethnicity data, with ethnicity taking precedence over race. To align this subgroup, we created a variable defining race/ethnicity as Hispanic, White non-Hispanic, and Black non-Hispanic within the ACS. HCUP provides primary payer data as well, while the ACS provides all available insurance information. As such, we created a variable in the ACS to capture likely primary payer among the U.S. population using the *Who Pays First?* Medicare User Guide (30). HCUP provides a continuum of rural/urban codes, which we defined as urban (metropolitan population ≥50,000) and rural (nonmetropolitan or micropolitan population ≤50,000). We used rural–urban continuum codes published by the U.S. Department of Agriculture Economic Research Service to categorize Public Use Microdata Area in the ACS by metropolitan status to align with the numerator variable (31). More information on aligning ACS data to calculate population denominators and rate calculations is provided in Supplementary Appendix 3.

Rate Calculation and Standardization

We calculated national- and state-level hospitalization rates per 10,000 people per year, using corresponding estimates from the ACS. We accounted for varying age distributions across states and years by using the direct method to age-standardize rates for race/ethnicity, rural/urban, and region to the 2010 U.S. adult population. Standardized rates should be interpreted as rates that would be observed if the populations had the age distribution of the national U.S. adult population in 2010.

Role of the Funding Source

Merck Sharp & Dohme Corp., a subsidiary of Merck & Co., Inc., Kenilworth, NJ, provided funding for this study. The funder had no role in the design or conduct of the study, collection, management, analysis, and interpretation of the data. Colleagues from the funder reviewed prepared tables and provided input on the study protocol and the manuscript.

RESULTS

Over 2008 to 2016, national diabetes-specific hospitalization rates from the NIS declined by ∼20% (95% CI −21.6, −16.6) from its peak of 28.6 hospitalizations/10,000 adults (n = 683,968) in 2011 to 22.0 hospitalizations/10,000 adults (n = 537,394) in 2016, which was similar to the decline seen for all hospitalizations nationally (Table 1). During that same period, all-cause diabetes hospitalizations decreased by 3.1% (95% CI −5.5, −0.7).

Individuals in the oldest age categories (65–74 and ≥75 years of age) had the greatest decrease in diabetes-specific hospitalizations in the NIS analysis (37.0–43.1% decrease), while we observed an increase in hospitalizations among the youngest age group (18–29 years old) (18.5% increase [95% CI 11.7, 25.3]) (Table 2). Also notable was that, among all adults, both rural and urban-dwelling individuals experienced a significant decrease in diabetes-specific admissions, but the decline was more dramatic for patients living in rural areas (22.3% decrease [95% CI −26.2, −18.4]) than urban (18.5% decrease [95% CI −21.2, −15.8]) (Table 2). Uninsured adults were one of the few groups with a statistically significant increase in diabetes-specific hospitalizations (22.8% increase [95% CI 13.3, 32.3]), while all insured patients experienced a decline in the rate of their diabetes-specific admissions (Table 2). Among insured patients, privately insured patients had the smallest decline in diabetes-specific hospitalizations (24.6% decrease [95% CI −30.6,

Table 1—Age-adjusted rates of average annual all-cause and diabetes-specific hospitalizations (per 10,000 people) among U.S. adult population from 2008 to 2016

	2008			2011			2014			2016/2017*			Change over 2008–2017		
	n	Rate	95% CI	*n*	Rate	95% CI	*n*	Rate	95% CI	*n*	Rate	95% CI	Absolute Δ	Percent Δ	95% CI
Total[a]															
National[b]	38,210,889	1,384.2	1,351.6, 1,416.7	36,962,415	1,306.1	1,276, 1,336.2	29,751,964	1,180.8	1,169.5, 1,192.1	30,188,612	1,166.0	1,154.9, 1,177.1	−218.2	−15.8	−17.9, −13.7
11-state sample	8,919,474	1,410.2	1,409.3, 1,411.1	8,901,850	1,359.6	1,358.7, 1,360.5	8,528,558	1,245.0	1,244.2, 1,245.9	8,646,340	1,204.5	1,203.6, 1,205.3	−205.7	−14.6	−14.7, −14.5
All-cause diabetes[a]															
National	6,950,056	303.2	295.1, 311.3	7,630,759	316.0	307.9, 324.2	7,450,098	291.2	288.0, 294.4	7,792,188	293.9	290.7, 297.2	−9.3	−3.1	−5.5, −0.7
11-state sample**	1,995,474	313.5	313.1, 314.0	2,110,087	316.7	316.3, 317.1	2,117,837	299.7	299.3, 300.1	2,236,038	298.3	297.9, 298.7	−15.2	−4.9	−5.1, −4.7
Arizona	136,665	285.4	283.9, 286.9	151,928	303.3	301.7, 304.8	145,259	267.4	266.0, 268.8	149,504	254.6	253.2, 255.9	−30.8	−10.8	−11.4, −10.2
Florida	513,663	313.6	312.7, 314.4	571,610	329.4	328.5, 330.2	609,185	327.2	326.3, 328.0	609,185	327.2	326.3, 328.0	17.2	5.5	5.2, 5.8
Iowa	69,999	279.9	277.8, 282.0	66,921	259.8	257.8, 261.8	63,462	238.2	236.4, 240.1	71,197	261.4	259.4, 263.3	−18.5	−6.6	−7.5, −5.7
Kentucky	136,395	413.9	411.7, 416.1	148,910	432.4	430.2, 434.6	142,519	396.9	394.9, 399	152,995	410.4	408.3, 412.4	−3.5	−0.8	−1.4, −0.2
Maryland	164,183	391.1	389.2, 393.0	157,750	354.6	352.8, 356.3	143,475	303.5	302.0, 305.1	145,066	290.5	289.0, 292.0	−100.6	−25.7	−26.2, −25.2
North Carolina	199,595	293.0	291.7, 294.3	224,177	302.1	300.9, 303.4	253,460	317.8	316.6, 319.1	248,593	291.0	289.8, 292.1	−2.0	−0.7	−1.2, −0.2
Nebraska	32,037	233.7	231.1, 236.3	30,809	213.8	211.4, 216.2	26,476	178.2	176.0, 180.3	41,315	264.7	262.1, 267.2	31.0	13.3	12.0, 14.6
New York	486,693	318.8	317.9, 319.7	506,044	326.0	325.1, 326.9	484,811	299.3	298.5, 300.2	497,642	300.7	299.9, 301.6	−18.0	−5.7	−6, −5.4
New Jersey	220,830	323.8	322.5, 325.2	214,143	299.7	298.4, 300.9	209,071	280.6	279.4, 281.8	213,858	275.1	273.9, 276.3	−48.8	−15.1	−15.6, −14.6
Utah	25,853	167.2	165.1, 169.2	28,056	172.3	170.3, 174.4	30,430	171.8	169.9 173.8	39,942	206.4	204.4, 208.5	39.3	23.5	22.0, 25.0
Vermont	9,561	184.1	180.4, 187.8	9,739	178.0	174.4, 181.5	9,689	169.2	165.8, 172.6	9,901	167.7	164.4, 171.1	−16.3	−8.9	−11.2, −6.6
Diabetes-specific[a]															
National	622,329	27.2	26.4, 27.9	683,968	28.6	27.8, 29.3	680,190	27.3	27.0, 27.7	557,394	22.0	21.7, 22.2	−5.2	−19.1	−21.6, −16.6
11-state sample**	177,944	28.5	28.4, 28.6	191,013	29.5	29.3, 29.6	192,072	28.5	28.3, 28.6	166,219	23.7	23.7, 23.9	−4.8	−16.6	−17.1, −16.1
Arizona	12,109	25.6	25.1, 26.0	14,135	29.0	28.5, 29.4	13,625	26.4	26.0, 26.9	11,585	21.3	20.9, 21.7	−4.2	−16.6	−18.6, −14.6
Florida	42,424	27.9	27.6, 28.2	47,934	29.9	29.7, 30.2	52,293	31.2	30.9, 31.5	48,505	27.4	27.1, 27.6	−0.5	−1.8	−2.6, −1.0
Iowa	5,220	22.0	21.4, 22.6	5,208	21.5	21.0, 22.1	5,204	21.0	20.5, 21.6	4,584	18.6	18.0, 19.1	−3.4	−15.4	−18.5, −12.3
Kentucky	9,540	29.1	28.5, 29.7	11,131	32.8	32.2, 33.4	11,809	34.0	33.4, 34.6	10,619	30.3	29.7, 30.9	1.2	4.1	1.7, 6.5
Maryland	13,226	31.2	30.6, 31.7	13,584	30.3	29.8, 30.8	13,087	27.9	27.5, 28.4	10,536	21.8	21.4, 22.2	−9.4	−30.1	−32.0, −28.2
North Carolina	19,316	28.0	27.6, 28.4	21,933	29.7	29.3, 30.1	22,830	29.5	29.1, 29.9	21,413	26.4	26.1, 26.8	−1.6	−5.7	−7.4, −4.0
Nebraska	2,493	18.5	17.7, 19.2	2,660	18.9	18.2, 19.6	2,799	19.5	18.8, 20.2	2,696	18.3	17.6, 19.0	−0.2	−1.1	−6.1, 3.9
New York	48,640	32.1	31.8, 32.4	48,451	31.6	31.3, 31.8	44,458	28.0	27.8, 28.3	33,676	21.1	20.8, 21.3	−11.0	−34.3	−35.3, −33.3
New Jersey	21,020	31.1	30.7, 31.6	20,770	29.6	29.2, 30.1	20,409	28.2	27.9, 28.6	16,760	22.6	22.3, 23.0	−8.5	−27.4	−28.9, −25.9
Utah	2,313	13.8	13.2, 14.4	2,593	14.6	14.1, 15.2	2,693	14.0	13.5, 14.6	2,785	13.4	12.9, 13.9	−0.5	−3.3	−8.0, 1.4
Vermont	771	15.2	14.2, 16.3	779	14.9	13.9, 16.0	861	16.2	15.1, 17.3	618	11.7	10.8, 12.7	−3.5	−23.0	−30.9, −15.1

Rates show hospitalization rates by state calculated using numerator data from the HCUP Nationwide Inpatient Sample Databases and denominator data from the IPUMS USA ACS from 2008 to 2017. All rates are age-standardized to the 2010 U.S. adult population using population estimates available from the Centers for Disease Control and Prevention Mortality Database. [a]Total number of adult hospitalizations, N = 135,113,880; total number of all-cause diabetes hospitalizations, N = 29,823,101; and total number of diabetes-specific hospitalizations, N = 2,543,882. [b]Denominator for national estimates is the total U.S. adult population; 2008: N = 230,169,098; 2011: N = 237,741,224; 2014: N = 245,365,242; and 2016: N = 249,576,134. Individual state denominators available in Supplementary Appendices 5 and 6. *National rates reflect 2016 estimates, and state average rates reflect average of 2016 and 2017 rates. **Rates and counts from the total 11-state sample were calculated using complete-case analysis, while state-specific estimates were completed using multiple imputation.

Table 2—Age-adjusted rates of diabetes-related hospitalizations per 10,000 people in the U.S. from 2008 to 2016

Variable	2008 Rate	2008 95% CI	2011 Rate	2011 95% CI	2014 Rate	2014 95% CI	2016 Rate	2016 95% CI	Change over 2008–2016 Absolute Δ	Change over 2008–2016 Percent Δ	Change over 2008–2016 95% CI
All-cause diabetes hospitalizations[a]											
Age (years)											
18–29	27.8	26.0, 29.5	29.0	27.3, 30.8	28.9	28.1, 29.6	30.5	29.7, 31.3	2.7	9.7	3.9, 15.5
30–44	84.9	80.0, 89.7	90.1	85.0, 95.2	86.7	84.7, 88.7	87.8	85.8, 89.8	2.9	3.4	−1.8, 8.6
45–64	309.7	293.9, 325.5	327.8	311.6, 344	314.7	308.1, 321.2	323.9	317.2, 330.6	14.2	4.6	−0.1, 9.3
65–74	820.5	781.2, 859.8	817.1	778.4, 855.8	717.2	702.7, 731.6	711.6	697.4, 725.8	−108.9	−13.3	−17.6, −9.0
≥75	1,155.8	1,098.6, 1,213	1222.0	1,166.3, 1,277.7	1,094.5	1,072.1, 1,116.8	1,086.7	1,064.6, 1,108.7	−69.1	−6.0	−10.5, −1.5
Sex											
Female	292.3	284.7, 300.0	303.2	295.5, 310.9	274.8	271.8, 277.8	273.5	270.4, 276.5	−18.8	−6.4	−8.8, −4.0
Male	318.5	309.5, 327.5	333.1	324.2, 342.1	312.1	308.4, 315.7	319.2	315.5, 322.9	0.7	0.2	−2.4, 2.8
Rural/urban[b]											
Rural	321.6	308.1, 335.1	322.6	307.3, 337.8	287.3	279.8, 294.9	290.7	283.7, 297.7	−30.9	−9.6	−13.6, −5.6
Urban	299.5	290.0, 309.0	315.2	306.0, 324.4	292.4	288.9, 296.0	295.1	291.4, 298.7	−4.4	−1.5	−4.3, 1.3
Insurance											
Medicaid	558.6	514.1, 603.1	515.5	476.1, 554.9	470.2	454.3, 486.1	423.4	409.6, 437.1	−135.2	−24.2	−31.2, −17.2
Medicare	963.5	916.5, 1,010.5	1,018.3	973.2, 1,063.4	905.0	886.6, 923.3	896.0	877.9, 914.1	−67.5	−7.0	−11.4, −2.6
Private	119.9	113.0, 126.9	118.1	110.3, 125.9	102.0	99.1, 104.8	100.8	98.0, 103.5	−19.1	−15.9	−21.1, −10.7
Uninsured	71.7	63.7, 79.7	76.2	68.5, 84.0	78.3	74.0, 82.5	97.2	91.7, 102.6	25.5	35.6	24.2, 47.0
Diabetes-specific hospitalizations[a]											
Age (years)											
18–29	10.8	10.0, 11.5	12.1	11.5, 12.8	12.8	12.5, 13.2	12.8	12.4, 13.2	2.0	18.5	11.7, 25.3
30–44	16.1	15.1, 17.1	17.8	16.8, 18.8	17.8	17.3, 18.3	15.0	14.6, 15.4	−1.1	−6.8	−12.3, −1.3
45–64	31.2	29.6, 32.9	33.8	32.1, 35.5	33.7	33.0, 34.5	27.0	26.4, 27.6	−4.2	−13.5	−18.0, −9.0
65–74	51.4	48.9, 54.0	50.1	47.6, 52.6	43.8	42.7, 44.8	32.4	31.6, 33.2	−19.0	−37.0	−41.4, −32.6
≥75	63.3	59.9, 66.7	62.1	58.9, 65.2	51.5	50.2, 52.8	36.0	35.1, 37.0	−27.3	−43.1	−47.7, −38.5
Sex											
Female	24.2	23.5, 24.9	24.8	24.2, 25.5	23	22.7, 23.3	17.7	17.4, 17.9	−6.5	−26.9	−29.1, −24.7
Male	30.6	29.7, 31.5	32.8	31.9, 33.7	32.2	31.7, 32.6	26.7	26.3, 27.1	−3.9	−12.7	−15.1, −10.3
Rural/urban[b]											
Rural	28.3	27.1, 29.4	28.9	27.5, 30.3	26.6	25.9, 27.3	22.0	21.4, 22.6	−6.3	−22.3	−26.2, −18.4
Urban	27.0	26.1, 27.9	28.6	27.8, 29.5	27.5	27.2, 27.9	22.0	21.7, 22.3	−5.0	−18.5	−21.2, −15.8
Insurance											
Medicaid	80.4	73.5, 87.3	74.1	68.7, 79.5	73.0	70.6, 75.5	54.9	53.1, 56.7	−25.5	−31.7	−39.1, −24.3
Medicare	67.4	64.2, 70.7	69.4	66.2, 72.5	61.7	60.4, 63.1	44.6	43.6, 45.6	−22.8	−33.8	−38.1, −29.5
Private	11.4	10.7, 12.1	11.6	10.9, 12.3	10.6	10.3, 10.9	8.6	8.3, 8.8	−2.8	−24.6	−30.6, −18.6
Uninsured	14.9	13.5, 16.4	16.4	14.8, 18.0	16.6	15.8, 17.5	18.3	17.4, 19.3	3.4	22.8	13.3, 32.3

Rates show hospitalization rates by state calculated using numerator data from the HCUP Nationwide Inpatient Sample Databases and denominator data from the IPUMS USA ACS from 2008 to 2016. [a]Total number of all-cause diabetes hospitalizations, N = 29,823,101; total number of diabetes-specific hospitalizations, N = 2,543,882; and total adult population over period, N = 962,851,698. [b]Rural/urban-specific rates are age-standardized to the 2010 U.S. adult population using data from the Centers for Disease Control and Prevention Mortality Database.

−18.6]) and Medicare patients the largest (33.8% decrease [95% CI −38.1, −29.5]) (Table 2).

While diabetes-specific admissions decreased in nearly all states, the greatest decrease was observed in New York state (34.3% decrease [95% CI −35.3, −33.3]), while Kentucky saw an increase in diabetes-specific admissions (4.1% [95% CI 1.7, 6.5]), and Utah saw no change (Supplementary Appendix 5). Rates of diabetes-specific hospitalizations decreased the most among adults ≥65 years in all states (range 16.3–47.5% decrease) (Supplementary Appendix 6). In Florida, Iowa, Kentucky, North Carolina, Nebraska, New Jersey, and Utah, rates of diabetes-specific hospitalizations increased among patients 18–29 years old (range 10.5–81.5% increase). No change in diabetes-specific hospitalization among 18–29-year-olds was observed in the remaining states; no state observed a decrease in diabetes-specific hospitalizations in this age group (Supplementary Appendix 6). All-cause admissions increased in Florida, Iowa, Nebraska, and Utah (range 5.5–25.3% increase) and decreased in the other states examined (range 0.2–25.7% decrease).

Hispanic patients had large decreases in diabetes-specific hospitalizations in New Jersey, New York, and Utah (range 25.9–47.1% decrease), experienced no change in their hospitalization rate in Maryland, and had an 81.1% increase in Kentucky (95% CI 34.4, 127.8). Black patients had increases in their rates of diabetes-specific hospitalizations in Kentucky (10.9% increase [95% CI 3.6, 18.2]) and Utah (48.3% increase [95% CI 7.1, 89.5]). In all other states, Black patients' rates of diabetes-specific hospitalizations decreased (range 9.9–38.5%). Diabetes-related admissions for White patients increased in Kentucky (9.3% increase [95% CI 6.7, 11.9]) and were stable over this period in Utah (Fig. 1 and Supplementary Appendix 6).

Rural diabetes-specific hospitalizations decreased in six states (Arizona, Florida, Maryland, Nebraska, New York, and Vermont; range 15.2–69.2%). New York (urban decrease 34.9% [95% CI −35.9, −33.9]; rural decrease 24.9% [95% CI −28.9, −20.9]) and Iowa (urban decrease 27.9% [95% CI −31.8, −24]; rural decrease 2.2% [95% CI −3, 7.4]) were the only states in which decreases in urban diabetes-specific hospitalizations were greater than those seen in rural areas. Kentucky saw an increase in rural diabetes-specific hospitalizations (12.9% [95% CI 9.2, 16.6]) and no change in urban diabetes-specific hospitalizations (0% [95% CI −3.5, 3.5]) (Supplementary Appendix 6). Rural diabetes-related admissions decreased in seven states (Arizona, Florida, Kentucky, Maryland, North Carolina, New York, and Vermont; range 13.0–66.3% decrease), while urban diabetes-related admissions decreased in five states (Arizona, Iowa, Kentucky, Maryland, and New York; range 3.7–22.1% decrease).

CONCLUSIONS

Overall, rates of diabetes-related hospitalizations in the U.S. decreased between 2008 and 2016, and the decline in diabetes-specific hospitalizations outpaced decreases seen in all-cause hospitalizations. State-level analysis of subgroups of patients revealed that this decrease is not evenly distributed across all demographic groups or geographic areas. For diabetes-specific hospitalizations, older adults had a downtrend in hospitalization rates, while younger adults (18–29 years old) worryingly had increasing rates of hospitalization between 2008 and 2016/2017. Rural areas had a decrease in diabetes-specific admissions in more states than did urban areas, and there were no consistent trends seen across racial/ethnic groups.

The finding that adults ≥65 years old had steady improvements in diabetes-specific hospitalization rates across all states may be due to several causes. Diabetes is very common among older adults, with >20% of people >65 years old carrying a diagnosis of diabetes in 2018, a number that has been increasing over recent years (11). One possible reason for the decrease in hospitalizations observed in this study, despite increasing diabetes prevalence in this subgroup over the time period studied, is that a large majority of patients in this group have insurance (32), potentially increasing their access to outpatient primary care and preventive screening that may prevent hospitalizations. Additionally, work to develop appropriate, patient-centered guidelines for diabetes care among older adults has expanded greatly over this time (7); the decline in diabetes-specific hospitalizations despite increasing overall prevalence of diabetes in this group may also be due to these advances in diabetes care.

Unlike older adults, we observed an increase in the rates of diabetes-related hospitalizations among young adults 18–29 years old. Overall diabetes prevalence among young adults increased during 2008 to 2017 (11), as did rates of complications of diabetes among younger people between 1990 and 2010 (33), possibly due to challenges related to diabetes control, including competing priorities (34), major life transitions (35), and gaps in care, such as infrequent HbA_{1c} checking (36), that could increase their risk for uncontrolled diabetes requiring hospitalization.

There was wide variability in trends in diabetes-specific hospitalizations across states among different racial/ethnic groups; however, estimates of national trends from the NIS were not available due to high missingness of race/ethnicity variables. The cross-state variability we observed highlights the need for states to systematically collect and report race/ethnicity data. To more accurately understand differences in diabetes hospitalizations by race/ethnicity, states also need to collect data on social determinants of health. One study examining "hot spots" and "cold spots" of emergency department and inpatient diabetes care as well as microvascular complications at the neighborhood level among racial and ethnic minorities in New York City found significant variation in the demographics and prevalence of hospital admissions and microvascular complications across neighborhoods (37). Studies that seek to describe and intervene on racial/ethnic disparities in diabetes-specific hospitalizations should be attentive to the heterogeneity these groups experience with access to care, diabetes management, and lifestyle change.

We hypothesize that our finding that decreases in diabetes-specific hospitalizations were more pronounced in rural areas may represent incomplete follow-up and poor access to care, potentially related to a decline in availability of rural hospitals. Over time, rural areas have experienced greater hospital closures than urban areas (38,39), so the declines in rural diabetes-specific hospitalizations we observed may be because there are no nearby hospitals for admission. A recent study additionally found that adults living in rural or socioeconomically deprived areas in the Midwest

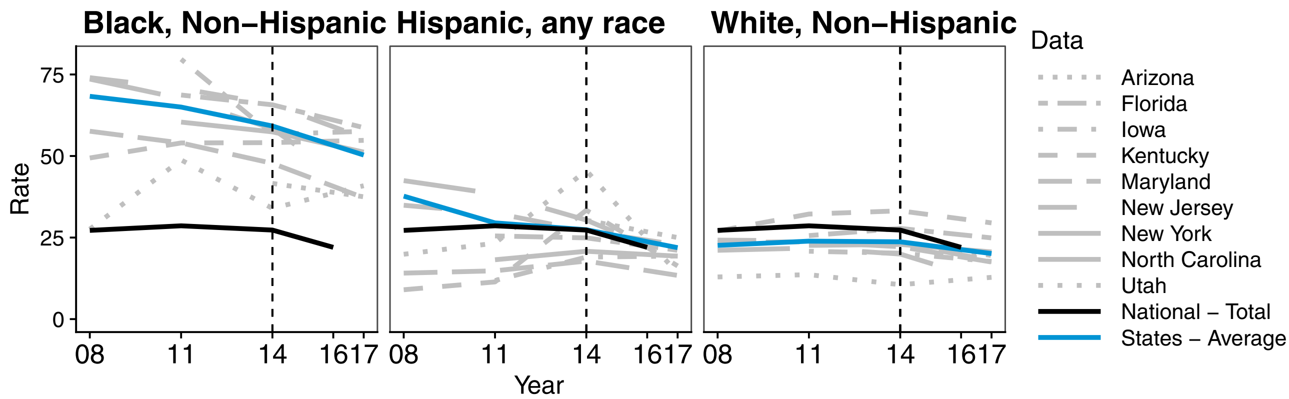

Figure 1—Age-adjusted rates of diabetes-specific hospitalizations among U.S. adults by race/ethnicity, years 2008–2017. Hospitalization rates were calculated using numerator data from the HCUP NIS and SID and denominator data from the IPUMS USA ACS from 2008 to 2017. All rates are age-standardized to the national 2010 U.S. adult population using data from the Centers for Disease Control and Prevention Mortality Database. Two benchmark lines are highlighted: the black National-Total line shows national hospitalization rates across all U.S. adults, regardless of race/ethnicity, and the blue 11 States-Average line shows average hospitalization rates across all states by race/ethnicity. Rates were not reported for state data with inconsistently coded race/ethnicity variables and/or subgroup estimates with estimates $n \leq 10$ events or relative SE $\geq$30%. Nevada did not supply race/ethnicity data. The dotted vertical line delineates the point within our data that the data transitioned from rates generated using ICD-9 codes to ICD-10 codes. Rates posttransition may not be directly comparable to rates prior to the transition.

had lower access to high-quality primary care and subsequently attained fewer diabetes care goals (40). Perhaps the rural patients in our sample, whether due to challenges with access to primary care or closures of rural hospitals (38,39), are not being admitted to the hospital at the rate they need to be. For both younger adults and rural-dwelling patients, additional exploration of trends in reasons for and outcomes of diabetes-related hospitalizations during this time could provide key information as to what specific factors may be driving the changes we observed.

Our observation of decreasing rates of diabetes-specific hospitalizations across most states—albeit with notable increases in rates of hospitalizations in a few outliers—has important implications for research and policy development. We did not observe any trend between improvements in rates of diabetes-related hospitalizations and Medicaid expansion status. In fact, Kentucky—one of the few states in the southeastern U.S. to expand Medicaid in 2014—was one of the only states that saw increases in rates of diabetes-related hospitalizations across nearly all demographic groups. Previous work has shown that while increases in diabetes diagnoses were observed soon after Medicaid expansion in states that opted-in to Medicaid expansion (41), improvements in self-reported health and medication adherence were also observed among patients living in these states (42), potentially leading to downstream improvements in rates of diabetes-related hospitalizations. Notably, these results further highlight that national trends in diabetes care may not reflect state or local trends. This is important, as public health and health care professionals consider the specific climate they work in and how educational, clinical, and policy interventions may impact their patient population and highlights the need for local policies and community-based interventions to address these state-level disparities.

This study has several limitations. First, because this was a secondary data analysis, we are limited in our analysis by what the data set contains. For example, we rely on accurate coding to correctly assign diabetes- and nondiabetes-related hospital admissions. Because the unit of observation was discharges, rather than individual patients, patients who were frequently admitted to the hospital may carry undue weight in this analysis. While frequently admitted patients are a heterogenous population, previous work has shown that they often require hospital admission for medical problems that are sensitive to ambulatory care (43). Additionally, because we are limited to state-level analyses, we were not able to account for variation within a state. Next, not all states reported race/ethnicity, so our assessment of disparities between racial and ethnic groups was limited to a subset of states of interest. We also did not differentiate between type 1 and type 2 diabetes. Finally, the time period we studied included a number of significant changes in the U.S., including the implementation of the Patient Protection and Affordable Care Act as well as the 2015 transition from ICD-9 to ICD-10. Researchers' ability to compare administrative claims data before and after the ICD transition has not been well-described, and it is difficult to know if temporal trends that cross 2015 are real or the result of changes in the ICD system (44). For this analysis, we are reassured that our observed trends are not the result of the ICD transition, as the trends observed in 2016/2017 appear to have started prior to 2015.

By including both national and state-level analyses, this study provides an important perspective on how trends in diabetes-related hospital admissions have changed over 2008 to 2017, with a specific investigation on how these trends are reflected in subgroups across the country. The ∼20% increase in diabetes-specific hospitalizations among young adults aged 18–29 years raises concerns about management of diabetes and prevention of complications in this vulnerable age group. Similarly, the decrease seen in rural hospitalizations for diabetes may paradoxically be cause for concern, as fewer hospitalizations may represent inadequate care in this case. Future studies that seek to describe similar trends should consider the high degree of variability between states and between subpopulations and include more granular analyses in their work, and health care providers, researchers, and policy makers should consider the need for state-specific solutions to address diabetes in their communities.

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