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Kidney transplant cases in US: study of determinants of variance in hospital charges and inpatient care

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Abstract

We investigate the factors that influence the variance in hospital charges and inpatient care for kidney transplant cases in the US. Using the AHRQ's (Agency for Healthcare Research and Quality) HCUP's (Hospital Cost and Utilization Project) NIS (National Inpatient Sample) database, we find that variance in hospital charges and inpatient care is driven by patient demographics and hospital variables. We find that variance in hospital charges and inpatient care is determined by patient-specific factors including age, gender, race, and income, and hospital factors such as size, type, and location. Our results provide a deeper understanding of the non-clinical factors that impact hospital charges and inpatient care for kidney transplant patients.

Keywords Hospital charges, Inpatient care, Kidney transplants, Hospital characteristics, Patient demographics

Key findings/implications of the manuscript

- The study aimed to analyze the determinants of variation in hospital charges and inpatient care among kidney transplant cases in the US.
- The results of the study reveal that several non-clinical factors, such as hospital variables and patient demographics, significantly influence the variation in hospital charges and inpatient care among kidney transplant cases.
- The study contributes to the literature on health economics by shedding light on the non-clinical factors that contribute to differences in healthcare utilization and expenditure among kidney transplant cases, which could inform healthcare policies and strategies aimed at improving healthcare access and affordability.

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Introduction

The United States healthcare system is marked by high expenditures with suboptimal outcomes, as evidenced by healthcare spending reaching $3.6 trillion in 2018—an increase of 4.6 percent from the previous year [13]. Despite this substantial financial input, there remains a misalignment between spending and healthcare outcomes, partly due to inefficiencies and disparities in healthcare provision [3].

Significant research has historically focused on the clinical determinants of hospital charges and inpatient care, such as patient morbidity and the types of medical procedures performed. Notable studies in this area include those by Philbin et al. [23], who explored the impacts of length of stay and procedure utilization on hospital charges for heart failure. While these investigations have provided valuable insights, the predominant focus has remained on clinical factors as determinants of hospital charges and inpatient care. For example, Finkler et al. [10] have extensively documented how clinical care processes and patient health status dictate healthcare expenditures. However, there is a notable gap in understanding how nonclinical factors—such as patient demographics and hospital characteristics—influence these costs. Recently, a growing stream of literature has begun to report that these nonclinical factors significantly impact hospital costs. Studies by Joynt et al. [19] and Jha et al. [18] have highlighted how factors such as hospital size, ownership, geographic location, and patient socioeconomic status play crucial roles in shaping healthcare expenses. This emerging focus is critical as it underscores nonclinical factors that could potentially highlight areas for improving cost-efficiency and equity in healthcare delivery.

In light of this, our study aims to dissect the influence of nonclinical factors on hospital charges and inpatient care in the context of kidney transplant cases in the US. Pollock et al. [24] have reported that hospitalization costs related to chronic kidney disease in the United States differ considerably among hospitalized patients. Patients who require invasive procedures, such as kidney transplants, incur significantly higher hospitalization costs. Additionally, kidney transplant procedures are among the most expensive single organ transplant procedures in the United States, according to Bentley [4]. As a result, kidney transplant hospitalizations represent a significant financial burden on healthcare systems and require further examination. By utilizing data from the AHRQ's HCUP's NIS database, we specifically analyze how variables like age, gender, race, income, hospital size, type, and location contribute to the variability in financial charges and care quality for kidney transplant patients.

The remainder of the paper is structured as follows: in Sect. "Literature review", we discuss the literature review. In Sect. "Research models and hypotheses", we present research models and hypotheses. In Sect. "Data sources and variables", we investigate research data sources and variables. In Sect. "Research sample and design", we analyze the research sample and design. In Sect. "Data analysis and results", we present data analysis and results. In Sect. "Discussion, implications and limitations", we discuss implications and limitations. We conclude in Sect. "Conclusion".

Literature review

According to the CDC, kidney disease, also known as chronic kidney disease, is a leading cause of death in the United States. It causes more deaths than breast cancer and prostate cancer (NVS 2021 report of 2018 data). In 2021, about 37 million US adults are estimated to have CKD, and most are undiagnosed. Forty percent of people that have severely reduced function and are not on dialysis are not aware of having CKD. The end-stage renal disease (ESRD) occurs when the kidneys fail, and the patient is treated with dialysis or kidney transplant. In the United States, diabetes and high blood pressure are the two main causes of kidney disease. In 2019, treating Medicare beneficiaries with CKD cost $87.2 billion, while treating people with ESRD cost an additional $37.3 billion (CDC, 2022).

Kidney disease is a leading cause of death for people of all racial and ethnic groups in the United States, including African American, American Indian, Alaska Native, Hispanic, and white men. For women from the Pacific Islands and Asian American, American Indian, Alaska Native, and Hispanic women. It is more common in people aged 65 years or older (38%), more common in women (14%) than men (12%), and more common in non-Hispanic black adults (16%) than in non-Hispanic White adults (19%) or non-Hispanic Asian adults (13%). (Chronic Kidney Disease Facts | cdc.gov).

Previous studies show alternative determinants associated with hospitalization and hospital charges. For example, Holland et al. [14] use demographic, clinical, and biochemical factors to predict hospitalization in a cohort of pre-dialysis patients. They find that advanced age, comorbid cardiovascular illness and anemia are independent predictors of non-elective hospitalization prior to dialysis initiation. Schrauben et al. [26] use multivariate-adjusted Poisson regression to identify clinical and nonclinical factors associated with hospitalization rates for participants enrolled in the Chronic Renal Insufficiency Cohort (CRIC) Study. They find that adults with CKD had a higher hospitalization rate than the general population that is hospitalized. The higher hospitalization was significantly associated with clinical factors (cardiovascular disease (31.8%), genitourinary (8.7%), digestive (8.3%), endocrine, nutritional or metabolic (8.3%), and respiratory (6.7%)) and nonclinical factors (age, race/ethnicity, and gender).

Chen et al. [5] find that the costs of EOL care for patients with CKD were driven by physician characteristics, facility factors, payment policies, and individual patient characteristics. Dai et al. [7] use random forest and least absolute shrinkage and selection operator regression models (LASSO) to predict hospitalization expenses for inpatients with CRF. They find that hospitalization expenses are significantly related to major procedures, medical payment methods, hospitalization frequency, length of stay, number of other diagnoses, and number of procedures. Ozieh et al. [21] examined the trends in healthcare expenditure in adults with chronic kidney disease (CKD) and other kidney diseases (OKD) in the U.S. from 2002 to 2011. They find that race/ethnicity, hospital location, patient location, marital status, gender, education, insurance type, and income were important predictors of CKD and associated expenditures. They conclude that CKD and OKD are significant cost-drivers that impose a significant economic burden to the US population. Smith et al. [28] find that CKD doubles the costs to the health care system and that comorbidities related to CKD contribute more to the cost of managing these patients than does CKD itself. They suggest the need to better manage the comorbid conditions to reduce medical care costs. Honeycutt et al. [16] show that the economic burden of CKD is higher among the older adult population. The earlier stages of CKD contributed the most costs, suggesting the need for early identification to better manage these costs.

Our research diverges from existing literature in several essential ways that address critical gaps in our understanding of healthcare cost drivers. First, by exclusively using a stratified national sample from the AHRQ dataset, we avoid the disparities that often arise from combining multiple databases, which can suffer from inconsistencies in data collection and labeling. This approach ensures that our findings are reflective of national trends and are not biased by the limitations of a single source.

Second, our focus shifts from predominantly clinical factors to structural, non-clinical determinants of healthcare costs and outcomes. While previous studies, such as those by Chen et al. [5] and Ozieh et al. [21], have explored various predictors of healthcare expenditures, they have often emphasized clinical and individual patient characteristics. In contrast, our study uniquely prioritizes non-clinical variables such as hospital ownership, location, and the sociodemographic profiles of patients. This pivot is critical because non-clinical factors can offer insights into systemic inefficiencies and disparities that clinical factors alone cannot provide. They illuminate how factors outside of direct patient care influence spending and outcomes, thus offering a broader scope for policy intervention and resource allocation.

Furthermore, the existing body of research largely concentrates on the direct medical determinants of cost and care quality in kidney disease management. By incorporating structural equivalents of clinical factors, such as the number of in-patient diagnoses and treatments, our model enriches the understanding of how these elements interact with non-clinical variables to affect costs and outcomes. This is not merely a methodological choice but a strategic focus that responds to the urgent need for policy-relevant insights that can drive cost efficiency and equity in healthcare delivery. The ultimate goal of our research is to unravel the complexities of hospital charge variances in kidney disease cases across the United States, leveraging the rich data available through AHRQ. This focus is in line with AHRQ's mission to enhance the understanding of healthcare costs and processes. By dissecting the impact of non-clinical variables on hospital charges and inpatient care, our study sidesteps the intricacies of individual clinical decision-making to spotlight broader systemic issues. This approach not only aligns with HIPAA regulations by maintaining patient privacy but also enhances the applicability of our findings to health policy and administrative strategies designed to mitigate disparities and improve efficiency in healthcare services.

Research models and hypotheses

Our study is anchored in the exploration of non-clinical determinants of healthcare costs and outcomes, specifically within the context of kidney transplant hospitalizations. Recognizing the significant variability in hospital charges for these cases, we employ a model that integrates social determinants and hospital characteristics to explain these variances.

Theoretical framework

The theoretical basis for our model derives from health economics and social determinants of health frameworks. These perspectives emphasize the role of systemic, non-clinical factors such as socioeconomic status, demographic characteristics, and institutional attributes in influencing health outcomes and economic aspects of healthcare. The model posits that non-clinical factors can have as significant an impact on healthcare costs and quality as clinical factors, a hypothesis that remains underexplored in kidney transplant care.

Research model

Our research model, depicted in Fig. 1, systematically illustrates the relationships between various non-clinical variables and hospital charges and inpatient care for kidney transplant patients. The model includes patient-specific variables such as age (continuous), gender, income, and race (categorical), alongside hospital-specific factors like division and ownership (categorical). Each of these variables is hypothesized to influence the total hospital charges and the quality of inpatient care, serving as a framework to guide our empirical analysis.

Hypotheses

Based on our theoretical framework and the identified research gaps, we formulate the following hypotheses:

> *H1*: Patient demographics (age, gender, race, and income) are significantly associated with the variance in hospital charges and inpatient care for kidney transplant patients.

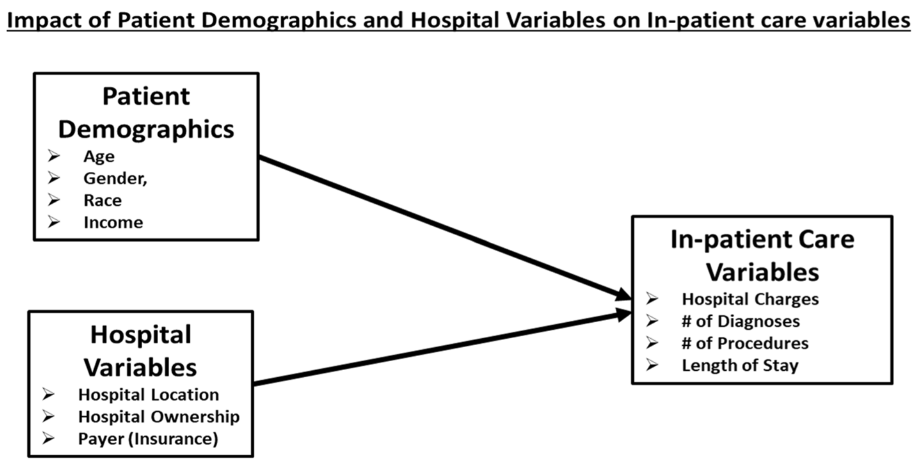

Fig. 1 Reasearch Model Impact of Patient Demographics and Hospital Variables on In-patient care variables

> *H2*: Hospital characteristics (size, location, and ownership type) significantly affect hospital charges and inpatient care for kidney transplant cases.

These hypotheses aim to explore the extent to which non-clinical factors contribute to cost and care variations, moving beyond the traditional focus on clinical determinants.

Model description

Our analysis leverages data from the AHRQ's HCUP NIS database for the year 2019, encompassing 4,213 kidney transplant hospitalizations. This dataset allows us to examine a broad range of charges—from $18,745 to $1,958,373—and to assess the impact of non-clinical variables on such variability. For instance, our preliminary analysis shows a wide range of diagnoses, treatments, and lengths of stay, which are controlled for, in our model to isolate the effects of non-clinical factors.

The focus on non-clinical variables responds to the need for a deeper understanding of how factors such as demographics and hospital administration impact healthcare economics and patient outcomes in a significant yet often overlooked way. This approach aligns with our broader aim to enhance the efficiency and equity of healthcare delivery through informed policy interventions.

Data sources and variables

The Agency for Healthcare Research and Quality (AHRQ) [1] is one of the twelve agencies that operate within the United States Department of Health and Human Services, focusing on enhancing the quality, safety, efficiency, and effectiveness of healthcare through research and support. AHRQ's budget for the fiscal year 2022 is over $488.8 million, which is allocated to compile open government data for healthcare research purposes. Since the early 1990s, AHRQ's project—The Health Care Cost and Utilization Project (HCUP)—has been collecting data from a representative sample of 4,568 hospitals across the United States.

The HCUP databases analyze individual hospital stays as their unit of analysis, which covers an entire inpatient episode from admission to discharge. We excluded records from VA hospitals, long-term care hospitals, and hospitals on Indian Reservations from our study. The hospitals employ a DRG (Diagnosis Related Group) code from 000 to 999 to classify each admission. Every year, the sample contains over 7 million records, each of which provides details for approximately 250 variables related to each admission.

National standards for patient rights regarding health information are established by the HIPAA Privacy Rule. The rule sets conditions for the use and disclosure of individually identifiable health information by covered entities to protect it. The definition of a limited data set is adhered to by the HCUP databases. A limited data set is healthcare data in which 16 direct identifiers, specified in the Privacy Rule, have been removed. The use of limited data sets does not mandate review by an institutional review board (IRB) as per HIPAA guidelines.

We focused on DRG = 652 (kidney transplants) for the year 2019. Our objective was to examine the impact of non-clinical variables like race, income, age, and gender of the patient on hospitalization charges and in-patient care.

Research sample and design

Research sample

It is important to note that the data we used for our kidney transplant research was collected in 2019, prior to the COVID-19 pandemic. The total number of patient records across all DRG codes in 2019 was 7,083,805 which had been collected from a stratified sample of 4,568 hospitals in the U.S. The hospital composition was 13% from the Northeast, 30% from the Midwest, 38% from the South, and 19% from the Western region. The hospitals in the sample were 20% government, non-federal hospitals: 64% private, not-for-profit hospitals, and 16% private, investor-owned hospitals. Of the total 7,083,805 records from 4,568 hospitals, the number of records in the database for kidney transplants (DRG code = 652) was 4,213 discharge records, which is the sample size for our research study.

Research design

To systematically examine the influences of various non-clinical factors on hospital charges and inpatient care, our research design employs a structured approach, starting with descriptive statistics. This initial phase is crucial to establish a baseline understanding of the data. Descriptive statistics offer foundational insights by summarizing the central tendency, dispersion, and shape of the dataset's distribution, with a particular focus on hospital charges and patient care metrics such as the number of diagnoses, procedures performed, and length of stay. Additionally, this approach elucidates the demographic profile of the patients, including age, gender, income, and race, as well as hospital variables such as division, payer type, and ownership. Establishing these descriptive parameters early in our analysis helps identify any patterns or outliers, setting the stage for a more informed application of complex statistical techniques like regression analysis.

Univariate regression analysis serves as the initial step towards understanding the individual impact of each independent variable on the dependent variables. By systematically examining one predictor at a time, this approach helps to isolate the linear associations between variables such as patient age, income, race, hospital division, payer type, and ownership, and the outcomes of hospital charges and inpatient care metrics. The construction of dummy variables for categorical predictors, as previously mentioned, prevents multicollinearity and allows for a clear interpretation of the effect each category has in relation to a reference category. The simplicity of univariate analysis makes it an indispensable tool in laying the groundwork for more complex analyses, providing initial insights that guide the formulation of hypotheses for multivariate testing.

Building on the insights provided by the univariate regression, multivariate regression analysis is employed to account for the interdependencies among all independent variables simultaneously. This comprehensive approach enables us to assess the combined effect of demographic and hospital-related factors on hospital charges and inpatient care outcomes. By including all relevant predictors in a single model, we can distinguish the unique contribution of each variable while controlling for others, thereby addressing potential confounding influences. This methodology not only enhances the robustness of our findings but also emphasizes the necessity of a holistic analysis to truly ascertain the predictive power and interactions of the variables involved.

Data analysis and results

Descriptive statistics

Table 1 presents the descriptive statistics of our sample of 4,213 cases. The variable descriptions used in our research are available on the AHRQ website: (https://www.hcup-us.ahrq.gov/db/nation/nis/nisdde.jsp). The descriptive statistics for the variables include mean, standard deviation, minimum, and maximum values. Our research model in Fig. 1 shows that hospital charges and in-patient care (# of Diagnoses, # Procedures and Length of Stay) are the dependent variables. The independent variables are patient age, gender, income, race and hospital division, Payer and Hospital Ownership. Age is a continuous variable with a mean value of 51.22 years, a modal value of 57 years and the median value of 54 years in the sample of 4,213 kidney transplants. Gender is a categorical variable with two categories (Male and Female). The sample of 4,213 patients is 59.9% male and 40.1% female. Race is a categorical variable measured in the AHRQ data set in 6 categories. The sample of 4,213 patients is 44.6% White, 25.6% Black, 17.4% Hispanic, 6.5% Asian, 0.7% Native American, 3.0% Other and 2.1% missing. Income is a categorical variable measured in the AHRQ data set in four quartiles (0–25 percentile), (26–50 percentile), (51–75% percentile) and (76–100% percentile) of the average income of the ZIP code of the patient is coming from. The sample of 4,213 patients is 26.6% in the 1st quartile, 23.1% in the 2nd quartile, 25.4% in the 3rd quartile, 23.5% in the 4th quartile, and missing income data is 1.4%. Payer is a categorical variable measured in the AHRQ data set in 6 categories. The sample of 4,213 patients is 61% Medicare, 5.6% Medicaid, 31.1% Private Insurance, 0.4% Self-pay, 0% No Charge, 1.8% Other and 0.1% missing. Hospital Division is a categorical variable measured in the AHRQ data set in 9 categories. Of the total 4,213 records for this DRG code (Kidney Transplants), and there were no missing values. The sample of 4,213 patients is 4.1% from New England (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut), 15.3% Middle Atlantic (New York, Pennsylvania, New Jersey), 13.8% from East North Central (Wisconsin, Michigan, Illinois, Indiana, Ohio), 7.6% West North Central (Missouri, North Dakota, South Dakota,

Table 1 Descriptive statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Hospital Charges	4200	$18,745	$1,958,373	$269,989	$18,745
# of Diagnoses	4213	2	40	14.81	6.00
# of Procedures	4213	1	25	2.79	2.18
Length of stay	4213	0	135	5.88	5.06
Age	4213	0	82	51.22	15.74
Gender	4213	0	1	0.4	0.49
Race	4123	1	6	2.00	1.21
Income Quartile	4155	1	4	2.46	1.13
Payer	4208	1	6	1.78	1.088
Hospital Division	4213	1	9	5.09	2.46
Hospital Ownership	219	1	3	1.89	0.47

Nebraska, Kansas, Minnesota, Iowa), 21% South Atlantic (Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida), 4.8% East South Central (Kentucky, Tennessee, Mississippi, Alabama), 12.6% West South Central (Oklahoma, Texas, Arkansas, Louisiana), 7.2% Mountain (Idaho, Montana, Wyoming, Nevada, Utah, Colorado, Arizona, New Mexico) and 13.6% Pacific (Alaska, Washington, Oregon, California, Hawaii). We do not have the more granular state level data in the database. Hospital Ownership is a categorical variable measured in the AHRQ data set in 3 categories. Of the total 4,213 records for this DRG code (Kidney Transplants), 94.8% of the records had a missing value for this variable in the database leaving only 5.2% or 219 records for data analysis. The sample of 219 patients is 17.4% Govt-Non-federal, 76.7% Private-not-for-profit, and 5.9% Private-investor-owned.

Univariate regression results

Four univariate regression models are used to examine the relationships between the dependent and independent variables, taken one by one on a univariate basis. The results of the univariate regression models are shown in Table 2. The results are discussed after Table 2.

The univariate regression of hospital charges with age as the independent variable shows a non-significant positive beta coefficient ($F=0.181$, $p=0.671$). Interpretation of the slope of the regression means that the baseline hospital costs are $273,175 and with each increment of 1 year in age there would be a reduction of $62 which is not statistically significant. Thus, for a 65-year-old liver transplant patient, the predicted hospital charge would be $269,145 which is not a big difference from the mean value of $269,989 for kidney transplants. Similarly, age was not a statistically significant determinant of # of procedures ($F=0.632$, $p=0.427$) or length of stay ($F=0.013$, $p=0.909$). However, age was a statistically significant determinant of the number of diagnoses ($F=264$, $p=0.000$) with a baseline of 10.1 diagnoses and with each increment of 1 year in age there would be an additional 0.1 diagnosis done. Thus, for a 65-year-old kidney transplant patient the estimated # of diagnoses would be 16.6.

Table 2 Univariate regression results

	Model 1	Model 2	Model 3	Model 4
	Dependent Variable in Regression Models 1–4			
Predictor Variable (Measure)[a]	**Hospital Charges**	**# of Diagnoses**	**# of Procedures**	**Length of Stay**
Age	F = .181, Not Sig	F = 264, Sig (.000)[a]	F = .632, Not Sig	F = .013, Not Sig
Gender	F = 0.515, Not Sig	F = 0.00, Not Sig	F = 1.748, Not Sig	F = .333, Not Sig
Race	F = 22.22, Sig (.000)[a]	F = 2.515, Sig (.028)[a]	F = 3.07, Sig (.009)[a]	F = 6.37, Sig (.000)[a]
Income	F = 0.584, Not Sig	F = 0.547, Not Sig	F = .403, Not Sig	F = 1.568, Not Sig
Payer	F = 5.372, Sig (.000)[a]	F = 30.34, Sig (.000)[a]	F = 1.964, Not Sig	F = 10.0, Sig (.000)[a]
Hospital Division	F = 66.44, Sig (.000)[a]	F = 4.14, Sig (.000)[a]	F = 6.17, Sig (.000)[a]	F = 5.13, Sig (.000)[a]
Hospital Ownership	F = 4.11, Sig (.018)[a]	F = 1.008, Not Sig	F = .453, Not Sig	F = 1.001, Not Sig

[a] Significant results related to the categorical measures have detailed explanations in the paper that show differences across categories relative to a baseline category

The univariate regression of hospital charges with gender as the independent variable shows no statistically significant relationship (F = 0.515, p = 0.473). Similarly, gender did not show any statistically significant impact on the number of diagnoses (F = 0.0, $P = 0.993$); the number of procedures (F = 1.748, $p = 0.186$) and the length of stay (F = 0.333, $p = 0.564$).

The univariate regression of hospital charges with race as the independent variable required creating dummy variables for this categorical variable and keeping the base (reference) category as White in interpreting the regression results. The results in Table 2 show that race is statistically significant in its impact on hospital charges (F = 22.22, $p = 0.000$). The baseline White group was charged the least amount ($248,940) and all other races were charged statistically significant higher amounts of $21,521 for Blacks; $59,481 for Hispanics; $51,573 for Asians. Only Native Americans were charged $24,521 lower than Whites. The race was a statistically significant factor impacting the number of diagnoses (F = 2.515, $p = 0.028$); the # of procedures (F = 3.067, $p = 0.009$) and the length of stay (F = 6.369, $p = 0.000$). The baseline Whites had the highest number of diagnoses at 14.73, except the Blacks who had on, average, 0.6 more diagnoses relative to the Whites., while all other groups had a statistically significant lower numbers of diagnoses relative to the baseline Whites. Similarly, the baseline Whites had the lowest # of procedures except the Native Americans who had, on average, 0.2 less procedures relative to the Whites, while all other groups had a statistically higher number of procedures relative to the beeline Whites.

The univariate regression of hospital charges with income as the independent variable required creating dummy variables for this categorical variable and keeping the base (reference) category as the 1st quartile in interpreting the regression results. The results in Table 2 revealed no statistically significant differences in hospital charges across the income groups (F = 0.584, $p = 0.625$). Though statistically insignificant, the beta coefficients show a gradual progression upward indicating that patients with higher income were charged higher, though not statistically significant, amounts. The baseline lowest income group was charged $266,542. Relative to this first and lowest income quartile, the second income quartile was charged $1,660 higher, the third income quartile was charged $5,966 higher and the fourth income quartile was charged $7,482 higher. Income also showed no statistically significant impact on the number of diagnoses (F = 0.547, $p = 0.650$); on the # of procedures (F = 0.403, $p = 0.751$), and the length of stay (F = 1.568, $p = 0.195$).

The univariate regression of hospital charges with Payer as the independent variable required creating dummy variables for this categorical variable and keeping the base (reference) category as Medicare in interpreting the regression results. The results in Table 2 show that the Payer variable significantly impacts the Hospital Charges (F = 5.371, $p = 0.000$). For the baseline Medicare category, the Hospital Charges were $276,388. Compared to this baseline (Medicare) group, only the Private Insurance group had a statistically significant lower amount of $21,022. All other payer groups did not have statistically significant differences relative to the Medicare Group.

With regards to # of diagnoses, the results in Table 2 show that the Payer variable significantly impacts the # of Diagnoses (F = 30.335, $p = 0.000$). The # of Diagnoses for the baseline Medicare category was 15.7 diagnoses. Compared to this baseline, all other groups of Payer had statistically significant lower # Diagnoses with the Medicaid 1.6 diagnoses lower, Private Insurance patients 2.4 diagnoses lower, Self-Pay 1.8 diagnoses lower, No Charge 5.7 diagnoses lower and Other 1.5 diagnoses lower.

Payer variable did not impact # of procedures (F = 1.964, $p = 0.081$). However, with regard to the length of stay, the results in Table 2 show that the Payer variable significantly impacts the length of stay (F = 10.006, $p = 0.000$). The length of stay for the baseline Medicare category was 6.1 days. Compared to this baseline, all other groups of Payer had statistically significantly lower length of stay with the Medicaid 0.85 days lower, Private Insurance patients 1 day lower, Self-Pay 0.35 days higher, No Charge 2.1 days lower and Other 0.1 day lower.

The univariate regression of hospital charges with Hospital Division as the independent variable required creating dummy variables for this categorical variable and keeping the base (reference) category as New England in interpreting the regression results. The results in Table 2 show that the Hospital Division variable significantly impacts the Hospital Charges (F = 66.44, $p = 0.000$). The Hospital Charges for the baseline New England category were $200,455. Compared to this New England baseline, all other groups showed statistically significantly higher incremental charges. The highest statistically significant charge relative to the baseline (New England) was in the Pacific region at $178,236, and the lowest was in the South Atlantic at $37,857. The average charge in the South Atlantic was so close to that in New England (baseline) that it was not statistically insignificant. Similarly, the Hospital Division variable impacted the # of Diagnoses (F = 4.14, $p = 0.000$). The baseline New England group had 15.4 diagnoses and all other groups had a lower number of diagnoses that ranged from 0 to 2. Also, the Hospital Division variable impacted # of procedures (F = 6.172, $p = 0.000$). For the baseline New England category was 3.16 procedures. Compared to this baseline New England group, all other categories of Hospital Division showed no statistically significant differences in # of procedures, except East South Central which showed a 0.81 lower number of procedures. The Hospital Division variable impacted length of stay (F = 5.127, $p = 0.000$). The baseline New England group had 6.9 days as length of stay on average, and all other groups had a lower number of days that ranged from 0.48 to 2.2 days as length of stay. Only the Mid Atlantic was not statistically significant from New England (baseline) and all other groups were statistically significantly lower relative to New England.

The regression of hospital charges with Hospital Ownership as the independent variable required creating dummy variables for this categorical variable and keeping the base (reference) category as Govt-Non-federal in interpreting the regression results. The results in Table 2 show that the Hospital Ownership variable significantly impacts the Hospital Charges (F = 4.11, $p = 0.018$). For the baseline Govt-Non-federal category, the Hospital Charges were $242,589. Compared to this baseline, the other two groups had a statistically significant higher incremental charge, namely, Private-not-for-profit with $37,700 and Private-investor-owned with $177,904. Clearly, investor-owned hospitals had the highest hospital charges and the government non-federal hospitals charged the lowest amount.

With regard to # of diagnoses, the results in Table 2 show that Hospital Ownership did not impact the # of Diagnoses (F = 1.008, $p = 0.367$). The # of Diagnoses for the baseline Govt-Non-federal hospitals was 16 diagnoses. Compared to this baseline, Private non-profit hospitals had 1.4 lower number of diagnoses and Private investor-owned hospitals had a 1.2 lower number of diagnoses. Hospital Ownership did not impact # of procedures (F = 0.453, $p = 0.636$), and the length of stay, (F = 1.101, $p = 0.334$). The # of procedures for the baseline Govt-Non-federal hospitals was 2.66. Private non-profit hospitals and Private investor-owned hospitals had a higher # of procedures of 0.41 and 0.57 respectively relative to the baseline. The length of stay for the baseline Govt-Non-federal hospitals was 5.5 days. Private non-profit hospitals and Private investor-owned hospitals had a length of stay of 1.02 days higher, and 0.4 days lower respectively relative to the baseline.

Multivariate regression results

Table 3 shows four multivariate regressions each with different dependent variables which are (1) Hospital Charges, (2) # of Diagnoses, (3) # of Procedures and (4) Length of Stay. Each of the categorical variables is represented in the predictors set by their respective dummy variables. Age is the only continuous independent variable in this full set of predictor variables.

For Model 1 in Table 3, the results show an intercept value of $228,123. Intercept value represents the predicted value when all the independent variables take on a value of zero. However, the categorical variables do not take on a value of zero and hence the intercept value cannot be interpreted in the traditionally accepted way. However, we can see in Model 1 results that females are charged $68,394 less than males; patients with private insurance are charged $52,079 less relative to Medicare patients; patients in the Pacific region (Alaska, Washington, Oregon, California, Hawaii) are charged $194,138 more relative to patients in New England region (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut); and finally patients in private, investor owned hospitals are charged $167,851 more relative to patients in Govt, non-federal hospitals. These specific statistically significant results may explain the intercept value ($228,123) in comparison with the overall mean value of kidney transplants hospital charges of $269,989. In summary, the predictor model allows a more nuanced understanding of factors that influence the hospital charges.

Table 3 Multi-variate regression results (Significant beta coefficients are highlighted)

	Model 1	**Model 2**	**Model 3**	**Model 4**
	Dependent Variable in the Multi-variate Regression Models 1–4			
Predictor Variable (Measure)[a]	**Hospital Charges**	**# of Diagnoses**	**# of Procedures**	**Length of Stay**
Intercept	**$228,123**	**13.76 Diagnoses**	**2.78 procedures**	**8.7 days**
Age	ß = -.019, p = 0.804	ß = .082, p = 0.307	ß = -.057, p = 0.477	**ß = -.190, p = 0.015 (-0.05 days)**
Baseline is Gender = 1 (Male); the beta shown below is relative to the baseline				
Female [Gender = 1]	**ß = -.185, p = 0.10 (-$68,394)**	ß = -.050, p = 0.509	ß = -.130, p = 0.084	ß = -.120, p = 0.100
Baseline is Race = 1 (White); the betas shown below are relative to the baseline				
Race = 2 (Black)	ß = -.021, p = 0.777	ß = -.124, p = 0.113	ß = -.013, p = 0.084	ß = -.068, p = 0.364
Race = 3 (Hispanic)	ß = .111, p = 0.158	ß = .060, p = 0.469	ß = .102, p = 0.214	ß = .101, p = 0.206
Race = 4 (Asian)	ß = -.002, p = 0.981	ß = .122, p = 0.110	ß = .034, p = 0.649	ß = -.047, p = 0.518
Race = 5 (Native American)	ß = -.004, p = 0.956	ß = .069, p = 0.351	ß = -.003, p = 0.963	ß = -.017, p = 0.810
Race = 6 (Other)	ß = .092, p = 0.189	ß = .048, p = 0.517	ß = .032, p = 0.665	ß = .019, p = 0.793
Baseline is Income = 1 (1st Quartile of Income); the betas below shown are relative to the baseline				
Income = 2 (2nd Quartile Income)	ß = -.053, p = 0.526	ß = .086, p = 0.328	ß = .063, p = 0.471	ß = -.048, p = 0.569
Income = 3 (3rd Quartile Income)	ß = -.042, p = 0.618	ß = .073, p = 0.412	ß = -.018, p = 0.841	ß = -.030, p = 0.726
Income = 4 (4th Quartile Income)	ß = -.123, p = 0.169	ß = -.028, p = 0.762	ß = .007, p = 0.939	ß = -.069, p = 0.447
Baseline is Payer = 1 (Medicare); the betas shown below are relative to the baseline				
Payer = 2 (Medicaid)	ß = -.059, p = 0.467	ß = -.047, p = 0.577	ß = -.028, p = 0.738	ß = .011, p = 0.897
Payer = 3 (Private Insurance)	**ß = -.137, p = 0.070 (-$52,079)**	ß = -.129 p = 0.105	ß = -.086, p = 0.278	**ß = -.164, p = 0.033 (-1.7 days)**
Payer = 4 (Self-Pay)	ß = .002, p = 0.983	ß = -.035, p = 0.640	ß = -.055, p = 0.463	ß = -.002, p = 0.981
Payer = 5 (No Charge)	**No data**	**No data**	**No data**	**No data**
Payer = 6 (Other)	ß = -.006, p = 0.933	ß = .005, p = 0.952	ß = .105, p = 0.163	ß = -.062, p = 0.397
Baseline is Hospital Division = 1 (New England); the betas shown below are relative to the baseline				
Hosp_Div = 2 (Middle Atlantic)	ß = .210, p = 0.068	ß = .071, p = 0.557	ß = .051, p = 0.671	ß = .044, p = 0.709
Hosp_Div = 3 (East North Central)	ß = .142, p = 0.214	ß = .137, p = 0.265	ß = .054, p = 0.658	ß = .088, p = 0.457
Hosp_Div = 4 (West North Central)	ß = .118, p = 0.266	ß = .084, p = 0.453	ß = -.004, p = 0.973	ß = .083, p = 0.438
Hosp_Div = 5 (South Atlantic)	ß = .118, p = 0.326	ß = .031, p = 0.809	ß = .074, p = 0.554	ß = .011, p = 0.930
Hosp_Div = 6 (East South Central)	ß = .037, p = 0.669	ß = .022, p = 0.809	ß = -.001, p = 0.992	ß = -.019, p = 0.828
Hosp_Div = 7 (West South Central)	ß = .197, p = 0.092	ß = .149, p = 0.223	**ß = .266, p = 0.029 (+ 1.95 procedures)**	ß = .193, p = 0.102
Hosp_Div = 8 (Mountain)	ß = .070, p = 0.459	ß = .072, p = 0.480	ß = .096, p = 0.340	ß = -.023, p = 0.814
Hosp_Div = 9 (Pacific)	**ß = .360, p = 0.001 (+ $194,138)**	ß = .135, p = 0.247	ß = .017, p = 0.881	ß = .057, p = 0.12
Baseline is Hospital_Ownership = 1 (Govt, non-federal); the betas shown below are relative to the baseline				
Hosp_Owner = 2 (Private, not for profit)	ß = .077, p = 0.310	ß = -.101, p = 0.218	ß = .055, p = 0.503	ß = .051, p = 0.520
Hosp_Owner = 3 (Private, investor owned)	**ß = .192, p = 0.013 (+ $167,851)**	ß = -.080, p = 0.326	ß = -.045, p = 0.584	ß = -.086, p = 0.273

[a] Significant results related to the categorical measures have detailed explanations in the paper that show differences across categories relative to a baseline category

For Model 2 in Table 3, the results show an intercept value of 13.76 diagnoses. None of the predictor variables showed any statically significant impact on the dependent variable. The overall mean value of # Diagnoses was 14.81 diagnoses. We cannot explain this difference, but view both measures as quite different conceptually, with the mean as a naked measure of the average value of all measurements, whereas the intercept value is the predicted value when all the predictor variables take on a value of zero which in our case is not possible.

For Model 3 in Table 3, the results show an intercept value of 2.78 procedures. Intercept value represents the predicted value when all the independent variables take on a value of zero. However, the categorical variables do not take on a value of zero and hence the intercept value cannot be interpreted in the traditionally accepted way. However, in Model 3 results only the West South Central (Oklahoma, Texas, Arkansas, Louisiana) region had 1.95 procedures higher relative to the New England (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut) region. The overall mean value of # Procedures was 2.79 procedures which is coincidentally very close to the intercept value. We cannot explain this coincidence, but view both measures as quite different conceptually, with the mean as a naked measure of the average value of all measurements, whereas the intercept value is the predicted value when all the predictor variables take on a value of zero which in our case is not possible.

Finally, for Model 4 in Table 3, the results show an intercept value of 8.7 days. Intercept value represents the predicted value when all the independent variables take on a value of zero. However, the categorical variables do not take on a value of zero and hence the intercept value cannot be interpreted in the traditionally accepted way. However, we can see in Model 4 results age is a statistically significant determinant of length of stay with a coefficient of -0.05. This, for example, means that a 65-year-old kidney transplant patient would have a length of stay of only 5.5 days compared to a much younger (45 years old) kidney transplant patient who would stay a day longer. Similarly, patients in private, investor-owned hospitals have 1.75 days less stay relative to patients in Govt, non-federal hospitals. The overall mean value of length of stay was 5.88 days while the intercept value is 8.7 days in the multivariate regression. We view both measures as quite different conceptually, with the mean as a naked measure of the average value of all measurements, whereas the intercept value is the predicted value when all the predictor variables take on a value of zero which in our case is not possible.

Taken together, our univariate and multivariate results show that patient-specific factors including age, gender, race, and income, and hospital factors such as size, type, and location are important determinants of variance in hospital charges and inpatient care for U.S. kidney transplant cases. Next, we discuss the above results and link them to existing literature with implications for addressing the widely observed variance in hospital charges and inpatient care.

Regarding the interpretation of our regression results, we would like to clarify that our independent variables are categorical measures. Due to the nature of these categorical variables, we employed a baseline group approach in our regression analysis. This approach is standard in regression modeling with categorical variables, where one category is chosen as the reference group against which all other categories are compared. This method allows us to assess the statistical significance of each category relative to the baseline group.

We acknowledge that interaction terms can provide deeper insights into the relationships between variables. However, incorporating interaction terms in a model with categorical independent variables can be challenging and complex, particularly when the number of categories is substantial. In our study, the primary objective was to identify the main effects of the categorical variables rather than their interactions. This decision was based on the scope and focus of our research.

Discussion, implications and limitations

Our methodological choice of measuring our independent variables as categorical (ordinal) variables) has limited our ability to explore the interaction effects among the independent variables on the dependent variable for the following reasons. First, the use of categorical independent variables necessitated defining a baseline group for comparison, which is a common approach in regression analysis with categorical data. Second, interaction terms were not included in the regression model due to the complexity and potential for overfitting, given the number of categories involved. Future research could explore these interactions in more detail. Third, the interpretation of regression coefficients should be understood within the context of the chosen baseline group, which may limit the generalizability of the findings.

Additionally, we have elaborated on the discussion of our regression results to provide a more nuanced interpretation of the significance of the variables. We have highlighted the practical implications of these findings and emphasized the need for cautious interpretation. The remaining part of this section is focused on discussion of the direct effects of the independent variables on the dependent variable.

Age has been studied in many earlier studies as a key determinant of hospital charges for a wide variety of hospitalizations. Past research found evidence that healthcare costs increase with patient age [6, 9, 17, 22]. Our findings are consistent with past research on age and healthcare. Age is positively correlated with Hospital Charges, # of Diagnoses, # of procedures and length of stay, and significant for # of procedures. The median age is 54 years in the sample of 4,213 records analyzed. Thus, the implication for future research studies is to examine the geriatric segments of the patients for more preventive care rather than in-patient care to minimize the economic impact.

Gender related findings in our study do not reveal statistically significant differences in the length of stay, # of diagnoses, # of procedures and hospital charges. The impact of gender in healthcare has been demonstrated in past research studies [8, 20]. We do not find evidence of differences in healthcare measures for females and males. Thus, the implication is that chronic kidney disease equally impacts healthcare measures for both genders.

Race variable revealed a statistically significant impact on hospital charges, # of diagnoses, # of procedures and length of stay. Our findings are consistent with several other studies that found disparities in healthcare access based on race [2, 12, 25]. However, access to universal healthcare seems to mitigate racial disparities in access and quality of healthcare [15].

Income variable in our study is a crude and aggregate measure based on the ZIP code of the patient and plugging that ZIP code in one of the four quartiles of national income. Hence, we do not believe that our findings are generalizable though some broad differences across income categories are suggested. Our results show no statistical differences between the quartiles. This implies that healthcare delivery is guided by standardized clinical protocols that are invariant of the income level of the patient.

Payer variable reveals interesting results. The baseline hospital charge for Medicare was $276,388. The hospital charge for the "Private Insurance" group was $21,022 lower than the baseline Medicare charge. The Payer variable of most groups was significantly lower for # of diagnoses and length of stay. One implication is that these findings raise an interesting topic for future research to be directed at examining the accounting practices of hospitals to bring to the surface the distinctions between charges and costs incurred at the procedural level.

The Hospital Division variable reveals some significant regional differences. The baseline hospital charge for New England was $200,455. Our results show that the Pacific (Alaska, Washington, Oregon, California, Hawaii) region is the most expensive at $178,236 higher than the baseline hospitalization charge for chronic kidney disease in the US. One implication is that these findings may provide some broad guidance for medical tourism to locate the least cost hospitals for chronic kidney disease cases.

Hospital Ownership indicates some significant differences in hospital charges. The baseline hospital charge for Govt-Non-Federal category was $242,589. Our results show that the Private-not-for-profit category had an insignificant difference of $37,700 over the baseline charge while the Private-investor-owned category was more expensive with a significant difference of $177,904 over the baseline charge. This implies that hospital ownership plays an important role in determining healthcare costs for chronic kidney disease cases.

As with all research studies, our study suffers from several limitations. One limitation of our study uses only cross-sectional data [27] and hence any temporal patterns cannot be inferred from our findings. The data is from 2019 which is one limitation of the study. For example, our study data comes from 2019 which is pre- Covid era. However, recent studies indicate many patients with severe COVID-19 are those with co-existing chronic conditions, including high blood pressure and diabetes, and both diseases increase the risk of kidney disease.[1] Another limitation is that our variables come from the AHRQ's HCUP database; and other variables possibly affect hospital charges and inpatient care. Another limitation is inherent in the categorical measurement of many of our research variables which limits the analysis of variance in the dependent variables using more robust statistical techniques.

Conclusion

In this study, we examined the impact of various categorical independent variables on the dependent variable using regression analysis. Our findings highlight the significance of these variables in shaping the outcomes, with each category being compared against a defined baseline group. This approach allowed us to discern meaningful patterns and relationships within the data.

While our analysis provides valuable insights, it is essential to acknowledge its limitations. The categorical nature of the independent variables necessitated the use of a baseline group for comparison, which may influence the interpretation of our results. Additionally, the complexity of incorporating interaction terms was beyond the scope of this study, suggesting an avenue for future research to explore these interactions in greater depth.

We use a sample of kidney transplant cases from a unique AHRQ-HCUP data set compiled in hospitals to investigate the factors that determine the variance in hospital charges and inpatient care for kidney transplant cases. We argue that there is still wide and unexplained variance in hospital charges and inpatient care despite increasing codification and standardization of clinical protocols for advanced procedures. We demonstrate that this variance in hospital charges and inpatient care for kidney transplant cases can result from patient-specific and hospital non-clinical factors.

Our study aligns with the medical profession's aim to provide excellent care to all patients, regardless of their age, gender, income, or race. We found that there is a lack of research based on data-driven insights into hospitalizations related to kidney disease, which highlights the

[1] https://www.hopkinsmedicine.org/health/conditions-and-diseases/coronavirus/coronavirus-kidney-damage-caused-by-covid19#:~:text=Signs%20of%20kidney%20problems%20in,kidney%20injury%20may%20require%20dialysis.

impact of non-clinical factors on hospital charges and inpatient care. Through our research, we aim to bridge this gap in knowledge. Our study draws upon the early twentieth century work of Mary Parker Follett, who stressed the importance of leaders possessing the "ability to grasp a total situation, i.e., see a whole, not a mere kaleidoscope of pieces" [11], p.168). Our research sheds light on the significance of non-clinical factors in understanding hospital charges and inpatient care for kidney transplant cases.

Overall, our results contribute to a better understanding of the categorical factors influencing the dependent variable. However, we urge caution in generalizing these findings beyond the context of our baseline group. Future studies should consider the potential interactions between variables and their broader implications. By doing so, researchers can build upon our work to develop a more comprehensive understanding of the dynamics at play.

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Authors' contributions
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Availability of data and material
Our study is based on publicly available data and their sources are cited in the paper.

Declarations

Ethics approval and consent to participate
We did not obtain ethics committee approval because the paper did not involve the collection of data on human subjects.

Consent for publication
We did not obtain consent for publication because our manuscript does not include personal or clinical details of participants.

Competing interests
We have no relevant financial and non-financial competing interests related to this project to disclose.
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