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Understanding the diagnosing provider landscape for commercially insured patients with Early- or Middle-stage Huntington's Disease and their association with healthcare utilization using retrospective claims data

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Abstract

Understanding the diagnosing provider landscape for commercially insured patients with Early- or Middle-stage Huntington's Disease and their association with healthcare utilization using retrospective claims data

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Background: Huntington's Disease (HD) is a progressive neurodegenerative disorder with no curative therapy. Patients have a variety of symptoms, presenting movement, cognitive, and/or psychiatric impairments at the time of diagnosis. As the first step to improve the diagnosis and management for HD, it is necessary to understand the initial diagnosis of HD patients by different provider types and its potential association with health care resource utilization (HCRU) and costs after initial diagnosis.

Objective: To describe the diagnosing and managing healthcare provider landscape in early- and middle-stage HD patients, and their association with HCRU and costs.

Methods: We used the Merative MarketScan Commerical Claims database. Using a published claim-based algorithm, our study included adult patients who were diagnosed with either early- or middle-stage HD between July 1st, 2017 and June 30th, 2021 without any history of HD diagnosis in the past. We followed up their all-cause HCRU and costs for six months after initial diagnosis. First, we calculated the percentage of early- and middle-stage HD patients who were diagnosed by primary care providers (PCPs), neurologists, psychiatrists, or other provider types.

We assessed the association of patients' demographic and clinical characteristics with diagnosing provider type. We also assessed the frequency of post-diagnosis visits with each provider type, stratified by diagnosing provider type. By performing a series of regression models, we estimated the associations between diagnosing provider type and all-cause HCRU and costs including inpatient stays, outpatient visits, and outpatient medications.

Results: There were 429 eligible patients with early- or middle-stage HD in our study. Among those, 48.0% were diagnosed by neurologists, 35.9% by PCPs, 11.7% by psychiatrists, and 4.4% by other provider types. Patients' age and region were significantly associated with the provider type who diagnosed their HD condition. After diagnosis, we found that the number of healthcare visits with neurologists was significantly different by diagnosing providers. We did not find any significant relationships between diagnosing provider and HCRU or costs.

Conclusion: Most patients with early- or middle-stage HD initiated disease management through diagnosis by either a neurologist or PCP. Initial diagnosis by specialists may improve the linkage to care and further management by specialists who may introduce multidisciplinary care.

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1. INTRODUCTION

Huntington's Disease (HD) is a progressive neurodegenerative disorder with a prevalence of 6.5 cases per 100,000 persons and an incidence of 1.2 cases per 100,000 person-years in the United States in 2016.[1] It is estimated that the mean annual direct cost of HD is $35,579 and the indirect cost is $90,187 in the United States in 2022.[2] HD is caused by a cytosine-adenine-guanine (CAG) trinucleotide repeat expansion in the huntingtin gene (HTT) on chromosome 4p.[3] There is no current cure for HD, and the treatments available do not stop or delay disease progression. Therefore, gold standard patient care involves symptom management to improve patient's quality of life (QoL).

Patients with HD show various symptoms ranging from movement impairments to cognitive and psychiatric symptoms. Some of the most common motor symptoms are chorea, dystonia, and bradykinesia.[4] Many psychiatric symptoms such as depression, anxiety, and apathy prevail throughout patient disease journey, even occurring in premanifest HD.[5] Previous studies have shown that pre-diagnosed patients with psychiatric symptoms are at an increased risk of death by suicide.[6,7] Given a broad range of early symptoms of HD, the role of diagnosing providers is important to detect the condition and ensure patients receive an appropriate care at the beginning of their disease journey.

HD patients are diagnosed and managed by different types of healthcare providers depending on their pre-diagnosis symptoms. Primary care physicians (PCP) often recognize their symptoms first and may refer patients to specialists for further genetic testing and symptom assessment to confirm the diagnosis of HD.[8] After diagnosis, a wide range of HD symptoms can be best managed in specialist multidisciplinary clinics.[9] Neurologists and psychiatrists often serve as overall care coordinator for HD patients, whereas psychologists provide appropriate counseling about grief and family support.[10]

On top of the aforementioned importance of HD patient's initial diagnosis and the value of specialists in patient care, the type of healthcare providers who manage patients can determine the disease prognosis and healthcare utilizations, as shown in other disease conditions. For example, patients with chronic pancreatitis were more likely to adhere to alcohol cessation when followed by pancreas specialists than PCP, and patients with asthma were found to have

significantly improved outcomes when managed by asthma specialists compared to PCP.[11,12] There is a lack of understanding of which providers diagnose and manage HD patients, and if the type of diagnosing provider is associated with different healthcare utilization patterns among HD patients. We hypothesized that patients with early- or middle-stage HD diagnosed by PCPs receive different post-diagnosis care compared to patients who were diagnosed by a specialist. Understanding the healthcare provider landscape, healthcare resource utilization (HCRU), and cost of managing HD will aid in filling the gaps in current literature.

2. METHODS

2.1 Study Design and Data Source

We conducted a retrospective, cross-sectional, descriptive study, using the Merative MarketScan® Commercial Claims database. We sought to describe the distribution of providers who first diagnose patients with early- or middle-stage HD and those who manage them for the first 6 months after diagnosis. We further evaluated patient HCRU and costs associated with different diagnosing provider types.

The study period was from January 1st, 2017 through December 31st, 2021 **(Figure 1)**. The index date was defined as the first date when either an outpatient or inpatient claim included the ICD-10 code for HD (G10) in any diagnosis variable. If the setting of diagnosis was inpatient, the date of discharge was chosen as the index date. Patients were required to have continuous enrollment 6 months prior to and 6 months after the index date.

At the time of the analysis, MarketScan data met Health Insurance Portability and Accountability Act of 1996 (HIPAA) requirements for fully de-identified data sets.[13] Institutional Review Board (IRB) approval at the University of Washington was not required, as the study met criteria for non-human subjects research as specified by the Human Subjects Division at the University of Washington.

2.2 Inclusion and Exclusion Criteria

Patients 18 years or older who were newly diagnosed with HD between 07/01/2017 and 06/30/2021, defined by the first observation of ICD-10 code G10 after a 6-month period with no

HD diagnoses, were included in the study. Patients with prescription fills for antipsychotics or vesicular monoamine transporter type 2 (VMAT2) inhibitors in the 6 months prior to the index date were excluded. We also excluded patients who were identified as being in late-stage HD, based on the previously published algorithm that was developed to identify HD stages in the MarketScan data.[14] The algorithm defines anyone with the following claims to be in late-stage HD: use of nursing home care, use of a feeding tube, incontinence, bedsores, use of hospice care, two or more falls within 1 month, or dysphagia. In addition, we excluded any claims with missing or uninterpretable provider type information. Uninterpretable provider types were those without specific type of provider, such as facilities like "acute care hospital" or "urgent care facility", and services like "radiology" or "laboratory".

2.3 VARIABLES OF INTEREST

2.3.1 *Baseline Demographics and Clinical Characteristics*

We assessed all baseline demographics including age, sex, region, and health plan type on the index date. "AGE" was a continuous variable measured in years, "SEX" was a binary variable consisting of male or female, and "REGION" was a categorical variable that tells the geographic region of patient residence (northeast, north central, south, or west). The definition for each health plan type in "PLANTYP" was derived from the *MarketScan Commercial Claims and Encounters Users Guide*.[15] We created a binary classification of nine plan types based on their requirement for PCP referral for specialty care. We defined the setting of diagnosis on the index date to be either inpatient or outpatient. Finally, we calculated a Charlson Comorbidity Index (CCI) using ICD-10 diagnosis codes collected during the 6-month pre-index period.[16-18]

2.3.2 *Diagnosing and Managing Provider Types*

The types of providers of interest were PCP, neurologist, and psychiatrist. We grouped other types of providers, such as gynecologists or pulmonologists, as "other". Provider type was identified using the MarketScan's variable "STDPROV".

We defined the diagnosing provider type as the provider type seen for the visit on each patient's index date. If a patient had multiple claims on the index date, we used the MarketScan

variable “SEQNUM”, which tells us the numerical sequence of every record, to identify which claim took place first to identify the initial diagnosing provider.

We defined the managing providers as the providers in any claims during the 6-month follow-up period.

2.3.3 *Healthcare Resource Utilization*

We calculated the all-cause inpatient length of stay by counting the total number of days of hospitalization during the first 6 months of diagnosis. We also calculated the number of unique hospitalizations, the number of unique days with an outpatient visit, and the number of unique outpatient drugs that a patient received during the first 6 months of diagnosis, regardless of their indication.

2.3.4 *Healthcare Costs*

We defined total healthcare costs as the sum of inpatient service costs, outpatient service costs, and outpatient pharmaceutical costs. We adjusted the costs for inflation using the medical care component of the consumer price index to reflect the inflated costs in 2022 US Dollars.

We listed all Market Scan variables used in our analysis and their definition in **Appendix 1**.

2.4 Descriptive Analysis

We summarized baseline demographics and clinical characteristics with mean and standard deviation (SD) for continuous variables and count and percentage for categorical variables.

2.5 Statistical Analysis

We first compared the proportion of patients who were first diagnosed with HD by PCP, neurologist, or psychiatrist using chi-square goodness-of-fit test. We then assessed the difference in the mean number of encounters with each provider type during the follow-up period stratified by diagnosing provider type using one-way analysis of variance (ANOVA) test.

To assess the association between baseline characteristics and diagnosing provider type, we used a multinomial logistic regression with diagnosing provider type as the outcome and

patient baseline characteristics (sex, age, setting of diagnosis, health plan type, and CCI) as predictors.[19]

Prior to performing a regression analysis to test the association between diagnosing provider and the outcomes, we evaluated the distributions for our four HCRU and cost outcomes to determine the appropriate regression models. For count-based outcomes (inpatient hospitalizations, inpatient length of stay, outpatient visit days, and number of unique outpatient drugs), we first estimated the proportion of claims with zero counts. We also evaluated the overdispersion of the outcome variables to choose between Poisson and negative binomial distributions. Given the significant overdispersion of outcome variables and higher goodness-of-fit score with a negative binomial model, we assumed negative binomial distribution on the count-based outcome variables [20,21,22] For the cost outcomes, we assumed a gamma distribution due to the typical distribution of health care costs in chronic diseases.

First, we constructed two-part models to compare the estimated mean inpatient length of stay and the number of unique hospitalizations among patients who were diagnosed by different provider types. In the first part of the model, we performed a logistic regression to estimate the probability of patients having a hospitalization. In the second part, we performed a generalized linear regression with negative binomial distribution to compare the estimated inpatient length of stay conditional on being hospitalized. We adjusted for all patient baseline characteristics.

Second, we ran multivariable generalized linear regression with negative binomial distribution to compare the estimated mean days of outpatient visits and the mean number of unique outpatient drugs among patients diagnosed by different provider types. We included hospital length of stay as well as patient baseline characteristics as covariates to adjust because patients with long inpatient stays, by definition have less opportunity to utilize outpatient services and prescription claims, which could potentially confound the relationship between diagnosing provider types and outpatient outcomes.

Last, we used a multivariable generalized linear regression with gamma distribution to compare the estimated total costs and total patient out-of-pocket costs among patients diagnosed by different provider types, adjusting for all patient baseline characteristics.

All statistical test results included 95% confidence intervals (CI) and the p-value. Data collection was performed using SAS version 9.4 (SAS Institute, Cary, NC) and all statistical analyses were performed using R 4.2.2 (R Core Team, 2022).

All regression models and their specifications are provided in **Appendix 2**.

3. RESULTS

3.1 BASELINE CHARACTERISTICS

We identified 429 eligible patients with early- or middle-stage HD to be included in the analysis (**Table 1**). The average age was 49 years and 55.7% of the study population were female. Most patients in our study resided in the South (42.2%) and the North central (31.5%) region of the US. 82.5% of them had health plans that did not require PCP referral for specialty visits. 89.0% of them were diagnosed in the outpatient settings. For underlying health comorbidities, 69.9% of them had CCI equal to 0 and 21.1% had CCI greater than or equal to 1.

3.2 DIAGNOSING AND MANAGING PROVIDER TYPES

We found that most patients in our analysis were diagnosed by neurologists (48.0%) and PCPs (35.9%). The rest were diagnosed by psychiatrists and "others" (11.7%, and 4.4%, respectively) (**Table 2**).

We found that patient age and region were statistically significantly associated with diagnosing provider type (**Table 3**). After adjusting for covariates, one-year increase in age was significantly associated with 2% higher odds of being diagnosed by neurologists instead of PCPs (95% CI: 0.00 to 4.00). Also, the odds of being diagnosed by neurologists were 2.77 times higher than that of being diagnosed by PCP for patients in the North central region than patients in the Northeast region, after adjusting for other covariates (95% CI: 1.35 to 5.67).

When we compared the mean number of unique inpatient and outpatient encounters between patients who were diagnosed by different provider types, we found that the number of post-diagnosis visits with neurologists was significantly different by diagnosing providers (p-value: <0.01). The number of post-diagnosis follow-ups with other provider types such as PCPs, psychiatrists, and "others' were not significantly different by diagnosing provider types.

3.3 HEALTHCARE RESOURCE UTILIZATION

When comparing the unadjusted mean estimates, patients diagnosed by psychiatrists showed the highest mean days of inpatient length of stay (2.11 days) and unique count of hospitalizations (0.32), while having the lowest outpatient visits (4.63 visit days) (**Table 4**). Patients diagnosed by neurologists had the lowest mean 6-month total costs ($23,761 neurologists vs. $32,607 PCPs vs. $42,389 psychiatrists). Patients diagnosed by psychiatrists had approximately double the cost paid by health plan, compared to patients diagnosed by either PCPs or neurologists ($33,317 vs. $17,817 vs. $18,074, respectively).

From the binary component of the two-part model, we found that there was no association between the chance of having a hospital stay and diagnosing provider type. (**Table 5**). Among the patients with hospitalizations, we did not find an association between diagnosing provider type and the length of hospital stay. We found patients with CCI of 2 or 3+ had significantly higher rate ratio of hospital length of stay compared to those with CCI of 0 (CCI 2: 9.09, CCI 3+: 5.77). We also did not find an association between diagnosing provider type and the number of unique hospitalizations (**Table 7**).

Patients diagnosed by psychiatrists had significantly fewer outpatient visits than those diagnosed by PCPs (rate ratio: 0.48; 95% CI: 0.26 to 0.95) (**Table 6**). Also, patients with health plans not requiring PCP referral for specialist visits had significantly lower rates of outpatient visits than those that required PCP referral (rate ratio: 0.60; 95% CI: 0.43 to 0.85).

We did not find any significant association between diagnosing provider type and the number of unique outpatient drugs (**Table 8**). We found that after adjusting for covariates, patients with CCI greater than 0 had a significantly higher number of unique outpatient medications than those with CCI score of 0 (all p-values: <0.01).

3.4 HEALTHCARE COSTS

After adjusting for covariates, there was no difference in either total cost or patient out-of-pocket cost among patients diagnosed by different provider types (**Table 9 & 10**). We found that the adjusted estimated total cost was $102,187 higher for the sickest patients with CCI score greater than 3 than those with CCI score of 0 (95% CI: $37,728 to $166,646; p-value < 0.01). The adjusted estimated out-of-pocket cost was $949 lower for patients with health plans that do

not require PCP referral than those with PCP referral requirements (95% CI: -$1,497 to -$400; p-value < 0.01).

4. DISCUSSION

We conducted a retrospective, cross-sectional study to describe the distribution of types of providers who diagnose and manage patients with early- or middle-stage HD. Almost half of our study population was diagnosed by neurologists. Given that chorea, a neurological disorder, is the most prominent symptom in early- and middle- stage HD, abnormal movements are likely to be assessed and diagnosed by neurologists.[23,24] On the other hand, about a third of HD patients were diagnosed by PCPs. Patients with more general symptoms such as vertigo or headache/migraine may be readily assessed by PCPs.[25]

We did not find any meaningful association between patients' demographic and clinical characteristics and the type of diagnosing providers, except for age and region. Older HD patients may be more frequently diagnosed by neurologists than PCPs, which is consistent with an increased burden of overall neurologic conditions in older adults.[26] Our study also suggests that insurance requirements of PCP referrals for specialty care is not associated with the type of providers who diagnose early- or middle-stage HD patients. It is possible that patients with easily visible symptoms such as dystonia or abnormal eye movements were subject to a direct diagnosis by PCPs without being referred to specialists.[27,28]

We found a significant association between the type of initial diagnosing provider and the providers who managed post-diagnosis cares. In particular, patients diagnosed by one provider type were followed by the same type of provider after diagnosis. This may imply that patients who were diagnosed by specialists have more access to post-diagnosis care managed by specialists. Routine follow-up visits with specialists are important for patients as the *Physician's Guide to the Management of Huntington's Disease the Third Edition* suggests a neurologist or psychiatrist to be the overall care coordinator in management of HD.[29] In addition, given that the genetic testing protocol from the *Huntington's Disease Society of America* (HDSA) suggests a comprehensive discussion and thorough counseling before confirming the diagnosis, patients are encouraged to visit specialists for additional resources to support psychological and societal

burden of HD diagnosis.[10] A 2022 study by Leeberger L, et al. also found that practices led by neurologists were better equipped to provide multi-disciplinary care.[30]

Despite the association between the initial diagnosing provider type and the providers treating the patients for the next six months after diagnosis, we did not find any differential trend in HCRU by the diagnosing provider types. Patients diagnosed by neurologists generally showed lower utilization compared to those diagnosed by PCPs after adjusting for covariates. Moreover, the estimated mean total cost during 6-month follow-up period for patients diagnosed by PCPs was $12,476, and it was $2,352 lower for those diagnosed by neurologists, but $24,175 higher for those diagnosed by psychiatrists, after adjusting for covariates. However, none of the results were statistically significant. Considering that our study observed healthcare visits for the first six months after diagnosis, patients in earlier stages of HD may not yet present complicated symptoms and receive similar post-diagnosis cares such as disease burden education or treatment for mild unusual movements, regardless of diagnosing provider type.[30]

Our study has several limitations. Our study population may not be generalizable to the broader HD patient population, as the MarketScan dataset only includes those with employer-covered insurance. Had we included patients with Medicaid in our study, our results may have looked different as patients with Medicaid have vastly different HCRU.[31] Another limitation is that we assessed all-cause HCRU instead of HD-related HCRU, therefore we cannot interpret our HCRU and cost results to be attributable to HD. We used all-cause HCRU due to the limited number of post-diagnosis observations. Lastly, HCRU may look different in the longer follow-up period, as it may take longer time to observe the impact of the diagnosing provider type on patient care. Longer follow-up time would allow further progression of HD, potentially yielding higher HCRU.[32,33] However, the symptoms among patients with late-stage HD would likely be managed by specialists, regardless of diagnosing provider type. Hence, our result on no significant difference in post-diagnosis HCRU by diagnosing provider type may persist even with a longer follow-up period.

Our study characterized the landscape of diagnosing and managing providers for patients with early- or middle-stage HD. Our results emphasized the important role of neurologists and PCPs in capturing the early symptoms of HD. Neurologists have the potential to improve post-diagnosis HD care by offering continuous and multidisciplinary care.

5. CONCLUSION

Most HD patients were diagnosed by neurologists or PCPs and had different patterns of follow-up care based on the diagnosing provider. We did not find any significant trend in overall HCRU or costs between different types of diagnosing provider. Further studies should assess both overall and HD-specific HCRU among HD patients to capture a more granular scope of patient burden associated with diagnosing provider.

6. TABLES

Table 1. Baseline Demographics and Clinical Characteristics					
	All HD Patients	**Diagnosing Provider Types**			
		PCP	Neurologist	Psychiatrist	Others*
Counts	429	154	206	19	50
Age (years), mean (SD)	49.0 (11.4)	48.1 (11.4)	50.7 (10.7)	45.5 (13.4)	45.9 (12.7)
Female, n (%)	239 (55.7)	82 (53.2)	114 (55.3)	11 (57.9)	32 (64.0)
Region, n (%)					
Northeast	67 (15.6)	22 (14.3)	27 (13.1)	4 (21.1)	14 (28.0)
North central	135 (31.5)	27 (17.5)	94 (45.6)	6 (31.6)	8 (16.0)
South	181 (42.2)	82 (53.2)	68 (33.0)	7 (36.8)	24 (48.0)
West	46 (10.7)	23 (14.9)	17 (8.3)	2 (10.5)	4 (8.0)
Health plan**, n (%)					
PCP referral required	75 (17.5)	29 (18.8)	30 (14.6)	4 (21.1)	12 (24.0)
PCP referral not required	354 (82.5)	125 (81.2)	176 (85.4)	15 (78.9)	38 (76.0)
Diagnosis setting, n (%)					
Inpatient	47 (11.0)	13 (8.4)	25 (12.1)	3 (15.8)	6 (12.0)
Outpatient	382 (89.0)	141 (91.6)	181 (87.9)	16 (84.2)	44 (88.0)
CCI					
0	300 (69.9)	115 (74.7)	140 (68.0)	15 (78.9)	30 (60.0)
1	59 (13.8)	20 (13.0)	28 (13.6)	1 (5.3)	10 (20.0)
2	34 (7.9)	7 (4.5)	21 (10.2)	2 (10.5)	4 (8.0)
3+	36 (8.4)	12 (7.8)	17 (8.3)	1 (5.3)	6 (12.0)

*Other providers include various specialists like hematologists, pulmonologists, nephrologists, gynecologists, etc.
**PCP referral required health plans: HMO/EPO, POS; PCP referral not required health plans: Basic/Comprehensive, PPO, HDHP
PCP: primary care physician; CCI: Charlson comorbidity index; HMO: health maintenance organization; EPO: exclusive provider organization; POS: point-of-service; PPO: preferred provider organization; HDHP: high deductible health plan; CCI: Charlson comorbidity index

Table 2. Managing Provider Types During 6-month Follow-up					
	Diagnosing Provider Types				
	PCP	Neurologist	Psychiatrist	Others	p-value*
Number of diagnosed patients, n (%)	154 (35.9)	206 (48.0)	19 (4.4)	50 (11.7)	<0.01
Unique Encounters, mean					
PCP	3.66	2.85	2.58	1.58	0.13
Neurologists	0.25	1.41	0.21	0.42	<0.01
Psychiatrists	0.42	0.31	2.00	0.26	0.06
Others – total†	5.99	4.62	6.05	8.52	0.22
Others with PCP	2.16	1.05	0.58	0.50	
Others with Neurologists	0.11	0.35	0.05	0.06	
Others with Psychiatrists	0.05	0.05	0.11	0.04	

*Chi-square goodness-of-fit test for number of diagnosed patients and ANOVA test for unique encounters
†Not mutually exclusive
PCP: primary care physician

Table 3. Results from the multinomial logistic regression for diagnosing provider type (outcome) and various patient factors (independent variables)							
Independent variables	PCP	Neurologist		Psychiatrist		Others	
		OR	95% CI	OR	95% CI	OR	95% CI
Intercept		0.48	(0.11, 2.05)	0.94	(0.07, 13.46)	1.34	(0.20, 9.00)
Age		1.02	(1.00, 1.04)	0.98	(0.94, 1.02)	0.97	(0.94, 1.00)
Sex							
Male		Ref.		Ref.		Ref.	
Female		1.26	(0.81, 1.96)	1.39	(0.52, 3.72)	1.63	(0.83, 3.21)
Region							
Northeast		Ref.		Ref.		Ref.	
North central		2.77	(1.35, 5.67)	1.20	(0.29, 4.92)	0.44	(0.15, 1.28)
South		0.65	(0.34, 1.25)	0.42	(0.11, 1.58)	0.46	(0.20, 1.05)
West		0.60	(0.25, 1.40)	0.45	(0.07, 2.78)	0.23	(0.06, 0.84)
Health plan							
PCP referral required	Ref.	Ref.		Ref.		Ref.	
PCP referral not required		0.81	(0.45, 1.45)	1.19	(0.36, 3.93)	1.38	(0.62, 3.06)
Diagnosing setting							
Inpatient		Ref.		Ref.		Ref.	
Outpatient		1.05	(0.45, 2.46)	0.41	(0.09, 1.96)	0.95	(0.30, 3.03)
CCI							
0		Ref.		Ref.		Ref.	
1		0.84	(0.43, 1.67)	0.33	(0.04, 2.80)	2.29	(0.91, 5.76)
2		1.93	(0.74, 5.05)	2.08	(0.34, 12.87)	3.19	(0.83, 12.31)
3+		0.76	(0.30, 1.92)	0.39	(0.04, 4.20)	2.46	(0.73, 8.29)

PCP: primary care physician; Ref.: reference group; OR: odds ratio; CI: confidence interval

Table 4. Per-patient Healthcare Utilization and Costs for the first 6 month of diagnosis				
	All HD Patients	Diagnosing Provider Types		
		PCP	Neurologist	Psychiatrist
Counts	429	154	206	18
Healthcare utilization				
Inpatient length of stay (days), mean (SD)	0.40 (2.55)	0.37 (3.01)	0.30 (1.49)	2.11 (6.74)
Unique hospitalizations (counts), mean (SD)	0.10 (0.46)	0.09 (0.49)	0.09 (0.35)	0.32 (0.95)
Unique outpatient visits (counts), mean (SD)	9.54 (15.70)	10.60 (20.2)	9.22 (12.20)	4.63 (6.58)
Unique outpatient drugs (counts), mean (SD)	6.86 (6.82)	5.82 (6.27)	7.21 (7.01)	6.26 (5.92)
Costs (2022 USD), mean (SD)				
Total costs*	28,778 (64,882)	32,607 (88,725)	23,761 (40,966)	42,389 (53,815)
Inpatient service	9,350 (34,446)	8,677 (34,840)	7,723 (27,845)	22,790 (52,871)
Outpatient service	15,522 (51,410)	19,552 (80,881)	12,517 (17,595)	13,038 (22,784)
Outpatient Rx	3,906 (12,281)	4,378 (14,802)	3,521 (10,421)	6,560 (18,324)
Paid body*				
Out-of-pocket	2,401 (2,902)	2,200 (2,227)	2,491 (3,199)	3,460 (4,251)
Health plan	23,253 (45,131)	18,074 (40,815)	17,817 (36,362)	33,317 (53,156)

*Includes inpatient services, outpatient services, and outpatient drug costs
PCP: primary care physician

Table 5. Two-part model for length of stay (outcome) and provider type (independent variable)			
	Estimates	95% CI	p-value
Binary component*			
Intercept	0.01	(0.00, 0.08)	
Provider Type			
PCP	Ref.	Ref.	Ref.
Neurologist	1.02	(0.31, 3.38)	0.98
Psychiatrist	5.81	(0.92, 29.83)	0.07
Others	0.90	(0.16, 4.04)	0.90
Negative Binomial model**			
Intercept	0.78	(0.06, 10.40)	
Provider Type			
PCP	Ref.	Ref.	Ref.
Neurologist	1.63	(0.43, 6.21)	0.46
Psychiatrist	1.05	(0.15, 7.92)	0.95
Others	0.38	(0.06, 2.24)	0.26
Sex			
Male	Ref.	Ref.	Ref.
Female	1.41	(0.24, 2.20)	0.56
Region			
Northeast	Ref.	Ref.	Ref.
North central	1.10	(0.31, 3.63)	0.87
South	2.86	(0.74, 11.42)	0.13
West	4.06	(0.48, 36.36)	0.19
Health plan			
PCP referral required	Ref.	Ref.	Ref.
PCP referral not required	1.29	(0.13, 10.97)	0.79
CCI			
0	Ref.	Ref.	Ref.
1	3.39	(0.53, 24.28)	0.22
2	9.09	(1.49, 67.04)	0.03
3+	5.77	(1.49, 26.52)	<0.02
Age	1.00	(0.94, 1.06)	0.97

*Results of logistic regression to estimate the odds ratio of having any days of hospital stay among different diagnosing provider types, after adjusting for covariates.

**Results of negative binomial regression among the patients that have reported any days of hospital stay to estimate the rate ratio of hospital length of stay in days, adjusted for listed covariates.

CI: confidence interval; PCP: primary care physician; Ref: reference group, CCI: Charlson comorbidity index

Table 6. Negative binomial regression for outpatient visits (outcome) and provider type (independent variable)			
	IRR	95% CI	p-value
Unadjusted			
Intercept	10.62	(8.66, 13.18)	
Provider Type			
PCP	Ref.	Ref.	Ref.
Neurologist	0.87	(0.66, 1.15)	0.32
Psychiatrist	0.44	(0.24, 0.88)	0.01
Others	0.89	(0.59, 1.37)	0.57
Adjusted*			
Intercept	7.61	(3.96, 14.96)	
Provider Type			
PCP	Ref.	Ref.	Ref.
Neurologist	0.77	(0.58, 1.03)	0.07
Psychiatrist	0.48	(0.26, 0.95)	0.02
Others	0.85	(0.55, 1.33)	0.44
Sex			
Male	Ref.	Ref.	Ref.
Female	0.98	(0.76, 1.27)	0.88
Region			
Northeast	Ref.	Ref.	Ref.
North central	1.22	(0.81, 1.81)	0.32
South	1.02	(0.69, 1.47)	0.92
West	0.80	(0.49, 1.32)	0.37
Health plan			
PCP referral required	Ref.	Ref.	Ref.
PCP referral not required	0.60	(0.43, 0.85)	<0.01
CCI			
0	Ref.	Ref.	Ref.
1	1.08	(0.75, 1.60)	0.69
2	2.22	(1.43, 3.61)	<0.01
3+	1.22	(0.73, 2.10)	0.85
Age	1.01	(0.99, 1.02)	0.26
LoS	0.93	(0.89, 0.99)	0.02†

*Adjusted: multivariate model, adjusted for sex, age, region, health plan, CCI, LoS

IRR: incident rate ratio; CI: confidence interval; PCP: primary care physician; Ref: reference group, CCI: Charlson comorbidity index; LoS: inpatient length of stay

Table 7. Two-part model for unique hospitalization (outcome) and provider type (independent variable)			
	Estimates	95% CI	p-value
Binary component*			
Intercept	0.01	(0.00, 0.08)	
Provider Type			
PCP	Ref.	Ref.	Ref.
Neurologist	1.02	(0.31, 3.38)	0.98
Psychiatrist	5.81	(0.92, 29.83)	0.07
Others	0.90	(0.16, 4.04)	0.90
Negative binomial model**			
Intercept	0.61	(0.03, 8.07)	
Provider Type			
PCP	Ref.	Ref.	Ref.
Neurologist	0.97	(0.27, 3.43)	0.96
Psychiatrist	1.30	(0.21, 9.43)	0.78
Others	0.78	(0.16, 3.31)	0.74
Sex			
Male	Ref.	Ref.	Ref.
Female	1.60	(0.57, 4.62)	0.37
Region			
Northeast	Ref.	Ref.	Ref.
North central	0.94	(0.30, 3.59)	0.92
South	1.86	(0.55, 7.82)	0.35
West	2.04	(0.29, 15.79)	0.48
Health plan			
PCP referral required	Ref.	Ref.	Ref.
PCP referral not required	0.86	(0.14, 5.16)	0.87
CCI			
0	Ref.	Ref.	Ref.
1	1.95	(0.26, 13.50)	0.50
2	1.79	(0.19, 12.87)	0.58
3+	2.32	(0.69, 9.76)	0.21
Age	1.00	(0.93, 1.07)	0.90

*Results of logistic regression to estimate the odds ratio of having any unique hospitalizations among different diagnosing provider types, after adjusting for covariates.

**Results of Poisson regression among the patients that have reported any hospitalizations to estimate the rate ratio of number of unique hospitalizations, adjusted for listed covariates.

CI: confidence interval; PCP: primary care physician; Ref: reference group, CCI: Charlson comorbidity index

Table 8. Negative binomial regression for unique outpatient drugs (outcome) and provider type (independent variable)			
	IRR	95% CI	p-value
Unadjusted			
Intercept	5.82	(4.93, 6.91)	
Provider Type			
PCP	Ref.	Ref.	Ref.
Neurologist	1.24	(0.99, 1.55)	0.06
Psychiatrist	1.08	(0.66, 1.83)	0.77
Others	1.51	(1.09, 2.13)	0.01
Adjusted*			
Intercept	2.01	(1.23, 3.32)	
Provider Type			
PCP	Ref.	Ref.	Ref.
Neurologist	1.02	(0.83, 1.26)	0.83
Psychiatrist	1.04	(0.66, 1.69)	0.85
Others	1.54	(1.14, 2.10)	<0.01
Sex			
Male	Ref.	Ref.	Ref.
Female	1.26	(1.05, 1.51)	0.01
Region			
Northeast	Ref.	Ref.	Ref.
North central	1.40	(1.05, 1.86)	0.02
South	1.33	(1.02, 1.74)	0.03
West	1.05	(0.73, 1.52)	0.79
Health plan			
PCP referral required	Ref.	Ref.	Ref.
PCP referral not required	0.90	(0.71, 1.15)	0.37
CCI			
0	Ref.	Ref.	Ref.
1	1.73	(1.33, 2.27)	<0.01
2	1.94	(1.39, 2.74)	<0.01
3+	2.97	(2.16, 4.15)	<0.01
Age	1.01	(1.00, 1.02)	0.03
LoS	1.02	(0.98, 1.08)	0.20

*Adjusted: multivariate model, adjusted for sex, age, region, health plan, CCI, LoS

IRR: incident rate ratio; CI: confidence interval; PCP: primary care physician; Ref: reference group, CCI: Charlson comorbidity index; LoS: inpatient length of stay

Table 9. Generalized linear model with gamma distribution for total costs (outcome) and provider type (independent variable)			
	Marginal Effects*	95% CI	p-value
Unadjusted			
Intercept†	32,607	(23,670, 46,671)	
Provider Type			
PCP	Ref.	Ref.	
Neurologist	-8,846	(-21,887, 4,195)	0.17
Psychiatrist	9,782	(-32,518, 51,082)	0.62
Others	-128	(-22,348, 22,093)	0.99
Adjusted**			
Intercept†	12,476	(5,230, 31,257)	
Provider Type			
PCP	Ref.	Ref.	Ref.
Neurologist	-2,352	(-11,937, 7,234)	0.63
Psychiatrist	24,175	(-14,753, 63,103)	0.12
Others	6,581	(-10,771, 23,933)	0.43
Sex			
Male	Ref.	Ref.	Ref.
Female	3,184	(-5,611, 11,979)	0.48
Region			
Northeast	Ref.	Ref.	Ref.
North central	-3,377	(-18,809, 12,055)	0.66
South	-6,380	(-20,653, 7,893)	0.35
West	-4,017	(-22,668, 14,634)	0.68
Health plan			
PCP referral required	Ref.	Ref.	Ref.
PCP referral not required	1,848	(-10,295, 13,992)	0.76
CCI			
0	Ref.	Ref.	Ref.
1	4,290	(-5,885, 14,465)	0.38
2	9,318	(-6,410, 25,046)	0.17
3+	102,187	(37,728, 166,646)	<0.01
Age	245	(-171, 660)	0.24

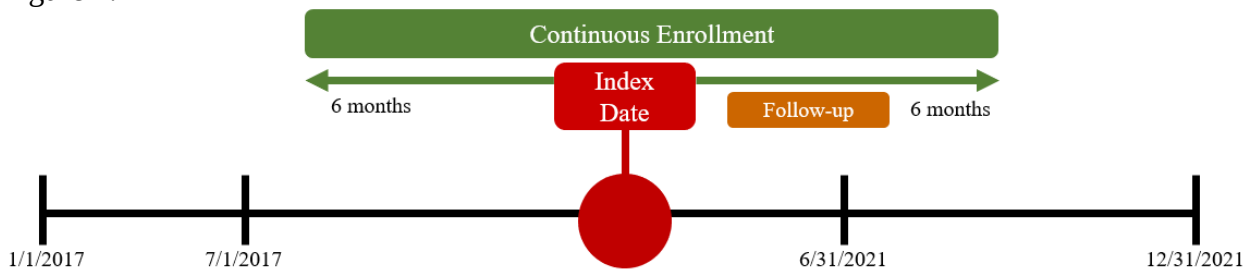
*Marginal effects represent the amount of change in costs by each category relative to the reference group for categorical variables. For continuous variables, it represents the amount of change in total costs by one unit change of independent variable.
**Adjusted: multivariate model, adjusted for sex, age, region, health plan, CCI
†Intercepts represent the total estimated cost for the baseline reference group.
CI: confidence interval; PCP: primary care physician; Ref: reference group; CCI: Charlson comorbidity index

Table 10. Generalized linear model with gamma distribution for out-of-pocket costs (outcome) and provider type (independent variable)			
	Marginal Effects*	95% CI	p-value
Unadjusted			
Intercept†	2,200	(1,834, 2,670)	
Provider Type			
PCP	Ref.	Ref.	Ref.
Neurologist	291	(-287, 868)	0.33
Psychiatrist	1,259	(-634, 3,153)	0.12
Others	44	(-802, 891)	0.92
Adjusted**			
Intercept†	1,852	(963, 3,652)	
Provider Type			
PCP	Ref.	Ref.	Ref.
Neurologist	351	(-260, 961)	0.26
Psychiatrist	1,257	(-643, 3,156)	0.12
Others	66	(-798, 929)	0.88
Sex			
Male	Ref.	Ref.	Ref.
Female	386	(-158, 929)	0.17
Region			
Northeast	Ref.	Ref.	Ref.
North central	-253	(-1,114, 609)	0.56
South	117	(-733, 967)	0.79
West	-389	(-1,410, 632)	0.46
Health plan			
PCP referral required	Ref.	Ref.	Ref.
PCP referral not required	-949	(-1,497, -400)	<0.01
CCI			
0	Ref.	Ref.	Ref.
1	-237	(-1,003, 529)	0.56
2	-231	(-1,196, 735)	0.65
3+	537	(-693, 1,768)	0.35
Age	8	(-17, 33)	0.54

*Marginal effects represent the amount of change in costs by each category relative to the reference group for categorical variables. For continuous variables, it represents the amount of change in total costs by one unit change of independent variable.
**Adjusted: multivariate model, adjusted for sex, age, region, health plan, CCI
†Intercepts represent the total estimated cost for the baseline reference group.
CI: confidence interval; PCP: primary care physician; Ref: reference group; CCI: Charlson comorbidity index;

7. FIGURES

Figure 1.



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9. APPENDIX

Appendix 1.

Table S1. MarketScan variables of interest

Variable	Name	Reason
Inpatient Services		
ENROLID	Enrollee ID	Unique patient identifier
AGE	Age of patient	Baseline characteristics
SEX	Gender of patient	Baseline characteristics
REGION	Region	Baseline characteristics
PLANTYP	Plan indicator	Baseline characteristics
ADMDATE	Date of admission	Identify index date
DAYS	Length of stay	Identify length of stay
DSTATUS	Discharge status	Exclusion criteria – hospice (2 SNF, 50/51 hospice)
DX1	Diagnosis code 1	HD diagnosis
DX2	Diagnosis code 2	HD diagnosis
DX3	Diagnosis code 3	HD diagnosis
DX4	Diagnosis code 4	HD diagnosis
PAY	Payment	Gross payment to a provider for a service
NETPAY	Payments Net	Identify payment made by health plan
COPAY	Copayment	Identify copayment amount
COINS	Coinsurance	Identify coinsurance amount
DEDUCT	Deductible	Identify deductible amount
COB	COB and Other Savings	Identify savings amount
STDPROV	Provider type	Identify type of provider
SEQNUM	Sequence name	Sequence of unique identifier
Outpatient Services		
ENROLID	Enrollee ID	Unique patient identifier
AGE	Age of patient	Baseline characteristics
SEX	Gender of patient	Baseline characteristics
REGION	Region	Baseline characteristics
PLANTYP	Plan Indicator	Baseline characteristics
DX1	Diagnosis code 1	HD diagnosis
DX2	Diagnosis code 2	HD diagnosis
DX3	Diagnosis code 3	HD diagnosis
DX4	Diagnosis code 4	HD diagnosis
SVCDATE	Date service incurred	Identify index date
PAY	Payment	Gross payment to a provider for a service
NETPAY	Payments Net	Identify payment made by health plan
COPAY	Copayment	Identify copayment amount
COINS	Coinsurance	Identify coinsurance amount
DEDUCT	Deductible	Identify deductible amount

COB	COB and Other Savings	Identify savings amount
STDPROV	Provider type	Identify type of provider
SEQNUM	Sequence name	Sequence of unique identifier
Outpatient Pharmaceutical Claims		
ENROLID	Enrollee ID	Unique patient identifier
SVCDATE	Date service incurred	Identify index date
PAY	Payment	Gross payment to a provider for a service
NETPAY	Payments Net	Identify payment made by health plan
COPAY	Copayment	Identify copayment amount
COINS	Coinsurance	Identify coinsurance amount
DEDUCT	Deductible	Identify deductible amount
COB	COB and Other Savings	Identify savings amount
THERCLS	Therapeutic class	Identify class of medication
NDCNUM	National drug code	Identify name of medication

Table S2. Outcomes Definition using MarketScan variables

Outcome	**MarketScan Variables**	**Definition**
Baseline Demographics and Clinical Characteristics		
Health plan type	PLANTYP	Requires PCP referral for specialty care: *HMO, EPO, POS* Does not require PCP referral for specialty care: *Basic, Comprehensive, PPO, CHDP, HDHP*
Diagnosing and Managing Provider Types		
Provider type	STDPROV	PCP: 200 (medical doctor), 204 (internal medicine), 206 (multispecialty physician group), 240 (family practice), 245 (geriatric medicine), 400 (pediatrician), 825 (nurse practitioner), 845 (physician assistant) Neurologist: 260 (neurology) Psychiatrist: 365 (psychiatry)
Healthcare Costs		
Total cost	PAY	Gross payment to a provider for a service
Out-of-pocket cost	COPAY, COINS, DEDUCT	COPAY + COINS + DEDUCT
Health plan cost	NETPAY	Payment made by health plan

Table S3. HD-Related Medications

Medication Name*	Therapeutic Drug Class	Generic Product ID (GENNME**)
Tetrabenazine	VMAT2i	Tetrabenazine
Deutetrabenazine	VMAT2i	Deutetrabenazine Deutetrabenazine;Deutetrabenazine
Valbenazine	VMAT2i	Valbenazine Valbenazine;Valbenazine
Risperidone	SGA	Risperidone
Olanzapine	SGA	Olanzapine
Aripiprazole	SGA	Aripiprazole
Haloperidol	FGA	Haloperidol
Fluphenazine	FGA	Fluphenazine Hydrochloride
Clonazepam	Benzodiazepine	Clonazepam
Lorazepam	Benzodiazepine	Lorazepam

*Selected based on International Guidelines for the Treatment of Huntington's Disease[34]
**MarketScan variables

Appendix 2. Regression model specification

A. Multinomial logistic regression model for Table 3.

Ho: $\beta_{all} = 0$

There is no association between the selected patient and the type of diagnosing physician.

Ha: $\beta_{HMO/EPO} > 0$

The *HMO/EPO* health plan is associated with higher odds of being diagnosed by PCP.

$E(Yi|Xi) = \beta_{sex}X_{sex} + \beta_{setting}X_{setting} + \beta_{age}X_{age} + \beta_{region}X_{region} + \beta_{healthplan}X_{healthplan} + \beta_{CCI}X_{CCI}$

Y = type of diagnosing physician type (categorical; 0 = PCP, 1 = neurologist, 2 = psychiatrist)

X_{sex} = gender of patient (binary; 0 = male, 1 = female)

$X_{setting}$ = setting of diagnosis (binary; 0 = inpatient, 1 = outpatient)

X_{age} = age of patient (continuous; years)

X_{region} = region of patient (categorical; 0 = northeast, 1 = north central, 2 = south, 3 = west, 4 = unknown)

$X_{healthplan}$ = type of healthplan (binary; 0 = requires PCP referral, 1 = does not require PCP referral)

X_{CCI} = Charlson Comorbidity Index (ordinal; 0, 1, 2, 3+)

B. Two-part model with logistic regression and generalized linear regression with negative binomial distribution for Table 5.

Ho: $\beta_{provider} = 0$

There is no association between per-patient mean inpatient length of stay during the first 6 months after diagnosis and the type of diagnosing provider.

Ha: $\beta_{provider} < 0$

The per-patient mean inpatient length of stay during the first 6 months after diagnosis is lower in patients first diagnosed by specialists than those diagnosed by primary care physicians.

$E(Yi|Xi) = \beta_{provider}X_{provider} + \beta_{sex}X_{sex} + \beta_{age}X_{age} + \beta_{region}X_{region} + \beta_{healthplan}X_{healthplan} + \beta_{CCI}X_{CCI}$

Y = per-patient mean inpatient length of stay during the first 6 months of diagnosis (continuous; days)

$X_{provider}$ = type of diagnosing physician type (categorical; 0 = PCP, 1 = neurologist, 2 = psychiatrist)

X_{sex} = gender of patient (binary; 0 = male, 1 = female)

X_{age} = age of patient (continuous; years)

X_{region} = region of patient (categorical; 0 = northeast, 1 = north central, 2 = south, 3 = west, 4 = unknown)

$X_{healthplan}$ = type of healthplan (binary; 0 = requires PCP referral, 1 = does not require PCP referral)

X_{CCI} = Charlson Comorbidity Index (ordinal; 0, 1, 2, 3+)

C. Multivariable generalized linear regression with negative binomial distribution for Table 6.

Ho: $\beta_{provider} = 0$

There is no association between mean counts of outpatient visit during the first 6 months after diagnosis and the type of diagnosing provider.

Ha: $\beta_{provider} < 0$

The mean counts of outpatient visit during the first 6 months after diagnosis is lower in patients first diagnosed by specialists than those diagnosed by primary care physicians.

$E(Yi|Xi) = \beta_{provider}X_{provider} + \beta_{sex}X_{sex} + \beta_{age}X_{age} + \beta_{region}X_{region} + \beta_{healthplan}X_{healthplan} + \beta_{CCI}X_{CCI} + \beta_{inpatient}X_{inpatient}$

Y = mean counts of outpatient visit during the first 6 months of diagnosis (continuous; days)

X_{sex} = type of diagnosing physician type (categorical; 0 = PCP, 1 = neurologist, 2 = psychiatrist)

X_{sex} = gender of patient (binary; 0 = male, 1 = female)

X_{age} = age of patient (continuous; years)

X_{region} = region of patient (categorical; 0 = northeast, 1 = north central, 2 = south, 3 = west, 4 = unknown)

$X_{healthplan}$ = type of healthplan (binary; 0 = requires PCP referral, 1 = does not require PCP referral)

X_{CCI} = Charlson Comorbidity Index (ordinal; 0, 1, 2, 3+)

$X_{inpatient}$ = inpatient length of stay (continuous, days)

D. Two-part model with logistic regression and generalized linear regression with negative binomial distribution for Table 7.

Ho: $\beta_{provider} = 0$

There is no association between the mean number of unique hospitalizations during the first 6 months after diagnosis and the type of diagnosing provider.

Ha: $\beta_{provider} < 0$

The number of unique hospitalizations during the first 6 months after diagnosis is lower in patients first diagnosed by specialists than those diagnosed by primary care physicians.

$E(Yi|Xi) = \beta_{provider}X_{provider} + \beta_{sex}X_{sex} + \beta_{age}X_{age} + \beta_{region}X_{region} + \beta_{healthplan}X_{healthplan} + \beta_{CCI}X_{CCI}$

Y = mean number of unique hospitalizations during the first 6 months of diagnosis (continuous; days)

X_{sex} = type of diagnosing physician type (categorical; 0 = PCP, 1 = neurologist, 2 = psychiatrist)

X_{sex} = gender of patient (binary; 0 = male, 1 = female)

X_{age} = age of patient (continuous; years)

X_{region} = region of patient (categorical; 0 = northeast, 1 = north central, 2 = south, 3 = west, 4 = unknown)

$X_{healthplan}$ = type of healthplan (binary; 0 = requires PCP referral, 1 = does not require PCP referral)

X_{CCI} = Charlson Comorbidity Index (ordinal; 0, 1, 2, 3+)

E. Multivariable generalized linear regression with negative binomial distribution for Table 8.

Ho: $\beta_{provider} = 0$

There is no association between mean number of unique outpatient drugs during the first 6 months after diagnosis and the type of diagnosing provider.

Ha: $\beta_{provider} < 0$

The mean number of unique outpatient drugs during the first 6 months after diagnosis is lower in patients first diagnosed by specialists than those diagnosed by primary care physicians.

$E(Yi|Xi) = \beta_{provider}X_{provider} + \beta_{sex}X_{sex} + \beta_{age}X_{age} + \beta_{region}X_{region} + \beta_{healthplan}X_{healthplan} + \beta_{CCI}X_{CCI} + \beta_{inpatient}X_{inpatient}$

Y = mean number of unique outpatient drugs during the first 6 months of diagnosis (continuous)

X_{sex} = type of diagnosing physician type (categorical; 0 = PCP, 1 = neurologist, 2 = psychiatrist)

X_{sex} = gender of patient (binary; 0 = male, 1 = female)

X_{age} = age of patient (continuous; years)

X_{region} = region of patient (categorical; 0 = northeast, 1 = north central, 2 = south, 3 = west, 4 = unknown)

$X_{healthplan}$ = type of healthplan (binary; 0 = requires PCP referral, 1 = does not require PCP referral)

X_{CCI} = Charlson Comorbidity Index (ordinal; 0, 1, 2, 3+)

$X_{inpatient}$ = inpatient length of stay (continuous, days)

F. Multivariable generalized linear regression with gamma distribution for Table 9.

Ho: $\beta_{provider} = 0$

There is no association between mean total costs during the first 6 months after diagnosis and the type of diagnosing provider.

Ha: $\beta_{provider} > 0$

The mean total costs during the first 6 months after diagnosis are higher in patients first diagnosed by specialists than those diagnosed by primary care physicians.

$E(Yi|Xi) = \beta_{provider}X_{provider} + \beta_{sex}X_{sex} + \beta_{age}X_{age} + \beta_{region}X_{region} + \beta_{healthplan}X_{healthplan} + \beta_{CCI}X_{CCI}$

Y = mean total health care cost during the first six months of diagnosis (continuous; US dollars)

$X_{provider}$ = type of diagnosing physician type (categorical; 0 = PCP, 1 = neurologist, 2 = psychiatrist)

X_{sex} = gender of patient (binary; 0 = male, 1 = female)

X_{age} = age of patient (continuous; years)

X_{region} = region of patient (categorical; 0 = northeast, 1 = north central, 2 = south, 3 = west, 4 = unknown)

$X_{healthplan}$ = type of healthplan (binary; 0 = requires PCP referral, 1 = does not require PCP referral)

X_{CCI} = Charlson Comorbidity Index (ordinal; 0, 1, 2, 3+)

G. Multivariable generalized linear regression with gamma distribution for Table 10.

Ho: $\beta_{provider} = 0$

There is no association between patient out-of-pocket mean costs during the first 6 months after diagnosis and the type of diagnosing provider.

Ha: $\beta_{provider} > 0$

The patient out-of-pocket mean costs during the first 6 months after diagnosis are higher in patients first diagnosed by specialists than those diagnosed by primary care physicians.

$E(Yi|Xi) = \beta_{provider}X_{provider} + \beta_{sex}X_{sex} + \beta_{age}X_{age} + \beta_{region}X_{region} + \beta_{healthplan}X_{healthplan} + \beta_{CCI}X_{CCI}$

Y = mean out-of-pocket costs during the first 6 months of diagnosis (continuous; US dollars)

$X_{provider}$ = type of diagnosing physician type (categorical; 0 = PCP, 1 = neurologist, 2 = psychiatrist)

X_{sex} = gender of patient (binary; 0 = male, 1 = female)

X_{age} = age of patient (continuous; years)

X_{region} = region of patient (categorical; 0 = northeast, 1 = north central, 2 = south, 3 = west, 4 = unknown)

$X_{healthplan}$ = type of healthplan (binary; 0 = requires PCP referral, 1 = does not require PCP referral)

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