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Potentially Preventable Hospitalizations in Medicare Patients with Diabetes: a Comparison of Primary Care Provided by Nurse Practitioners versus Physicians

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Abstract

Background—Few comparisons exist of the quality of primary care provided by nurse practitioners (NPs) versus physicians.

Methods—Patients with a diagnosis of diabetes in 2007–2010 (n=345,819) who received all primary care from NPs or from generalist physicians in a given year were selected from a national sample of Medicare beneficiaries. We compared the rate of potentially preventable hospitalizations among patients who received primary care from NPs versus generalist physicians. Various statistical methods—including multivariable analysis, inverse probability weighting of propensity score, non-pooling propensity score adjustment and matching, and instrumental variable (IV) analysis—were used to control for differences in patient characteristics between the two groups.

Results—Patients who received all of their primary care from NPs or from physicians differed by age, gender, race/ethnicity, socioeconomic status, residential area and number of provider visits in the previous year. Non-pooling propensity matching substantially reduced the differences, but neither IV approach satisfactorily reduced the differences. In multivariable analyses, receipt of primary care from an NP was associated with a decreased risk of hospitalization for potentially preventable conditions (OR: 0.90, 95%CI=0.87–0.93). Similar results were found using conditional logistic regression models with propensity methods. We found smaller reductions in our analyses of “other hospitalizations” (OR: 0.96, 95%CI=0.95–0.98). Both IV analyses showed associations between NP care and lower potentially preventable hospitalizations, but only one result was statistically significant.

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Conclusion—Using potentially preventable hospitalizations as a quality indicator, primary care provided by NPs was at least comparable to that provided by generalist physicians.

Introduction

Primary care provided by nurse practitioners has been promoted as a means of addressing the shortage of primary care physicians (1–2). There was a 15 fold increase in the number of patients receiving care from NPs from 1998 to 2010 (3), and 22 states have changed their policies to allow NPs to practice and prescribe without physician supervision (4). However, some medical groups have raised concerns about primary care delivered solely by NPs, arguing that outcomes might not be comparable, particularly in complex patients (5–6). A number of trials in controlled settings have found comparable outcomes between the two groups (7–9), but there have been no population-based studies of outcomes of primary care delivered by NPs and MDs.

In the present study, we compared the rates of potentially preventable hospitalizations in older diabetic patients who received primary care from NPs only versus those who received care from primary care physicians only. We examined diabetes because it is an ambulatory sensitive condition for which good primary care should reduce hospitalizations (10–11). To address the concern that NPs deliver care to healthier and less complex patients (6, 12), we used a range of statistical approaches, including multivariable analyses, inverse probability of treatment weighting with a propensity score, non-pooling propensity score adjustment, non-pooling propensity score matching, and instrumental variable analysis. We examined two outcomes not expected to vary substantially by model of care to explore any persistence of residual confounding. Finally, we conducted sensitivity analyses to estimate the potential impact of unmeasured residual confounding. Our overall hypothesis was that rates of potentially preventable hospitalization would be comparable for patients who received primary care from NPs versus physicians.

Methods

Establishment of the Study Cohort

We identified diabetic patients who received all of their primary care either from NPs with no care from generalist physicians (general practitioner, family physician, general internist or geriatrician), or all of their primary care from generalist MDs with no care from NPs (Figure 1). The NP cohort was selected from 100% national Medicare data using the diabetes indicator from the CMS Chronic Disease Data Warehouse (CCDW) (13). The sensitivity and specificity of the CCDW diabetes algorithms were 0.91 and 0.95, respectively (14). Patients with billing records for two or more outpatient evaluation and management (E&M) services by NPs in a given year and with no outpatient E&M services from generalist physicians in that year were classified as receiving NP care only. We chose the NP cohort from 100% data to ensure sufficient power for our proposed analyses on the within state comparisons.

The MD cohort was selected from a 5% sample of national Medicare data using the diabetes indicator from CCDW. Patients with at least two outpatient E&M services from generalists

and no outpatient E&M services from NPs in a given year were classified as receiving MD care only.

Individual NP and MD cohorts were established for each year in 2007–2010. We conducted both cross-sectional and longitudinal analyses with these cohorts. For the cross-sectional analyses, we pooled the four annual cohorts. In this analysis, each patient could have multiple records. In the longitudinal analyses, we defined the model of care, NP or MD, in one year (2007, 2008, 2009), and the outcome was assessed in the next year. In this cohort, patients were censored at date of death, loss of coverage, switching to the other provider group or at the end of one year follow-up (Appendix 1).

Measures

Medicare enrollment files provided information on patient age, gender and race/ethnicity. We used a Medicaid indication in the enrollment file as a proxy for low income (15). We generated Elixhauser comorbidity measures (with diabetes removed from the list) for each enrollee from all claims in the 12 months before each study year using both inpatient and physician claims from MEDPAR, OUTSAF and Carrier files (16). Each comorbidity was included as a separate covariate in the analyses. Elixhauser comorbidities were chosen because they are not influenced by primary care practice styles (17) and they predict mortality, morbidity and healthcare utilization outcomes (16). We also included as comorbidities diagnoses that are potential complications of diabetes, such as retinopathy, neuropathy, kidney disease and uncontrolled diabetes, such as hypoglycemia, hyperglycemia and ketoacidosis (see Appendix 3 for specific diagnoses codes). We categorized size of residential area into metropolitan, non-metropolitan urban and rural using Rural-Urban Continuum Codes (18).

Study Outcome

The outcome was hospitalization for a potentially preventable condition in a given year (19, Appendix 2). We also examined hospitalizations for uncontrolled diabetes using an algorithm developed and validated for identifying hypoglycemia hospitalization (20–21) or diagnoses indicating poor diabetes control (Appendix 3).

Statistical Analyses

Our analyses included multivariable analyses, inverse probability treatment weighting (IPTW) with a pooling propensity score, non-pooling propensity score adjustment, non-pooling propensity score matching and IV analyses. Multivariable analyses allow us to assess the entire study cohort whereas non-pooling propensity approaches allow us to implicitly control for variation across states in regulations on the scope of NP practice for patients that fall in the overlap of propensity scores between the two groups. We conducted IV analyses in an attempt to control for unmeasured confounders (22–24).

Multivariable Analyses—We analyzed the average differences between patients who received care from NPs versus physicians in the cross-sectional cohorts using marginal models, Generalized Estimating Equation (GEE) with a binominal distribution, logit link and an autoregressive working correlation matrix (25). We reported the odds ratio (OR) for

the outcome associated with NP care with 95% confidence intervals (CI) based on a modified sandwich estimate of variance to account for patient clustering (26). To adjust for clustering within states, we treated state as a covariate in the GEE analyses. We also used GEE models to assess differences in hospitalization rates between the two groups in the longitudinal analyses, accounting for the length of follow-up.

Propensity Score Analysis—We calculated the non-pooling propensity that a patient would be cared for by an NP from a logistic regression model that incorporated the patient characteristics listed in Table 1 for each state and year (27). We used the propensity scores in two conditional logistic regression models. First, we adjusted for decile of propensity score and year in the model. Second, we matched the patients cared for by primary care physicians to those cared for by NPs with a 1:1 ratio without replacement. We used a matching algorithm based on the nearest Mahalanobis metric within the calipers of width equal to 0.25 of the standard deviation of the logit of the non-pooling propensity score (28–29). About 92.3% of patients receiving primary care from NPs were matched to those cared for by physicians. We examined the assumptions for use of propensity score analyses, including overlap, balance and ability to assess comparability of estimates across deciles (Appendix 4, 5). Patients with propensity scores in the overlap regions within each state (99.3% of the cohort) were included in the models. We also calculated propensity scores from pooled samples and used it to conduct IPTW analyses. The inverse of the propensity score was used to weight each patient in the NP group, and the inverse of one minus the propensity score was used to weight each patient in the MD group. States were included as a fixed effect.

Instrumental Variable Analysis—We explored the use of two IVs: the proportion of diabetes patients who received care from an NP by Hospital Referral Region (HRR, n=306), and whether a state required physician supervision of NPs for practice and prescriptions (n=51) (3). We coded the states requiring physician supervision of both practice and prescription as “1”; otherwise as “0” based on our previous study (3). Primary care provider availability was included in all of the IV analyses because it is related NP availability and also may be related to the outcomes (3). The number of primary care physicians per 100,000 residents in the Hospital Service Area was obtained from the Dartmouth Atlas of Health Care for 2006, the closest year available for our study period. The number of physician assistants per 100,000 residents in the county in 2007 and 2010 was obtained from the 2011–12 Area Resource File. Both IVs were strongly associated with having an NP as a primary care provider (partial F test=83794.0, $p<0.0001$; partial F test= 3145.5, $p<0.0001$). Two different estimation methods, two stage residual inclusion (2SRI) and IV probit models (30–32) were employed for the IV analyses. The 2SRI model estimates the effect of care by NPs on potentially preventable hospitalization by estimating residuals of prediction of having NP care from the first stage logistic regression model adjusted for covariates. These residuals plus receipt of care by NP and additional covariates were then included into the second stage GEE model to estimate the difference in hospitalization between patients cared for by NPs and physicians. The IV probit model is similar to the 2SRI model but uses probit models in both stages.

Evaluation of Analytical Approaches

To assess the validity of the different analytic methods, we calculated standardized difference scores, which demonstrate the balance of measured covariates between two groups and are independent of sample size. The standardized differences for categorical variables were calculated from the Mahalanobis distance method and compared between groups (33) (Appendix 6).

We also examined the persistence of residual confounding in our analyses. We chose two outcomes not anticipated to differ between patients who received primary care from NPs versus physicians: total mortality and hospitalizations for conditions not classified as potentially preventable. The four year mortality difference between the two groups was examined using a Cox proportional hazard model.

To estimate the potential impact of residual unmeasured confounders, we conducted sensitivity analyses (34). We postulated an unmeasured confounder with absolute differences of 5%, 10% and 20% in levels of prevalence. These prevalence estimates were chosen because, except for urban versus rural location, all the absolute differences in the prevalence of known confounders between the NP and physician groups were <20% (Table 1). For each prevalence value, a range of effect sizes (ORs of 1.5, 2.5, and 3.5 for the unmeasured confounder) were selected. Most of the known confounders had effect sizes (ORs) ranging from 0.80 to 2.85, with most below 2.0 (Appendix 7). The estimated difference in outcomes between the two groups was determined using multivariable analyses with further adjustment for the unknown confounder.

Finally, to assess whether the assumption of the impact of NP care on outcomes varied by complexity of patient conditions and residential area, we tested the interaction between NP care and the number of Elixhauser comorbidities and the interaction between NP care and rural/urban residence, in the GEE model and conditional logistic models. We performed all analyses using SAS v.9.3 (SAS Institute, Cary, NC).

Results

The four annual study cohorts included 93,443 Medicare patients with diabetes who received all their primary care from NPs (136,348 person-years) and 252,376 patients with diabetes who received all their primary care from physicians (553,890 person-years). Table 1 presents the characteristics of patients, stratified by type of primary care provider. Due to the large sample sizes, even small differences between the two groups were statistically significant. The last column presents the standardized difference for each covariate. Many — including Medicaid enrollment, race/ethnicity, number of provider visit in prior year, hypertension, rural location and year — were greater than 10%, indicating imbalance (35).

We calculated the standard difference between the NP and physician groups for the multivariable analyses, non-pooling propensity adjustment and matching, and instrumental variable analyses. As shown in Appendix 6, the standardized differences for all patient characteristics were substantially smaller for the non-pooling propensity matched cohort

(=2.1%) than for the unadjusted differences of the entire study cohort. For the two IV approaches, the standardized differences remained large (>20%) for at least two variables.

Table 2 shows the association of care by NPs with potentially preventable hospitalizations from multivariable analyses and propensity analyses. The unadjusted rates are presented, along with the ORs generated from multivariable analyses and conditional logistic regression models. Multivariable analysis indicates that patients who received care from NPs were less likely to be hospitalized for a potentially preventable condition (OR: 0.90, 95% CI=0.87–0.93). The IPTW and two conditional logistic regression models, with propensity adjustment or propensity matching, produced similar results. We repeated these analyses with the longitudinal cohort, and found similar results (data not shown). The association between NP care and hospitalizations for poor diabetes control (e.g., hypoglycemia, hyperglycemia, etc.) in the multivariable analysis also showed similar results (OR: 0.94, 95% CI=0.90–0.98) (Table 2).

Table 2 also shows the association of care by NPs with hospitalizations other than those for potentially preventable hospitalizations. Patients cared for by NPs had lower rates of other hospitalizations in the multivariable analysis (OR: 0.96, 95%CI=0.95–0.99). The association of NP care was significantly smaller for other hospitalizations than for potentially preventable hospitalization (OR: 0.96 vs. 0.90, $p=0.001$). Analyses using propensity adjustment and propensity matching showed almost identical results.

Table 3 shows the results from the two IV analyses. The IV analysis with the proportion of receiving NP care in an HRR produced results similar to those in Table 2 [ORs for potentially preventable hospitalization of 0.91 (95%CI=0.83–1.00) and 0.82 (95%CI=0.74–0.89) from IV probit and 2SRI, respectively]. The IV analysis with state regulation on NP practice showed a non-significant decrease in odds of potentially preventable hospitalization associated with NP care [OR: 0.94 (95%CI=0.68–1.31) and 0.86 (95%CI=0.59–1.25)]. We also examined the effect of using both IVs in the same model. This model yielded results that were identical to the first IV model.

Significant interactions between NP care and patient comorbidity for potentially preventable hospitalizations were observed using both multivariable analyses and conditional logistic regression models. As shown in Appendix 8, the association of NP care with potentially preventable hospitalizations decreased but was still significant except for < 3% of patients in the highest comorbidity category. We also found significant interactions between NP care and residential area in both analyses. Patients cared for by NPs had lower rates of potentially preventable hospitalizations in non-metropolitan urban areas [OR: 0.76 (95% CI=0.72–0.80)] and rural areas [OR: 0.75 (95% CI=0.65–0.87)]. However, there was no significant difference between patients cared for by NPs versus MDs in urban areas [OR: 0.97 (95% CI=0.94–1.01)].

If the underlying health status differs between patients cared for by NPs versus physicians and is not completely controlled for by the measures of comorbidity and prior hospitalizations, the all-cause mortality rate might differ between the two groups. The 4-year

mortality rate was 17.15% for patients cared for by NPs and 16.97% for those cared for by physicians [hazard ratio: 1.00 (95% CI: 0.97–1.03) adjusted for patient characteristics].

Table 4 presents the results of sensitivity analyses in which we estimated the impact of an unmeasured confounding variable. When the difference in prevalence of an unmeasured confounder between two groups was small (e.g., 5%) and the postulated magnitude of the confounder was not large, the association of potentially preventable hospitalization associated with receipt of NP care generally remained significant. With greater difference in the prevalence or magnitude of the effect size for a potential confounder, the association of lower potentially preventable hospitalizations with NP care either disappeared or was reversed.

Discussion

We hypothesized that rates of potentially preventable hospitalization would be comparable between diabetic patients who received primary care from NPs versus physicians. The results suggesting a lower rate of potentially preventable hospitalization in patients receiving NP care were unexpected. These results may represent a valid finding of better outcomes from primary care delivered by NPs. Alternatively, they may have resulted from confounding by selection biases not completely controlled for in the analyses. We will discuss each possibility.

Randomized controlled trials have found that NPs spend more time with patients, give patients more information and follow up patients more frequently than do physicians (36–38). NPs are more likely to address psychosocial factors that affect adherence with medication (39) and are easier to access (40). These may have contributed to the lower number of potentially preventable hospitalizations we observed.

On the other hand, patients who seek care from physicians may have more complex or serious health problems to an extent not completely captured by administrative claims data. We assessed this, albeit indirectly, in several ways. First, adjustment for the measured confounders had only a small effect on the odds of potentially preventable hospitalization associated with NP care. Before adjustment, the OR for potentially preventable hospitalization was 0.86 (95% CI=0.84–0.89); this changed to 0.90 (95% CI=0.87–0.93) after adjustment. Second, the 4-year mortality rates for patients cared for by NPs and physicians did not differ, suggesting no serious differences in underlying health status. Third, we assessed hospitalizations other than those considered potentially preventable (19). Patients cared for by NPs also had lower rates of other hospitalizations, although the decrease was significantly less than that for potentially preventable hospitalizations. The lower “other” hospitalization rate could be taken as evidence of residual confounding. Alternatively, some of the “other” hospitalizations may also be sensitive to quality of primary care.

Our finding that the impact of NP care was stronger in non-metropolitan areas is important. The shortage of physicians in rural areas has persisted for over 30 years (41). Differences in access to NPs versus physicians may be greater in rural areas. Physicians in rural areas may

have a larger patient burden, decreasing their ability to spend sufficient time with patients, or initially treat and follow-up with them in a time-efficient manner.

In the sensitivity analyses, we postulated a range of differences in prevalence and magnitude of an unmeasured confounder. To conclude that patients cared for by NPs have a higher rate of potentially preventable hospitalizations than those cared for by physicians, the difference in prevalence of an unmeasured confounder must be large (e.g., 20% in the NP group vs. 40% in the physician group) with a large effect size (e.g., OR: 2.5).

Among all of the statistical methods used, non-pooling propensity score matching resulted in the best balance in covariates between the two groups. However, all propensity score analyses were based on the assumption that all variables affecting the treatment assignment and outcome have been measured.

IV analysis is a widely used method to control for unmeasured confounding in observational studies (21–23). However, such results should be interpreted carefully. The IVs used were based on geographic differences among the 306 HRRs in the proportion of patients seeing NPs, or differences among states in regulations restricting NP practice. Geographic differences are widely used in IV analyses of outcomes (21). The assumption in both IVs is that NP use and NP regulation are not associated with factors, such as diet or exercise, which may impact the outcome, and that are not assessed. NP use is associated with availability of primary care physicians (3), which in turn can impact preventable hospitalizations. We controlled for physician and physician assistant supply in the IV analyses. However, the possibility of endogeneity cannot be ruled out. In addition, while our IV analyses reduced the imbalance of characteristics between the NP and physician groups, two covariates remained larger than 20%. Another limitation was the relatively broad confidence interval associated with the estimate based on the state regulation IV. Finally, IV analyses estimate the treatment effect on the marginal population, patients who would receive care from NPs in states with liberal regulations but not in states with restricted regulations.

There are additional limitations in our study. First, we studied patients with fee-for-service Medicare coverage. The results may not be applicable to younger patients or commercially insured patients. Second, because our study focused on the period 2007 through 2010, results may not be generalizable to the current period. Third, some patients classified as receiving all their primary care from physicians may have received some care from NPs. Medicare allows physicians to submit E&M charges for a split or shared visit in which both the physician and NP treat the patient (42). In such situations, the physician rather than the NP would normally submit the charge, because NPs have a 15% lower reimbursement rate (43). Also, patients may receive care from NPs who do not have their own provider identifier. Finally we studied patients receiving all of their primary care from only NPs or only MDs, not those seeing both NPs and MDs. About 18% of diabetes patients who had at least two outpatient visits to primary care providers received care from both NPs and MDs compared to 0.8% who received care from NPs only. However, the proportion cared for only by NPs is growing rapidly (3).

In conclusion, using a broad range of analyses and study designs, we found no evidence that older diabetic patients who received all of their primary care from NPs had a higher risk of potentially preventable hospitalization than those who received primary care from physicians. These findings support previous research suggesting that NPs provide comparable quality of clinical care as physicians. In view of the growing role of NPs in the US healthcare system, information on the quality of NP care holds broad clinical and public health relevance.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Summary of the selection of 4 annual cross-sectional study cohorts for two groups (NPs and generalist physicians) of patients. Notes: ^a Patients were identified as having diabetes in the study year and in the prior year from CMS CCDW. ^b Patients in the NP group were identified from 100% Medicare patients who received all of their primary care from NPs. ^c Patients in the MD group were identified from a 5% national sample of Medicare patients. ^d For OREC (Original Reason for Entitlement Code), "0" meant that the beneficiary's original entitlement to Medicare benefits was not specified as disability or end stage renal disease. ^e The beneficiary was not continuously enrolled in Medicare Part A and B, or was enrolled in an HMO in the prior or the study year. ^f In the study year, NP selection criteria were that the beneficiary had at least two outpatient visits to NPs (specialty code: 50) and no visits to generalist physicians (specialty codes: 01, 08, 11, 38). ^g MD selection criteria were that the beneficiary had at last two visits to generalist physicians and no visits to NPs.

Table 1

Characteristics of diabetic patients stratified by whether they received primary care from NPs or MDs for the entire study cohort¹

	NP	MD	P Value ²	Std. Diff (%) ³
N	136,348	553,890		
Age (mean $\pm$ Std. Dev.)	76.56 $\pm$ 6.27	77.14 $\pm$ 6.52	< .0001	-9.15
Gender (%)				
Male	37.76	41.96	< .0001	-8.60
Female	62.24	58.04		
Race (%)				
Non-Hispanic White	84.29	80.01	< .0001	11.90
Black	8.15	9.41		
Hispanic	4.43	6.09		
Other	3.13	4.49		
Medicaid eligibility (%)				
Yes	17.71	13.29	< .0001	12.24
No	82.29	86.71		
Provider visits in prior year (Mean $\pm$ Std. Dev.)	8.90 $\pm$ 6.93	10.27 $\pm$ 7.54	< .0001	-18.93
Comorbidity index (%)				
Congestive heart failure	9.45	9.77	0.0004	-1.08
Valve disease	5.07	6.32	< .0001	-5.39
Pulmonary circulation disease	1.46	1.34	0.0012	0.97
Peripheral vascular disease	8.75	10.91	< .0001	-7.25
Hypertension	74.09	79.07	< .0001	-11.78
Paralysis	0.65	0.85	< .0001	-2.29
Neurological disorders	3.29	3.86	< .0001	-3.07
Chronic pulmonary disease	11.92	12.35	< .0001	-1.32
Hypothyroidism	12.57	14.17	< .0001	-4.70
Renal failure	9.67	8.55	< .0001	3.89
Liver disease	0.75	0.87	< .0001	-1.34
Peptic ulcer	0.03	0.05	0.0087	-0.84
Acquired Immune Deficiency Syndrome	0.05	0.03	< .0001	1.16
Lymphoma	0.84	0.72	< .0001	1.33
Metastatic cancer	0.94	0.60	< .0001	3.87
Solid tumor w/out metastasis	8.11	8.69	< .0001	-2.09
Rheumatoid arthritis	2.30	2.88	< .0001	-3.71
Coagulopathy	1.87	2.30	< .0001	-2.97
Obese	4.18	3.51	< .0001	3.46
Weight loss	1.27	1.42	< .0001	-1.30
Fluid and electrolyte disorders	7.32	8.03	< .0001	-2.66
Chronic blood loss anemia	0.77	1.11	< .0001	-3.55

	NP	MD	P Value ²	Std. Diff (%) ³
Deficiency Anemia	14.17	17.23	< .0001	-8.43
Alcohol abuse	0.28	0.27	0.3339	0.29
Drug abuse	0.10	0.08	0.0265	0.65
Psychoses	1.81	2.01	< .0001	-1.44
Depression	3.98	3.52	< .0001	2.38
Total number of comorbidity (Mean $\pm$ Std. Dev.)	1.86 $\pm$ 1.59	2.00 $\pm$ 1.64	< .0001	-9.17
Diabetes Complications (%)				
Yes	32.07	31.82	0.0743	0.54
No	67.93	68.18		
Uncontrolled Diabetes (%)				
Yes	35.65	32.34	< .0001	6.98
No	64.35	67.66		
Hospitalization in prior year (%)				
0 (None)	78.78	78.15		
1	14.13	14.46	< .0001	1.62
2	4.45	4.58		
3	2.64	2.81		
Rural/Urban (%)				
Metropolitan	58.50	82.75		
Non-metropolitan urban	35.33	15.71	< .0001	55.86
Rural	6.17	1.55		
Study year (%)				
2007	19.95	23.59		
2008	22.59	23.60	< .0001	11.66
2009	26.59	26.44		
2010	30.86	26.38		

NP=nurse practitioners; MD= physician primary care providers; Std. Diff=standardized difference.

¹ The entire study cohort is the stacked 4-year annual study cohort, which included 93,433 patients who received care from NPs (136,348 person-years) and 252,376 patients who received care from MDs (553,890 personal-years).

² By Chi-square test for categorical variables and t-test for continuous variables.

³ Standard differences greater than 10% represented potential imbalances in the corresponding variables.

Table 2

Unadjusted rates and odds ratio of potentially preventable hospitalization, hospitalization for uncontrolled diabetes and other hospitalization stratified by NP and MD cohorts, analyzed by various approaches

Cohort	Analysis	Potentially Preventable Hospitalization			Uncontrolled diabetes Hospitalization			Other Hospitalization ⁶		
		Unadjusted rate (Adjusted Rate)		Adjusted Odds Ratio ⁵ (95% CI)	Unadjusted Rate (Adjusted Rate)		Adjusted Odds Ratio ⁵ (95% CI)	Unadjusted Rate (Adjusted Rate)		Adjusted Odds Ratio ⁵ (95% CI)
		NP	MD		NP	MD		NP	NP	
Pooled 4 annual study cohorts ¹	Multivariable analyses ²	4.72 (3.71)	5.44 (4.11)	0.90 (0.87 to 0.93)	2.28 (1.82)	2.48 (1.95)	0.94 (0.90 to 0.98)	17.52 (16.95)	18.91 (17.49)	0.96 (0.95 to 0.98)
Pooled 4 annual study cohorts excluding those without overlapping pooling propensity score	IPTW of pooling propensity score	4.72 (3.90)	5.44 (4.14)	0.94 (0.90 to 0.97)	2.28 (1.84)	2.48 (1.95)	0.95 (0.90 to 0.99)	17.52 (16.96)	18.91 (17.46)	0.96 (0.94 to 0.98)
Pooled 4 annual study cohort excluding those without overlapping non-pooling propensity score	Conditional logistic regression model adjusted for non-pooling propensity score ³	4.70	5.41	0.89 (0.86 to 0.92)	2.27	2.48	0.92 (0.88 to 0.96)	17.50	18.87	0.96 (0.94 to 0.98)
Non-pooling propensity matching cohort	Conditional logistic regression model ⁴	4.64	5.39	0.86 (0.82 to 0.89)	2.23	2.51	0.88 (0.84 to 0.93)	17.38	18.09	0.96 (0.94 to 0.98)

NP=nurse practitioners; MD=physician primary care providers; CI=confidence intervals.

¹The pooled 4 annual cohorts included patients who received care from NPs or from physicians for at least one year in 2007–2010.

²The multivariable analyses were adjusted for age, gender, race, and Medicaid eligibility; comorbidity index; provider visits in prior year, comorbidity index, diabetes complications, uncontrolled diabetes, and hospitalization in prior year; year of study, and rural or urban nature of residential areas; and state of residence.

³The non-pooling propensity conditional logistic regression model was adjusted for decile of propensity score and clustering within state of residence.

⁴The propensity score matching conditional logistic regression was adjusted for clustering within state of residence.

⁵Odds ratios represent the estimated odds for NP compared with MD on potentially preventable hospitalizations, hospitalizations for uncontrolled diabetes, and other hospitalizations, based on the adjusted models. The corresponding 95% confidence interval is also presented.

, 'Other hospitalization', represents all hospitalizations not included in the definition of 'potentially preventable hospitalization'.⁹

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Table 3

Potentially preventable hospitalization stratified by NP and MD cohorts and analyzed by instrumental variable analyses

Instrumental variable	Unadjusted Rate		IV probit	Two stage residual inclusion
	NP	MD	Odds Ratio (95% CI)	Odds Ratio (95% CI)
Proportion of receiving NP care at HRR ¹	4.96	5.62	0.91 (0.83 to 1.00)	0.82 (0.74 to 0.89)
State regulation ²	5.10	5.37	0.94 (0.68 to 1.31)	0.86 (0.59 to 1.25)

NP=nurse practitioners; MD=physician primary care providers; CI=confidence interval; HRR=hospital referral region.

¹ Patients in the NP and MD groups residing in HRRs with the rate of patients cared for by NPs 15.65% and > 15.65%, respectively.

² Patients in the NP and MD groups residing in 25 states with and 25 states and DC without the requirement of physician supervision for practice and prescriptions.

Table 4

Sensitivity analyses of the association between NP care and rate of a potentially preventable hospitalization, controlling for an unmeasured binary confounder

Prevalence of confounder		Odds Ratio Associated with Confounder	Potentially Preventable Hospitalization
MD	NP		Odds Ratio ^I (95% CI)
25%	20%	1.5	0.92 (0.89 to 0.95)
25%	20%	2.5	0.95 (0.92 to 0.98)
25%	20%	3.5	0.98 (0.94 to 1.01)
10%	5%	1.5	0.92 (0.89 to 0.95)
10%	5%	2.5	0.96 (0.93 to 0.99)
10%	5%	3.5	1.00 (0.97 to 1.03)
30%	20%	1.5	0.94 (0.91 to 0.97)
30%	20%	2.5	1.00 (0.97 to 1.04)
30%	20%	3.5	1.05 (1.02 to 1.09)
15%	5%	1.5	0.94 (0.91 to 0.98)
15%	5%	2.5	1.03 (0.99 to 1.06)
15%	5%	3.5	1.10 (1.06 to 1.14)
40%	20%	1.5	0.98 (0.95 to 1.01)
40%	20%	2.5	1.11 (1.07 to 1.14)
40%	20%	3.5	1.20 (1.16 to 1.24)
25%	5%	1.5	0.99 (0.95 to 1.02)
25%	5%	2.5	1.15 (1.11 to 1.19)
25%	5%	3.5	1.30 (1.26 to 1.34)

NP=nurse practitioners; MD=physician primary care providers; CI=confidence interval.

^I Odds ratios represent the estimated odds for NP care compared with MD care controlling for an unmeasured confounder.