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Self-efficacy remains a vital factor in reducing the risk of dialysis in type 2 diabetes care

Kuomeng Liao, MD, PhD[a], Kuan-Chia Lin, PhD[b,c], Shang-Jyh Chiou, DrPH[d,*] ⓘ

Abstract

Studies have provided promising outcomes of the pay-for-performance (P4P) program or with good continuity of care levels in diabetes control.

We investigate the different exposures in continuity of care (COC) with their providers and those who participate in the P4P program and its effects on the risk of diabetes diabetic nephropathy in the future.

We obtained COC and P4P information from the annual database, to which we applied a hierarchical linear modeling (HLM) in 3 levels adjusted to account for other covariates as well as the effects of hospital clustering and accumulating time.

Newly diagnosed type 2 diabetes in 2003

At the individual level, those with a higher Diabetes Complications Severity Index (DCSI) score have a higher likelihood of diabetic nephropathy than those with a lower DCSI (OR, 1.46), whereas contrasting results were obtained for the Charlson Comorbidity Index (CCI) (odds ratio[OR], 0.88). Patients who visited family physicians, endocrinologists, and gastroenterologists showed a lower likelihood of diabetic nephropathy (OR, 0.664, 0.683, and 0.641, respectively), whereas those who continued to visit neurologists showed an increased risk of diabetic nephropathy by 4 folds. At the hospital level, patients with diabetes visiting primary care clinics had a lower risk of diabetic nephropathy with an OR of 0.584 than those visiting hospitals of other higher levels. Regarding the repeat time level, the patients who had a higher COC score and participated in the P4P program had a reduced diabetic nephropathy risk with an OR of 0.339 and 0.775, respectively.

Diabetes control necessitates long-term care involving the patients' healthcare providers for the management of their conditions to reduce the risk of diabetic nephropathy. Indeed, most contributing factors are related to patients, but we cannot eliminate the optimal outcomes related to good relationships with healthcare providers and participation in the P4P program.

Abbreviations: CCI = Charlson Comorbidity Index, COC = continuity of care, DCSI = Diabetes Complications Severity Index, ESRD = end-stage renal disease, HbA1c = hemoglobin A1c, HLM = hierarchical linear modeling, ICC = intraclass correlation coefficient, ICD = international classification of diseases, NHI = national health insurance, OR = odds ratio, P4P = pay-for-performance, T2DM = type 2 diabetes, UPC = usual provider continuity.

Keywords: continuity of care, diabetics diabetic nephropathy, hierarchical linear modeling, pay-for-performance, type 2 diabetes

1. Introduction

Diabetes is a serious public health problem affecting 463 million adults globally.[1] In 2007, the USA had spent approximately 327 billion USD for diabetes-related interventions,[2] with an increase in the overall risk of premature death from complications including cardiovascular disease, kidney failure, leg amputation, and vision loss. In 2016, over 1.6 million deaths worldwide were directly associated with diabetes, more particularly among patients receiving diabetes control.[3] Although diabetes is one of the most common diseases with high medical costs, patients can be managed through diet, regular exercise, medication, and glucose monitoring for a better quality of life.[4]

Considering the chronic nature of diabetes, patients usually need to establish long-term collaboration with their healthcare providers regarding appropriate medications or participate actively in decision-making regarding therapy including dietary guidance, for better diabetes control. In 1996, Taiwan's health authorities adopted the Diabetes Shared Care Network of Hickman, Drummond, and Grimshaw [5] and has been advocating the pay-for-performance (P4P) cost scheme to improve quality control under the national health insurance (NHI) system. Since 2001 in Taiwan, the P4P program has provided comprehensive diabetes management in line with the

American Diabetes Association guidelines. For example, the NHI requires the healthcare providers to assess the patient's medical history, perform physical and laboratory examinations with a management plan for the basic reimbursement points, and apply for additional points if patients regularly seek for medical consultation on an annual basis. The P4P program generally yields positive outcomes [6–10], but some concerns with mixed effects have been reported.[11,12] Notably, this program offers financial incentives that encourage physicians to provide enhanced self-care education and annual diabetes-specific testing (eye examinations and laboratory tests including the hemoglobin A1c [HbA1c] level) to their patients. The P4P payment scheme was described in a previous study (supplementary materials).[9] However, this program is voluntary, and patients tend to participate irregularly without awareness and depend on their physicians' intention. In addition, only one-third of patients with type 2 diabetes mellitus (T2DM) have participated in the P4P program and have been less cooperative for a long time.[13]

In chronic disease management, maintaining a good patient–healthcare provider relationship in line with the concept of continuity of care (COC) is also important to avoid providing fragmented healthcare services to the patients.[14] If COC indicators are unfavorable (or the patient or physician may have moved to another place), such relationship should be seriously dealt with. The positive effects of diabetes management in patients with high COC levels include improved adherence, decreased cost, and decreased hospitalization rate.[15–19]

However, several factors are related to future diabetes complications, including diabetic nephropathy and end-stage renal disease (ESRD), which is expected to develop in 30% to 40% of patients with T2DM.[20–22] In particular, the factors associated with ESRD development include the self-reported health status,[23] diabetes duration,[24] and the HbA1c level,[25] as well as the determinants of the physician- or hospital-level variations related to patient outcomes.[26] To reduce patients' risk of developing ESRD, we need to maintain their glycemic and blood pressure levels within the normal range— the optimal intervention for patients with T2DM.[27–29] However, different specialists offer different qualities of diabetes care.[30,31] No 2 providers have the same medical practices, and health authorities usually advocate the benefits (e.g., lower hospitalization and mortality rates and improved quality of life) of better COC in diabetes treatment.[32,33] Nevertheless, through P4P participation.[34] or good COC levels,[23] positive outcomes can be achieved in diabetes control. However, the nest effect from patients who either participated in the P4P program frequently or maintained a therapeutic relationship with their healthcare providers remains insufficiently studied.

For patients who maintained a good relationship with their healthcare providers or who participated in the P4P program, we asked the following question: which type of exposure affects the risk of developing diabetes-related complications (e.g., diabetic nephropathy) in the future? Traditional methodology (e.g., regression) may be inappropriate, but the use of hierarchical linear modeling (HLM) may be the solution to consider the cluster effect from the medical institution and the time effect from the P4P program participation or COC indicator. For example, through HLM, we can deal with the cluster effect from the medical institution where patients with the same healthcare providers may receive similar treatment procedures. Further, we can examine the association between patients' performance and the method of therapy provided by different specialists. The NHI provides the optimal information regarding patient preference in providers in Taiwan, considering that patients are free to visit their physician without restrictions and participation in P4P is voluntary and decided by their provider.

Numerous studies mentioned above have provided promising outcomes on controlling T2DM from participating in P4P programs or by maintaining good relationships with their providers (COC concept). However, few studies have investigated on whether participating in P4P programs or maintaining good relationships with providers reduce the likelihood of future diabetes complications, such as diabetic nephropathy, particularly from longitudinal NHI databases. Thus, this study aimed to examine patients with T2DM who had different COC exposures to various diabetes care–related providers and those who participated in the P4P program, and to evaluate their effects on the risk for diabetic nephropathy development. This study is the first to apply the three-level HLM for estimating the effects of hospital clustering and time accumulation in diabetes care.

2. Methods

2.1. Study design

This study is a retrospective longitudinal research. Started in 1995, the NHI includes data on >99% of the population of Taiwan. Using the international classification of diseases (ICD)-9-CM code (250) and A code (A181) as the selection criteria,[35] the database defined patients with newly diagnosed diabetes as those who were treated with oral hypoglycemic agents or who had at least inpatient diabetes diagnosis records. In 2003, 120,000 patients with diabetes were randomly selected to establish the NHI claims database for diabetes. The current study used the 1997 to 2013 databases containing all medical records of selected patients with diabetes, representing an optimal longitudinal study sample. The Institutional Review Board (IRB) of the National Taiwan University approved this study (201509ES006). The IRB waived the need for informed consent from the patients because the datasets used in this study consists of anonymized, de-identified nationwide data.

2.2. Dependent variable

The main outcome measure was diabetic nephropathy (as defined by the ICD-9-CM codes 250.40 and 250.42 or case type 05) with at least 3 records indicating such complication. We excluded those patients who had medical records related to diabetic nephropathy (ICD-9-CM codes 583.X, 584.X, 585, and 586 or case type 05) that occurred before 2003.

2.3. Hierarchical linear modeling

The effect clustered at the medical institution was explored using the HLM, and the repeat-time effect based on patient and physician behaviors was considered. In this study, 3 HLM levels were performed: level 1, the time effect considering the P4P program and the COC index; level 2, the patients' attributers and their most frequently visited specialists; and level 3, the effect clustered according to the medical institution size and the most frequently visited institution for T2DM care during the study period.

2.4. Level 1: Time effect with the continuity of care index and the pay-for-performance program

Considering that the usual provider continuity (UPC) index is commonly indicated for measuring longitudinal COC, we used it to define COC in the study population. In calculating the UPC index (0–1; 1 indicates that the patient went to the same regular physician in all visits), the number of times a patient visits the main diabetes care provider is divided by the total number of times the patient visits all providers for diabetes care (denominator) in a yearly base. Moreover, we used the payment code P1409c (annual management fee) to determine whether or not the patient participated in the P4P program (Yes/No) in any given year during the study period (2003–2013). Therefore, every patient had 11 records in UPC and P4P annually in the study period.

2.5. Level 2: Individual variables

The following parameters were analyzed: age, sex, monthly payroll bracket, urbanization (high, medium, or low), and comorbidities (as assessed by the Charlson Comorbidity Index [CCI] and/or Diabetes Complications Severity Index [DCSI]). In particular, the data on patient age, monthly payroll bracket, CCI, and DCSI were collected from the NHI. At this level, we had information of the most visited physicians involved in diabetes care, including family physicians, cardiovascular specialists, general physicians, endocrinologists, gastroenterologists, and neurologists. The DCSI quantifies 7 diabetes complications graded by severity as 0, 1, or 2 and sums up to a range of 0 to 13.[36] Meanwhile, CCI accumulates the comorbidity level scores of 19 predefined comorbid conditions weighted by 1, 2, 3, and 6.[37] Both DCSI and CCI excluded the medical records related to diabetic nephropathy.

2.6. Level 3: Medical institution

The medical institution size of medical centers, regional hospitals, local hospitals, and primary care clinics was measured by the number of times the patients visit for T2DM care during the study period; the most frequently visited institution had the highest size.

2.7. The algorithm equation displays as follow

H: medical institution, H1–H3 (regional hospital, local hospital, clinic); AREA_G: urbanization; IN: income level, IN1–IN5 ($<17{,}780$; $17{,}781$–$28{,}800$; $28{,}801$–$45{,}800$; $45{,}801$–$72{,}800$; >72801); M: most visited physician, M1–M6 (family medicine, general medicine, endocrinology, gastroenterology, cardiovascular, neurology); TRANS_NO: year number (2003–2013): P4P_mark: participating in the P4P program.

Mixed Model

$$\eta = \gamma_{00c} + \gamma_{001}*H1 + \gamma_{002}*H2 + \gamma_{003}*H3 + \gamma_{01c}*AGE + \gamma_{02c}*GENDER + \gamma_{03c}*AREA\_G + \gamma_{04c}*DCSI + \gamma_{05c}*CCI + \gamma_{06c}*IN1 + \gamma_{07c}*IN2 + \gamma_{08c}*IN3 + \gamma_{09c}*IN4 + \gamma_{010c}*IN5 + \gamma_{011c}*M1 + \gamma_{012c}*M2 + \gamma_{013c}*M3 + \gamma_{014c}*M4 + \gamma_{015c}*M5 + \gamma_{016c}*M6 + \gamma_{10c}*UPC + \gamma_{20c}*TRANS\_NO + \gamma_{30c}*P4P\_MARK + r_0 + u_{00}$$

2.8. Statistical analysis

To provide an overview of the study population, we described the baseline characteristics of patients. Next, HLM was applied according to the study aim using the information related to intraclass correlation coefficient (ICC) at 3 levels. Level 1 variance was not estimated from the data but was constrained, and 3.29 was often used in ICC calculation.[38] Later, we used an integrated figure (Fig. 1) to measure the odds ratio (OR) for
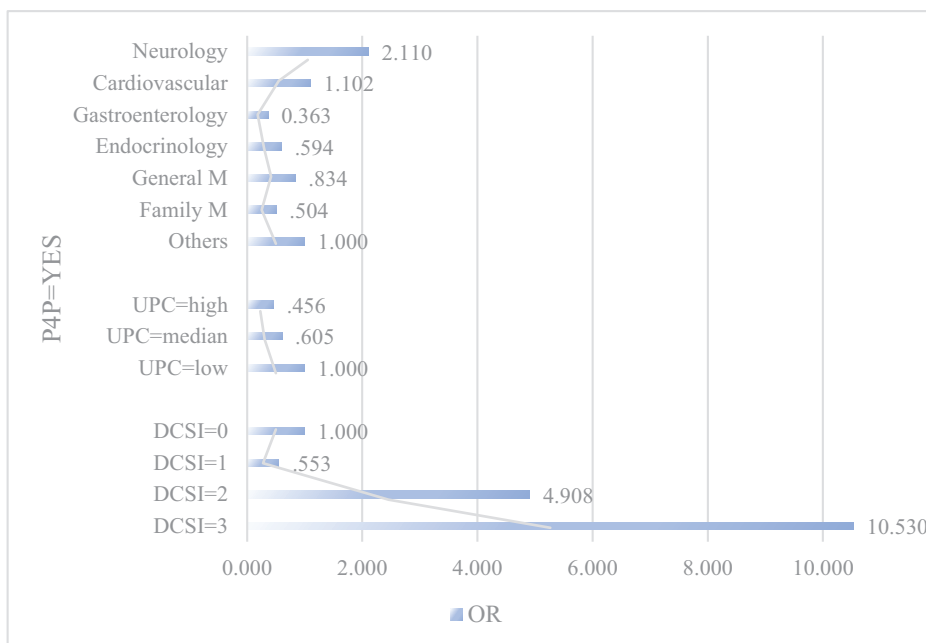

Figure 1. The odds ratio in different catalogs of most visit doctors, UPC, and DCSI among type 2 diabetes patients participating in the P4P program. DCSI = Diabetes Complications Severity Index, OR = odds ratio, P4P = pay for performance, UPC = usual provider continuity.

Table 1

The characteristics using in Hierarchical Linear Modeling for patients with type 2 diabetes (n = 54588).

Level	Variable	N	%
Medical institution (3)	Medical center	9835	18.3
	Regional Hospital	12333	22.9
	Local Hospital	12146	22.6
	Clinic	19470	36.2
Individual information (2)	Age	55.25 ± 13.9	
	Gender male	29169	53.5
	female	25331	46.4
	Income (depend)	18086	33.2
	<17780	11726	21.5
	17781–28800	19819	36.4
	28801–45800	3201	5.9
	45801–72800	1355	2.5
	>72801	313	0.6
	Urbanization 12	30048	55.1
	34	17869	32.8
	567	6579	12.1
	DCSI (mean ± SD)	0.028 ± 0.21	
	CCI (mean ± SD)	0.958 ± 1.23	
	Most visit doctor (Others)	16760	30.7
	Family Medicine	10594	19.4
	General internal Medicine	11730	21.5
	Endocrinology	8039	14.7
	Gastroenterology	2326	4.3
	cardiovascular	3893	7.1
	Neurology	1246	2.3
Repeat time (1)	UPC (mean ± SD)	0.797 ± 0.23	
	P4P (rate)	10.6%	

CCI = Charlson Comorbidity Index, DCSI = Diabetes Complications Severity Index, P4P = pay for performance, SD = standard deviation, UPC = usual provider continuity.

Table 2

The risk of diabetic nephropathy from hierarchical linear modeling.

Level	Variable	Odds ratio	95% CI
Medical institution (3)	Medical center	1	
	Regional Hospital	0.885	(0.622, 1.260)
	Local Hospital	0.844	(0.605, 1.176)
	Clinic	0.584*	(0.427, 0.799)
Individual information (2)	Age	0.987*	(0.982, 0.993)
	Gender (male)	1.364*	(1.176, 1.582)
	Income (depend)	1	
	<17780	1.045	(0.870, 1.256)
	17781–28800	0.566*	(0.472, 0.679)
	28801–45800	0.292*	(0.190, 0.449)
	45801–72800	0.102*	(0.037, 0.279)
	>72801	0.100*	(0.012, 0.824)
	Urbanization	1.115	(0.998, 1.246)
	DCSI	1.456*	(1.138, 1.864)
	CCI	0.877*	(0.819, 0.939)
	Most visit doctor (Others)	1	
	Family Medicine	0.664*	(0.529, 0.833)
	General Medicine	0.849	(0.686, 1.050)
	Endocrinology	0.683*	(0.538, 0.866)
	Gastroenterology	0.641*	(0.414, 0.991)
	cardiovascular	0.849	(0.635, 1.136)
	Neurology	4.617*	(3.379, 6.307)
Repeat time (1)	UPC	0.339*	(0.265, 0.432)
	Year	0.869*	(0.850, 0.888)
	P4P	0.775*	(0.642, 0.936)
ICC	Level 1		3.290
	Level 2	70%	8.703
	Level 3	4%	0.461

CCI = Charlson Comorbidity Index, CI = confidence interval, DCSI = Diabetes Complications Severity Index, ICC = intraclass correlation, P4P = pay for performance, UPC = usual provider continuity.
* P < .001.

diabetic nephropathy stratified at different levels of DCSI (from low to high: 0, 1, 2, and over 3) and UPC (low, 0–0.6; median, 0.6–0.869; and high, ≥0.87) and according to the most visited specialists for diabetes care. We also compared patients who participated in the P4P program and those who did not. The UPC levels were established according to distribution using quantile regression. Moreover, all statistical data were analyzed using HLM 6.08 (for Windows) and SAS 9.3.1 (SAS Institute, Cary, NC, USA). The significance level was set at 0.05.

3. Results

This study included 54,588 patients with T2DM. Table 1 summarizes their baseline characteristics. The most frequently visited institution type for diabetes care was the primary care clinics (36%), followed by the regional (22.9%)/local (22.6%) hospitals and medical centers (18.3%). The mean age of T2DM onset was 55.25 ± 13.9 years. The average DCSI and CCI scores were 0.028 and 0.958, respectively, indicating that most patients with diabetes did not have severe comorbidities (98.1% of DCSI and 47.3% of CCI were 0). Furthermore, the most frequently visited specialists for diabetes care were the general physicians (21.5%), followed by family physicians (19.4%) and endocrinologists (14.7%). The average COC score measured by UPC was 0.8, and the P4P participation record accounted for 10% during the study period (2003–2013) and 28.9% in the study population, respectively.

Table 2 shows the HLM results. Based on ICC, 70% and 4% of the patients belonged to level 2 (individual) and level 3 (hospital), respectively. The possible factors attributed to kidney disease belonged to the individual level (level 2), and they were affected when they were seemingly neglected by the hospital. At the individual level, males had 1.36 times increased risk of developing diabetic nephropathy compared with females. Those with higher DCSI scores were more likely to develop diabetic nephropathy than those with lower scores (OR, 1.46; 95% confidence interval [CI], 1.138–1.864; P < .001). Conversely, diabetic nephropathy was more likely to occur in those with higher CCI scores than in those with lower scores (OR, 0.88; 95% CI, 0.819–0.939; P < .001). Unsurprisingly, the risk for diabetic nephropathy was higher in patients with T2DM who visited family physicians, endocrinologists, and gastroenterologists (OR, 0.664, 0.683, and 0.641, respectively) but was fourfold lower in those who continued to visit neurologists. At the medical institution level (level 3), patients with diabetes visiting primary care clinics had a lower risk for diabetic nephropathy (OR, 0.584; 95% CI, 0.427–0.799; P < .001) than those visiting higher-level hospitals. Regarding the repeat-time level, the patients who had higher UPC scores and participated in the P4P program were less likely to develop diabetic nephropathy (OR, 0.339 and 0.775; 95% CI, 0.265–0.432 and 0.645–0.936, respectively; P < .001). Furthermore, the year effect showed an experience curve effect with an OR of 0.87, indicating that those who continued treatment with their main healthcare providers or

participated in the P4P program for a long time had a reduced risk of developing diabetic nephropathy.

To understand the stratification effect better (Fig. 1), we provided the OR for diabetic nephropathy at different levels of DCSI (from low to high, 0 to over 3) and UPC (low, median, and high), as well as the OR for the most visited specialists, in patients with T2DM with P4P program participation. A higher DCSI score for P4P program participation indicated an increased risk for diabetic nephropathy, whereas a higher COC score showed contrasting results. Moreover, patients with T2DM who frequently visited family physicians, general physicians, endocrinologists, or gastroenterologists for diabetes care had a reduced risk for diabetic nephropathy, whereas those who frequently visited cardiovascular specialists or neurologists had an increased risk for diabetic nephropathy. These results are consistent with the previous part.

4. Discussions

According to the ICC results, we found significant facts related to the risk of developing diabetic nephropathy in patients with T2DM at the individual level. Apparently, patients are the primary caretakers of their disease who can reduce the risk of future complications rather than merely relying on medication, but we did not reduce the value of clinical therapy in diabetes control. Our study has obtained a conclusion similar to those of studies identifying the level of association between patients or providers and poor glycemic/ blood pressure management or delayed therapeutic intensification from HLM level 2[39,40] as well as some other studies.[10,41] To our knowledge, this study is the first to apply a three-level HLM to estimate the effects of hospital clustering and time accumulation in diabetes care, particularly using the data on the most visited specialists and those participating in the P4P program with a COC indicator.

Patients who frequently visited primary care clinics for diabetes care were less likely to develop diabetic nephropathy than those who visited other higher-level hospitals. The reason could be that the former may have benefited from the adjacent (accessible) medical team working in chronic disease control, particularly because health authorities advocate their cooperation under the Diabetes Shared Care Network. In addition, patients with mild diseases usually visit nearby clinics for diabetes control–related health services, whereas those with severe diseases are referred to higher-level hospitals, especially those with multiple chronic diseases. In this study, the CCIs for medical centers, regional hospital, local hospital, and primary care clinics were 48.1%, 45.1%, 43.4%, and 50.6% (CCI=0), respectively.

At the individual level, a higher DCSI score is unsurprisingly associated with an increased risk for diabetic nephropathy. DCSI models the severity of diabetes complications at any time point, and its scores are a significant determining factor of diabetic nephropathy,[42–44] thereby capable of indicating poor diabetes control. However, CCI showed opposite results. Our study suggests that younger patients had a lower CCI, and those with a higher CCI require more time from healthcare providers to treat difficult and complicated conditions or to counter other severe disease courses, leaving less time to focus on urinalysis indicators. Thus, the lower CCI group had a lower risk of developing diabetic nephropathy. Furthermore, patients may prefer their familiar physicians for diabetes management, and certain medical practices are considered minor but significant predictors of

HbA1c level reduction.[45] In our study, those who visited family physicians and endocrinologists had a reduced risk for diabetic nephropathy. Some patients with T2DM visit gastroenterologists for weight or glycemic level control,[46] which can reduce the risk of developing future complications. Remarkably, the risk for diabetic nephropathy was high in our patients who visited neurologists for diabetes management, possibly because these patients had kidney diseases when they were diagnosed with T2DM and they were usually referred to neurologists for followup. Thus, considering their kidney health status, they had a higher risk for diabetic nephropathy.

Regarding the time effect at the time level, patients who participated in the P4P program had a reduced risk of developing diabetic nephropathy. Under this program, they received education on diet and health improvement as well as regular medical checkups. These results are consistent with those of other studies.[47–49] A synergistic effect occurs if a patient has a higher COC score, indicating that they maintain a good relationship with their providers, particularly according to the gradual changes in the learning curve (time effect). In Taiwan, patients can freely change their providers under the NHI coverage, and providers participate in the P4P program voluntarily. According to the longitudinal panel data in our study, an increased COC score in patients participating in the P4P program was associated with a reduced risk of developing diabetic nephropathy over time. If the patients already have a good relationship with their providers, the agency may encourage both parties to participate in the P4P program consistently with more financial incentives. In the long-term, a reduced diabetic nephropathy rate in patients with diabetes can lessen medical expenditures.[50]

Diabetes care requires a long-term relationship between patients and their care providers. Patients with T2DM who maintain a good relationship with their providers, participate in the P4P program, and/or follow the clinical guidelines may reduce the likelihood of developing diabetic nephropathy. Apart from encouraging patients to participate in the P4P programs or maintain a good relationship with their providers, health authorities should provide more incentives for providers or patients. One of these incentives is the regular survey of patients' health profiles and glucose levels to prevent diabetic nephropathy. Patients' self-management of their disease (T2DM) and coordination with their medical teams remain the best ways to maintain a good quality of life.

4.1. Strengths and limitations

The sample size and representativeness of the data for the entire study population were sufficient to explore the association between participation in the P4P program and the risk of developing diabetic nephropathy, a T2DM-related complication. Conventionally, a dichotomous outcome is usually employed for P4P program participation. In the present study, HLM was used to deal with the cluster effect from the hospital and time effects related to the P4P program and COC. However, this study also has few major limitations that must be addressed. First, although we determined the frequency of measuring the biomarker levels such as the HbA1c levels, we did not identify the actual levels from the database; consequently, the outcomes, which would indicate patients' diabetes control, remain unknown. Moreover, although the HLM findings revealed significant data, the benefits of participating in the P4P program require a stricter examination to clarify the long-term effects of this participation on preventing

diabetes-related complications. Finally, the quality of disease coding may have affected the estimation of the likelihood of developing retinopathy, possibly underestimating the results.

5. Conclusion

Most contributing factors are patient related, but the optimal outcomes related to keeping a good relationship with healthcare providers (e.g., good communication and better interpersonal relationship) and participation in the P4P program cannot be eliminated. Health authorities may consider advocating the P4P program for all patients with T2DM and educating them on the importance of self-efficacy in diabetes control. Disease self-management and collaboration with the medical team remain to be the best way for patients with T2DM to achieve a good quality of life.

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Author contributions

Conceptualization: Shang-Jyh Chiou.
Data curation: Shang-Jyh Chiou.
Formal analysis: Shang-Jyh Chiou.
Investigation: Kuan-Chia Lin.
Methodology: Kuan-Chia Lin.
Software: Kuan-Chia Lin.
Validation: Kuomeng Liao.
Writing – original draft: Kuomeng Liao, Shang-Jyh Chiou.
Writing – review & editing: Kuomeng Liao, Kuan-Chia Lin, Shang-Jyh Chiou.

References

[1] International Diabetes Federation. IDF Diabetes Atlas. 9th ed. Brussels, Belgium: International Diabetes Federation; 2019. https://www.diabete satlas.org/en/resources/

[2] American Diabetes Association. Economic Costs of Diabetes in the U.S. in 2017. Diabetes Care 2018;41:917–28.

[3] World Health Organization. Global report on diabetes 2016, Geneva, World Health Organization; 2016. https://goo.gl/4bkMQW.

[4] 2012;Hajos TR, Pouwer F, de Grooth R, et al. The longitudinal association between glycaemic control and health-related quality of life following insulin therapy optimisation in type 2 diabetes patients. A prospective observational study in secondary care. 21:1359–65. doi:10.1007/s11136-011-0051-0.

[5] Hickman M, Drummond N, Grimshaw J. A taxonomy of shared care for chronic disease. J Public Health Med 1994;16:447–54.

[6] Lai CL, Hou YH. The association of clinical guideline adherence and pay-for-performance among patients with diabetes. J Chin Med Assoc 2013;76:102–7.

[7] Hsieh HM, Gu SM, Shin SJ, Kao HY, Lin YC, Chiu HC. Cost-effectiveness of a diabetes pay-for-performance program in diabetes patients with multiple chronic conditions. PLoS One 2015;10: e0133163doi:10.1371/journal.pone.0133163.

[8] Hsieh HM, Tsai SL, Shin SJ, Mau LW, Chiu HC. Cost-effectiveness of diabetes pay-for-performance incentive designs. Med Care 2015;53: 106–15.

[9] Chen YC, Lee CT, Lin BJ, Chang YY, Shi HY. Impact of pay-for-performance on mortality in diabetes patients in Taiwan: a population-based study. Medicine (Baltimore) 2016;95:e4197doi:10.1097/MD.0000000000004197.

[10] Brown EC, Robicsek A, Billings LK, et al. Evaluating primary care physician performance in diabetes glucose control. Am J Med Qual 2016;31:392–9.

[11] Chang RE, Lin SP, Aron DC. A pay-for-performance program in Taiwan improved care for some diabetes patients, but doctors may have excluded sicker ones. Health Aff (Millwood) 2012;31:93–102.

[12] Chen TT, Chung KP, Lin IC, Lai MS. The unintended consequence of diabetes mellitus pay-for-performance (P4P) program in Taiwan: are patients with more comorbidities or more severe conditions likely to be excluded from the P4P program? Health Serv Res 2011;46:47–60.

[13] Chiou S-J, Liao K, Huang Y-T, Lin W, Hsieh C-J. Synergy between the pay-for-performance scheme and better physician–patient relationship might reduce the risk of retinopathy in patients with type 2 diabetes. J Diabetes Investigation 2021;12:819–27. doi: https://doi.org/10.1111/jdi.13422.

[14] Amjad H, Carmichael D, Austin AM, Chang CH, Bynum JP. Continuity of care and health care utilization in older adults with dementia in fee-for-service medicare. JAMA Intern Med 2016;176:1371–8. doi:10.1001/jamainternmed.2016.3553.

[15] Pan CC, Kung PT, Chiu LT, Liao YP, Tsai WC. Patients with diabetes in pay-for-performance programs have better physician continuity of care and survival. Am J Manag Care 2017;23:e57–66.

[16] Chen CC, Tseng CH, Cheng SH. Continuity of care, medication adherence, and health care outcomes among patients with newly diagnosed type 2 diabetes: a longitudinal analysis. Med Care 2013;51:231–7.

[17] Chen CC, Chen SH. Better continuity of care reduces costs for diabetic patients. Am J Manag Care 2011;17:420–7.

[18] Lin W, Huang IC, Wang SL, Yang MC, Yaung CL. Continuity of diabetes care is associated with avoidable hospitalizations: evidence from Taiwan's National Health Insurance scheme. Int J Qual Health Care 2010;22:3–8.

[19] Tsai HY, Chou YJ, Pu C. Continuity of care trajectories and emergency room use among patients with diabetes. Int J Public Health 2015;60:505–13.

[20] Alicic RZ, Rooney MT, Tuttle KR. Diabetic kidney disease: challenges, progress, and possibilities. Clin J Am Soc Nephrol 2017;12:2032–45.

[21] Rhee CM, Leung AM, Kovesdy CP, Lynch KE, Brent GA, Kalantar-Zadeh K. Updates on the management of diabetes in dialysis patients. Semin Dial 2014;27:135–45.

[22] Lim WH, Johnson DW, Hawley C, et al. Type 2 diabetes in patients with end-stage kidney disease: influence on cardiovascular disease-related mortality risk. Med J Aust 2018;209:440–6.

[23] Jang YJ, Choy YS, Nam CM, Moon KT, Park E-C. The effect of continuity of care on the incidence of end-stage renal disease in patients with newly detected type 2 diabetic nephropathy: a retrospective cohort study. BMC Nephrology 2018;19:127doi:10.1186/s12882-018-0932-3.

[24] Finne P, Groo H, Arffman M, et al. Cumulative risk of end-stage renal disease among patients with type 2 diabetes: a nationwide inception cohort study. Diabetes Care 2019;42:539–44.

[25] Inker LA, Astor BC, Fox CH, et al. KDOQI US commentary on the 2012 KDIGO clinical practice guideline for the evaluation and management of CKD. Am J Kidney Dis 2014;63:713–35.

[26] Tsugawa Y, Blumenthal DM, Jha AK, Orav EJ, Jena AB. Association between physician US News & World Report medical school ranking and patient outcomes and costs of care: observational study. BMJ 2018;362:k3640doi:10.1136/bmj.k3640.

[27] Parati G, Bilo G, Ochoa JE. Benefits of tight blood pressure control in diabetic patients with hypertension: importance of early and sustained implementation of effective treatment strategies. Diabetes Care 2011;34: S297–303.

[28] Mancia G. Blood pressure and glucose control in patients with diabetes. Am J Hypertension 2007;20:3S–8S. doi:10.1016/j.amjhyper.2007.04.016.

[29] O'Toole SM, Fan SL, Yaqoob MM, Chowdhury TA. Managing diabetes in dialysis patients. Postgrad Med J 1037;88:160–6. doi:10.1136/postgradmedj-2011-130354.

[30] Shah BR, Hux JE, Laupacis A, Zinman B, Zwarenstein M. Deficiencies in the quality of diabetes care: comparing specialist with generalist care misses the point. J Gen Intern Med 2007;22:275–9.

[31] Overland J, Yue DK, Mira M. Continuity of care in diabetes: to whom does it matter? Diabetes Res Clin Pract 2001;52:55–61.

[32] Weir DL, McAlister FA, Majumdar SR, Eurich DT. The interplay between continuity of care, multimorbidity, and adverse events in patients with diabetes. Med Care 2016;54:386–93.

[33] Knight JC, Dowden JJ, Worrall GJ, Gadag VG, Murphy MM. Does higher continuity of family physician care reduce hospitalizations in elderly people with diabetes? Popul Health Manag 2009;12:81–6.

[34] Hu HY, Jian FX, Lai YJ, Yen YF, Huang N, Hwang SJ. Patient and provider factors associated with enrolment in the pre-end-stage renal disease pay-for-performance programme in Taiwan: a cross-sectional study. BMJ Open 2019;9:e031354doi:10.1136/bmjopen-2019-031354.

[35] Hwang JC, Jiang MY, Lu YH, Weng SF. Impact of HCV infection on diabetes patients for the risk of end-stage renal failure. Medicine (Baltimore) 2016;95:e2431doi:10.1097/MD.0000000000002431.

[36] Chang HY, Weiner JP, Richards TM, Bleich SN, Segal JB. Validating the adapted Diabetes Complications Severity Index in claims data. Am J Manag Care 2012;18:721–6.

[37] Huang YQ, Gou R, Diao YS, et al. Charlson comorbidity index helps predict the risk of mortality for patients with type 2 diabetic nephropathy. J Zhejiang University Science B 2014;15:58–66. doi:10.1631/jzus.B1300109.

[38] Multilevel Analysis: An Introduction to Basic and Advanced Multilevel Modeling (2nd Edition), Tom A. B. Snijders & Roel J. Bosker. Los Angeles, CA: Sage, 2012, 368

[39] LeBlanc ES, Rosales AG, Kachroo S, Mukherjee J, Funk KL, Nichols GA. Do patient or provider characteristics impact management of diabetes? Am J Manag Care 2015;21:597–606.

[40] Abraham I, Demosthenes L, MacDonald K, et al. Hierarchical linear and logistic modeling of outcomes of antihypertensive treatment in elderly patients: findings from the PREVIEW study. Arch Gerontol Geriatr 2010;51:45–53.

[41] Hermans M, Van Gaal L, Rezette I, et al. Patient engagement impacts glycemic management with vildagliptin and vildagliptin/metformin (single pill) regimens in type 2 diabetes mellitus (the GLORIOUS study). Prim Care Diabetes 2016;10:425–33.

[42] Yu H-C, Tsai W-C, Kung P-T. Does the pay-for-performance programme reduce the emergency department visits for hypoglycaemia in type 2 diabetic patients? Health Policy Planning 2013;29:732–41. doi:10.1093/heapol/czt056.

[43] Pan CC, Huang HL, Chen MC, et al. Lower risk of end stage renal disease in diabetic nurse. Biomedicine (Taipei) 2017;7:25doi:10.1051/bmdcn/2017070425.

[44] Young BA, Lin E, Von Korff M, et al. Diabetes complications severity index and risk of mortality, hospitalization, and healthcare utilization. Am J Manag Care 2008;14:15–23.

[45] O'Connor PJ, Rush WA, Davidson G, et al. Variation in quality of diabetes care at the levels of patient, physician, and clinic. Prev Chronic Dis 2008;5:1–9.

[46] Du YT, Rayner CK, Jones KL, Talley NJ, Horowitz M. Gastrointestinal symptoms in diabetes: prevalence, assessment, pathogenesis, and management. Diabetes Care 2018;41:627–37.

[47] Hsu CC, Tu ST, Sheu WH. Diabetes atlas: achievements and challenges in diabetes care in Taiwan. J Formos Med Assoc 2019;doi:10.1016/j.jfma.2019.06.018.

[48] Chen Y-C, Lee CT-C, Lin BJ, Chang Y-Y, Shi H-Y. Impact of pay-for-performance on mortality in diabetes patients in Taiwan: a population-based study. Medicine 2016;95:e4197doi:10.1097/md.0000000000004197.

[49] Chen CC, Cheng SH. Does pay-for-performance benefit patients with multiple chronic conditions? Evidence from a universal coverage health care system. Health Policy Plan 2016;31:83–90.

[50] Couillerot-Peyrondet AL, Sambuc C, Sainsaulieu Y, Couchoud C, Bongiovanni-Delaroziere I. A comprehensive approach to assess the costs of renal replacement therapy for end-stage renal disease in France: the importance of age, diabetes status, and clinical events. Eur J Health Econ 2017;18:459–69.