ORIGINAL ARTICLE

Synergy between the pay-for-performance scheme and better physician–patient relationship might reduce the risk of retinopathy in patients with type 2 diabetes

Shang-Jyh Chiou[1], Kuomeng Liao[2], Yu-Tung Huang[3], Wender Lin[4], Chi-Jeng Hsieh[5]*

[1]Department of Health Care Management, National Taipei University of Nursing and Health Sciences, Taipei, Taiwan, [2]Department of Endocrinology and Metabolism, Zhongxiao Branch, Taipei City Hospital, Taipei, Taiwan, [3]Center for Big Data Analytics and Statistics, Chang Gung Memorial Hospital, Taoyuan City, Taiwan, [4]Department of Health Care Administration, Chang Jung Christian University, Tainan City, Taiwan, and [5]Department of Health Care Administration, Oriental Institute of Technology, New Taipei City, Taipei, Taiwan

ABSTRACT

Aims/Introduction: This study investigated whether participation by patients with type 2 diabetes in Taiwan's pay-for-performance (P4P) program and maintaining good continuity of care (COC) with their healthcare provider reduced the likelihood of future complications, such as retinopathy.

Materials and Methods: The analysis used longitudinal panel data for newly diagnosed type 2 diabetes from the National Health Insurance claims database in Taiwan. COC was measured annually from 2003 to 2013, and was used to allocate the patients to low, medium and high groups. Cox regression analysis was used with time-dependent (time-varying) covariates in a reduced model (with only P4P or COC), and the full model was adjusted with other covariates.

Results: Despite the same significant effects of treatment at primary care, the Diabetes Complications Severity Index scores were significantly associated with the development of retinopathy. After adjusting for these, the hazard ratios for developing retinopathy among P4P participants in the low, medium and high COC groups were 0.594 (95% confidence interval [CI] 0.398–0.898, $P = 0.012$), 0.676 (95% CI 0.520–0.867, $P = 0.0026$) and 0.802 (95% CI 0.603–1.030, $P = 0.1062$), respectively. Thus, patients with low or median COC who participated in the P4P program had a significantly lower risk of retinopathy than those who did not.

Conclusions: Diabetes care requires a long-term relationship between patients and their care providers. Besides encouraging patients to participate in P4P programs, health authorities should provide more incentives for providers or patients to regularly survey patients' lipid profiles and glucose levels, and reward the better interpersonal relationship to prevent retinopathy.

INTRODUCTION

Diabetes mellitus is a serious public health concern because of its many associated comorbidities and the high cost of healthcare[1,2]. Approximately 30–40% of patients with type 2 diabetes develop end-stage kidney disease[3–5], and approximately 20–40% develop retinopathy[6,7]. Patients can develop various other micro- and/or macrovascular complications if their diabetes is not well controlled. Most cases of type 2 diabetes are preventable. However, patients with type 2 diabetes can maintain a good quality of life if they manage their diet and medications, exercise regularly, and undergo regular blood glucose monitoring.

In diabetes care, some countries, such as the USA, apply the chronic care model[8] together with other disease management programs. Emphasizing interventions and combining the six

elements (health systems, decision support, clinical information systems, patient self-management support, community resources and delivery system design) of the chronic care model allows for more beneficial diabetes care, such as better clinical outcomes[9]. In 1997, Taiwan's health authorities adopted the concept of shared care from the UK[10] and created the Diabetes Shared Care Network. Since 2001, they have advocated a pay-for-performance (P4P) cost scheme under the National Health Insurance (NHI) system to improve quality control. The P4P program involves financial incentives that encourage physicians to provide their patients with enhanced education on self-care and annual diabetes-specific testing, including eye examinations and laboratory tests, such as hemoglobin A1c (HbA1c) levels. Many studies have recognized the beneficial effects of the P4P program, including the financial incentive provided by its design and the resulting improvements to diabetes care. For example, studies provide evidence for positive outcomes of the scheme, such as treatment adherence, cost-effectiveness, hospitalization rates and survival rates[11–15], although concerns have been expressed about providers cherry-picking patients[16,17]. The supplementary material of a previous study provides details of the P4P payment scheme [14]. Despite the benefits of the scheme, our previous study using longitudinal panel data showed that only one-third of the patients with type 2 diabetes in Taiwan participated in the scheme, and just 2% had participated for 10 consecutive years.

In today's patient-centered era, many governments and health insurance stakeholders have adopted the concept of continuity of care (COC) in healthcare to prevent patients from receiving fragmented healthcare services. The concept of COC, until 1990, offered more acceptable types of information, and longitudinal and interpersonal continuity from Hennen[18] and Haggerty [19], which provided measurement approaches, showed better outcomes and reduced healthcare utilization in patients with high COC indicators[20–23]. Studies on the application of COC in diabetes management have shown improved adherence, decreased costs, favorable health outcomes and a decreased hospitalization rate for patients with high COC indicators[24–28].

Diabetic retinopathy is the leading cause of vision loss in patients with chronic diabetes and those with ill-managed blood glucose levels [29]. We hypothesized that participation of patients with type 2 diabetes mellitus in the P4P scheme, with the incentives for the providers and regular checks attended by the patients, would reduce the incidence of diabetic retinopathy. We also hypothesized that maintaining a good relationship with healthcare providers would reduce the risk of retinopathy.

To test these hypotheses, we used data from Taiwan's NHI claims database, which includes data on >99% of the population of Taiwan. The database used in the present study contained all the medical records of eligible diabetes patients between 1997 and 2013, providing an ideal longitudinal study sample. Additionally, previous studies typically used population-averaged models (such as traditional regression models),

allowing for an easy comparison of different populations while adjusting for covariates. These studies were restricted, in that they included participation in the P4P program as a dichotomous outcome (yes/no). In contrast, the longitudinal data used in the present study allowed us to examine changes over time and the long-term effects of covariates (particularly, participation in the P4P program and a COC indicator). In particular, we were able to use subject-specific models (e.g., time-varying covariates) to draw conclusions by comparing the effects of successive responses from the same patient in the study[30].

The present study aimed to investigate whether participation by patients with type 2 diabetes in a P4P program and maintaining a good relationship with their healthcare provider, as measured by a COC index, reduced the likelihood of future complications, such as retinopathy. It should be noted that the outcomes from participating in the P4P program might be affected by different COC levels. For example, in patients with a high COC indicator, the P4P scheme might have limited effects. Therefore, we investigated the impact on outcomes from the P4P scheme among patients in the low, median and high COC groups.

METHODS

Study design and data

The present retrospective longitudinal study obtained data from Taiwan's 2003 NHI claims database for diabetes. The database was created in 2003 by randomly simplifying the NHI claims database to include 120,000 newly diagnosed diabetes patients treated with oral hypoglycemic agents, using the International Classification of Diseases (ICD)-9-CM code (250) and A-code (A181) as selection criteria [31]. This study was carried out between 2003 and 2013.

Continuity of care indicators

The Usual Provider Care (UPC) index was used as an indicator of COC[32]. The UPC index is widely used to measure longitudinal COC[33], and is calculated as the number of times a patient visited his or her main provider for diabetes care divided by the total number of times the patient visited all providers for diabetes care. We calculated the ratio every 365 days after the date of the first diagnosis. In the present study, we used arbitrary cut-off points of <0.5, 0.5–0.8 and ≥0.8 to categorize the patients in a low, medium and high COC group, respectively, for each year during the study period. Because the cut-off values for the UPC index were arbitrary, we carried out a sensitivity analysis using different cut-off values (0.4, 0.6, 0.7 and 0.9); this confirmed that the statistical outcomes were stable (Tables S1 and S2).

Dependent variable

The main outcome measure was retinopathy (as defined by the ICD-9-CM codes 250.50–250.53, 362.01 and 362.02), recorded at least three times in the database. The first DR date was used

to calculate the duration of retinopathy-associated events. This selection criteria were validated in a previous study [34].

Independent variables

Patients with newly diagnosed type 2 diabetes were selected from the NHI diabetes database, and the associated information on the independent variables was extracted from the main NHI claims database. The following parameters were included in the analysis: age, sex, monthly payroll bracket, urbanization (high, medium or low), diabetes complication severity index (DCSI), type of medical institution (medical center, regional hospital, local hospital or primary care clinic) and whether the patient participated in the P4P program (assessed once per year). The DCSI uses medical record data to develop a 13-point scale for quantifying the severity of complications[35], and several studies have validated the DCSI for predicting the risk of adverse outcomes in patients with diabetes[36,37].

The type of medical institution included the institution the patient visited most frequently for their diabetes care during the study period. We used the payment code, P1409c (annual management fee), to define whether the patient participated in a P4P scheme in any given year during the study period. Annual records of routine kidney tests (for protein, including a urine analysis and measurement of microalbumin level) or cardiovascular (CV) checkups (which measured total cholesterol, high-density lipoprotein, low-density lipoprotein and triglycerides) were examined. If the patient attended neither of these checkup tests in a year, the checkup test parameter was recorded as 0; if the patient attended one or both tests, it was recorded as 1. Furthermore, when a patient participated in the P4P program in a year during the study period, the checkup test parameter was recorded as 1, following the reimbursement scheme under the NHI.

Statistical analysis

We compared baseline patient characteristics between the three COC groups, and determined the percentages of patients in each group participating in the P4P program and the mean number of years of participation. Because we could extract the UPC index and P4P participation data from the annual databases, we used Cox regression analysis with time-dependent (time-varying) covariates in both a reduced model (with P4P participation or the UPC index alone, referenced as not participating in the P4P program and every UPC 0.1 numerical value) and a full model among the three groups. The full model was adjusted for other covariates to compare the effects of P4P participation and UPC index on the risk of retinopathy after adjustment on a yearly basis. We used SAS 9.3.1 (SAS Institute, Cary, NC, USA) to carry out the statistical analyses. The significance level was set at 0.05.

RESULTS

Table 1 shows the baseline patient characteristics among the low, medium and high COC groups, and the overall sample. There were significant differences between the three groups regarding most of the demographic variables, as well as the DCSI scores. Approximately 60% of the patients were in the high COC group. Those in the high COC group were slightly older and had higher DCSI scores. The percentage of patients participating in the P4P program declined from the low (16.2%) to high (12.9%) COC groups, but the average years of P4P participation showed the opposite trend (from 3.24 to 3.74 years). These findings suggest that patients with low COC might have had more opportunities to participate in the P4P program, whereas those with higher COC might have been more likely to remain in the P4P program. The percentage of patients undergoing annual kidney or CV tests was highest in the high COC group (41.2% vs 40.0% in the medium group and 40.2% in the low group). The crude incidence of retinopathy was approximately 13–19%, with a median follow-up time of 7.15–7.43 years.

We carried out a Cox regression analysis with time-dependent covariates to analyze the effect of UPC index and P4P participation after adjustments in all three groups (Tables 2,3). Table 2 shows the results of the reduced model (unadjusted), which compared the three groups, and evaluated hazard ratios (HRs), the UPC index (model I) and P4P participation (model II). The UPC index had a smaller figure on the likelihood of developing retinopathy in the low COC group than in the medium and high COC groups (HR 0.746, 95% CI 0.637–0.872; HR 0.861, 95% CI 0.795–0.936; HR 0.867, 95% CI 0.780–0.964, respectively). In the unadjusted model, the patients who participated in a P4P program had a significantly lower likelihood of developing retinopathy in all three groups (HR 0.608, 95% CI 0.414–0.893; HR 0.620, 95% CI 0.489–0.787; HR 0.679, 95% CI 0.530–0.869, respectively).

Table 3 shows the Cox regression models adjusted for the time-dependent (time-varying) covariates in the overall sample and in the three COC groups. Despite the same significant effect of the type of medical institution and DCSI scores, the HRs for P4P participation were 0.594 ($P = 0.012$), 0.676 ($P = 0.0026$) and 0.802 ($P = 0.1062$). This suggested that the patients who participated in the P4P program had a lower risk of retinopathy than those who did not, especially those in the low and medium COC groups. Conversely, the UPC index showed significant results in all three COC groups, with HRs of 0.773 ($P = 0.0012$), 0.883 ($P = 0.002$), and 0.858 ($P = 0.0048$), respectively. This suggests that maintaining a higher COC for patients with type 2 diabetes might reduce the risk of retinopathy, even without participation in the P4P program, especially for patients in the high COC group. In these three models, the patients treated at a clinic (primary care) had a lower likelihood of developing retinopathy than those visiting larger medical institutions (HRs 0.432, 0.351 and 0.585, respectively, $P < 0.001$). Additionally, patients with DCSI scores of ≥1 had a two- to fourfold higher risk of retinopathy than those with a DCSI of 0 in all three models (HRs 2.35, 2.95 and 4.31, respectively, $P < 0.001$). Undergoing an annual CV and/or kidney checkup showed a significant effect in the models for the medium and high COC groups (HRs 0.79 and 0.63,

Table 1 | Characteristics of observations from type 2 diabetes patients in the Taiwan National Health Insurance database

		All	Low COC	Median COC	High COC	P
		289,734 (100%)	28,963 (10.0%)	86,210 (29.8%)	174,561 (60.2%)	
		n (%)	n (%)	n (%)	n (%)	
UPC	Mean ± SD	0.8 ± 0.23	0.37 ± 0.07	0.62 ± 0.09	0.97 ± 0.06	
P4P[†]	Yes	40,917 (14.1)	4,704 (16.2)	13,747 (15.9)	22,466 (12.9)	<.0001
Sex	Female	132,669 (45.8)	12,840 (44.3)	39,359 (45.7)	80,470 (46.1)	<.0001
Age (mean ± SD)		54.9 ± 12.6	55.7 ± 12.9	55.2 ± 12.6	54.6 ± 12.6	<.0001
Income (NT$)	Dependents	99,655 (34.4)	6,757 (23.3%)	17,553 (20.4)	32,978 (18.9)	<.0001
	<17,780	57,288 (19.8)	9,662 (33.4%)	29,802 (34.6)	60,191 (34.5)	
	17,781–28,800	106,690 (36.8)	10,387 (35.9%)	31,639 (36.7)	64,664 (37.0)	
	28,801–45,800	16,991 (5.9)	1,388 (4.8%)	4,704 (5.5)	10,899 (6.2)	
	45,801–72,800	7,309 (2.5)	611 (2.1%)	1,995 (2.3)	4,703 (2.7)	
	72,801	1,708 (0.6)	156 (0.5%)	500 (0.6)	1,052 (0.6)	
Urbanization	1	159,274 (55.0)	14,979 (51.7)	46,415 (53.8)	97,880 (56.1)	<.0001
	2	95,569 (33.0)	9,774 (33.7)	28,858 (33.5)	56,937 (32.6)	
	3	34,765 (12.0)	4,207 (14.5)	10,913 (12.7)	19,645 (11.3)	
Medical institution	Medical center	50,544 (17.7)	4,934 (17.0)	14,760 (17.1)	30,850 (17.7)	<.0001
	Regional hospital	57,923 (20.3)	5,589 (19.3)	16,681 (19.3)	35,653 (20.4)	
	Local hospital	58,073 (20.4)	7,205 (24.9)	18,415 (21.4)	32,453 (18.6)	
	Clinic	118,400 (41.6)	10,450 (36.1)	34,634 (40.2)	73,316 (42.0)	
DCSI	0	283,931 (98.0)	28,303 (97.7)	84,381 (97.9)	171,247 (98.1)	<.0001
	1	3,903 (1.3)	411 (1.4)	1,209 (1.4)	2,283 (1.3)	
	≥2	1,900 (0.7)	249 (0.9)	620 (0.7)	1,031 (0.6)	
Kidney/CV test	Yes	118,116 (40.8)	16,358 (40.2)	48,212 (40.0)	94,463 (41.2)	<.0001
Average years of P4P participation		3.62	3.24	3.54	3.74	
Retinopathy[‡]	Incidence	15.0%	19.4%	16.9%	13.4%	<.0001
	Median (years)	7.21	7.15	7.26	7.43	

The χ^2-test and ANOVA were used. Low continuity of care (COC; <0.5), median COC (0.5–0.8) and high COC (≥0.8). The average years of pay-for-performance (P4P) participation were driven from the frequencies by those who participated in the P4P program in the study period among different COC groups and then the aggregate of the figures to calculate the mean. CV test, cardiovascular test; DCSI, Diabetes Complications Severity Index; NT$, New Taiwan dollar; P4P, pay-for-performance; UPC, usual provider care. [†]When patients had one record or more in the study period. [‡]This is a crude prevalence.

Table 2 | Risk of retinopathy in the reduced model from Cox regression with time-dependent (time-varying) covariates among low, median and high continuity of care groups

		All			Low COC			Median COC			High COC		
	Variable	HR	95% CI	P	HR	95% CI	P	HR	95% CI	P	HR	95% CI	P
Model I	UPC[†]	0.861	0.845–0.877	<.0001	0.746	0.637–0.872	0.0002	0.861	0.795–0.936	0.0002	0.867	0.780–0.964	0.0083
Model II	P4P join[‡]	1.356	1.282–1.435	<.0001	0.608	0.414–0.893	0.0113	0.620	0.489–0.787	<.0001	0.679	0.530–0.869	0.0021

COC, continuity of care; HR, hazard ratio; UPC, usual provider care. [†]Reference is every usual provider care (UPC) 0.1 numerical value. [‡]Reference has not joined the pay-for-performance (P4P) program.

respectively), indicating that having CV and/or kidney biomarkers checked annually during visits to the doctor's office reduced the likelihood of developing retinopathy. No significant effects were found for any of the remaining variables. A comparison of the three models showed that there was no fluctuation in the results, indicating statistical stability.

DISCUSSION

Among the type 2 diabetes mellitus patients in the present study with lower COC indicators (i.e., low and medium UPC indices), the likelihood of retinopathy decreased with participation in the P4P program. This might have been because, under the P4P requirements, physicians who were qualified

in metabolic specialties collaborated with other healthcare professionals to educate the patients on diet and health improvement, and provide regular medical checkups. Furthermore, the patients maintaining a good relationship with their healthcare provider(s), as shown by higher COC values, and those undergoing regular kidney or CV tests, also experienced a lower risk of retinopathy. A previous study similarly reported that participation in a P4P program improved the care of patients with diabetes through teamwork, provided they followed the clinical guidelines under the payment scheme[38]. Furthermore, chronic diseases require long-term care, and patients with type 2 diabetes benefit from a stable physician–patient relationship (in the high COC group) based on trust or from an integrated care team that can collaborate with other professionals to provide treatment in certain areas, such as dietary guidance and exercise coaching.

Risk factors for diabetic retinopathy include HbA1c levels, disease duration and systolic blood pressure levels. The incidence of diabetic retinopathy observed in the present study (13.3–19%) was lower than those reported in other studies (approximately 20–30%)[39,40]. One possible explanation is that we applied strict selection criteria and constructed a 10-year panel database with a large sample size, whereas the other studies were limited in sample size and study period.

Not surprisingly, patients with higher DCSI scores, which indicated that their diabetes was not well controlled, had an increased likelihood of retinopathy. This was consistent with previous studies that showed that poor control of diabetes increased the risk of complications, such as retinopathy[35,41].

Previous studies reported high levels of total cholesterol and triglycerides in most patients with diabetic retinopathy[42,43], although one study found no such association[44]. In the present study, we could only ascertain whether the patients underwent a renal and/or CV checkup; because of dataset restrictions, the outcomes of these tests were unknown to us. We found that patients who had regular CV or renal checkups had a reduced risk of retinopathy. This might have been because their healthcare providers were more aggressive in treating these patients. Clinical guidelines for providers, such as those from the American Diabetes Association, recommend microalbuminuria testing and regular annual eye examinations to reduce the risk of diabetic retinopathy[45,46]. The association between attendance at checkups and a lower risk of retinopathy was not observed in the low COC group. This suggests that the patients who did not maintain a good relationship with their diabetes care provider did not receive the advantage of regular diabetes monitoring.

Patients who received treatment at a primary care clinic had a lower risk of retinopathy. This might have been because the patients had more time to discuss diabetes control with their healthcare providers. A primary care clinic is typically close to the patient's residence, and healthcare professionals working at such clinics are likely to collaborate with other healthcare professionals to improve the patient's diabetes regimen. However, it is also possible that the patients who received treatment at a primary care clinic had less severe diabetes than those visiting larger facilities, such as medical centers, or regional or local hospitals, and therefore had a lower risk of retinopathy. Furthermore, a previous study reported that patients who participated in a P4P program had fewer comorbidities, because their care providers adopted a prudent attitude when enrolling patients in the program[16].

In the Cox regression model with time-varying covariates, a higher UPC index was associated with a reduced likelihood of retinopathy, with an HR of 0.77–0.88, indicating that patients with a good COC could benefit from maintaining a good relationship with their care providers. However, the effect of participating in a P4P program might shift those contributions to the UPC index or other variables; the effect was not significant in the high COC group. Furthermore, even though the rates of P4P participation were similar between the high and low COC groups, the patients in the low COC group did not participate in the P4P program as frequently (average years of P4P participation was 3.24 vs 3.74).

Our sensitivity tests using different UPC cut-off points to determine the COC groups showed that the statistics were quite stable. The different cut-off points should not be overemphasized while comparing the results of the three groups mentioned in the present study. Our findings suggest that, irrespective of a patient's physiological and disease condition, the best chronic disease management results came either from a good relationship between the patient and a provider who understood his or her diabetes situation and provided an appropriate regimen, or from a healthcare system that provided incentives and encouraged providers to offer diabetes treatment consistent with the guidelines within a collaborative team.

As the P4P program provides financial incentives for healthcare providers to deliver the integrated care for type 2 diabetes mellitus and patients can go to doctors' offices without restriction, the effect of COC might be slightly reduced under the *laissez-faire* NHI system in Taiwan. Therefore, the effect of participating in P4P driven by providers while having higher UPC indicators requires cooperation from patients. Furthermore, in the results of the interaction test for UPC and P4P, we identified significant effects in the high COC group (HR for the low, median and high groups of 0.463 [$P = 0.7713$], 11.55 [$P = 0.0650$] and 0.020 [$P = 0.0146$], respectively), which shows that collaborative effects between UPC and P4P were present in the high COC group. To reduce the risk of retinopathy in type 2 diabetes mellitus patients, a long-term endeavor and synergy comes from providers adopting the essence of P4P, and patients maintaining a good relationship, both working together. Many patients in the low COC group might not receive optimal benefit from participating in the P4P program, in which their provider would have provided eye examinations regularly or follow ups under the NHI requirements to improve their diabetes care. Financial incentives might help these patients increase their treatment adherence[47]. Authorities should consider implementing such

Table 3 | Risk of retinopathy from Cox regression with time-dependent covariates in the full model compared with participating in the pay-for-performance program or not among low, median and high continuity of care groups

		Model 1 (low COC)		Model 2 (median)		Model 3 (high COC)	
		HR	P	HR	P	HR	P
UPC[†]		0.773*	0.0012	0.883*	0.0020	0.858*	0.0048
P4P	Participating	0.594*	0.0120	0.676	0.0026*	0.802	0.1062
Age[‡]		0.990	0.0384	0.993	0.0188	1.002	0.4327
Sex	Female	1.008	0.9484	0.981	0.8061	0.967	0.6558
Monthly income (NT$)	Dependents	1		1		1	
	<17,780	1.174	0.3337	1.154	0.1464	1.138	0.1887
	17,780–28,800	1.106	0.5249	0.868	0.1440	0.838	0.0613
	28,801–45,800	1.262	0.4032	0.692	0.0615	0.915	0.6085
	45,801–72,800	1.201	0.6489	0.808	0.4301	1.169	0.4834
	>72,801	0.634	0.6520	0.602	0.3850	1.081	0.8642
Urbanization	1, 2	1		1		1	
	3, 4	0.935	0.6276	0.920	0.3274	0.880	0.1257
	5, 6, 7	1.152	0.4439	0.948	0.6847	0.935	0.6045
Medical institution	Medical center	1		1		1	
	Regional hospital	0.929	0.6833	1.121	0.2707	1.128	0.2694
	Local hospital	0.986	0.9321	0.881	0.2393	1.284	0.0221
	Clinic	0.442*	<.0001	0.361*	<.0001	0.596*	<.0001
DCSI	0	1		1		1	
	1	1.936	0.0852	2.064*	0.0011	2.788*	<.0001
	>2	4.118*	<.0001	2.717*	0.0001	2.131*	0.0177
Kidney/CV test	Yes	1.070	0.6000	0.791*	0.0036	0.632*	<.0001

CV, cardiovascular; DCSI, Diabetes Complications Severity index; HR, hazard ratio; NT$, New Taiwan dollar; P4P, pay-for-performance; UPC, usual provider care. Cox regression with time-dependent (time-varying) covariates. [†]Reference is every UPC 0.1 numerical value. [‡]Age is defined as the patients diagnosed in 2003 (years). *$P < 0.05$.

incentives for at-risk patients with type 2 diabetes. We, therefore, recommend that health authorities consider developing strategies, such as reminder messages, to encourage patients with low COC indicators to continually participate in the P4P program to improve their diabetes care.

Patients with type 2 diabetes can reduce the risk of retinopathy by improving their relationship with their care providers, thereby ensuring long-term monitoring of their diabetes. When such long-term care relationships are not possible, patients might benefit from participating in the P4P program, as the financial incentive design of this reimbursement system requires both patients and providers to be more alert about diabetes control. The rate of participation in P4P for diabetes patients in Taiwan <40%, and health authorities might face financial burdens because of additional incentives from the cost scheme for the aging population with type 2 diabetes. Health authorities should, therefore, consider adopting meaningful elements of the P4P program (such as the provision of regular checkups and/or integrated care teams) for diabetes control to reduce the risk of retinopathy. Additionally, it is important for the cost scheme of the NHI system to consider annual optometry checkups for patients with type 2 diabetes.

The present study had several strengths. It used the NHI claims database, which included longitudinal panel data of

patients with diabetes. The sample size and representativeness of the data for the entire population were ideally suited to exploring the association between P4P program participation and the risk of experiencing type 2 diabetes-related complications, such as diabetic retinopathy. Another reason why data from Taiwan's NHI are ideal for testing the effects of COC or P4P participation is that patients are free to choose their provider for diabetes care, and participation in the P4P is voluntary and decided by their provider. Besides using the annual database to estimate the rates of patients receiving CV and kidney checkup examinations, we used participation in the P4P program and COC indicators as time-dependent covariates in the Cox proportional hazards regression model. In contrast, most previous studies have used a dichotomous outcome for P4P participation using a traditional approach.

However, the present study was not without limitations. First, the database did not include information on biomarker levels, including HbA1c, or the results of the CV and renal checkups; thus, the analysis only included the frequency of the usage of these tests without outcomes that could show the success of diabetes control. The database did not provide biomarker level information (for example, %HbA1c) for analysis to determine the real change in physiological condition. Future clinical studies are required to provide further evidence-based

findings. Furthermore, although the findings of the three models showed significant data, a stricter examination of the benefits of joining a P4P program is required to clarify the long-term effects on reducing the risk of diabetes-related complications. Additionally, an improved study design would be to choose type 2 diabetes patients with/without participation in a P4P program, and to divide them into three groups to construct the model: (i) high COC without P4P participation; (ii) low COC without P4P participation; and (ii) those participating in P4P. After attempting this, we found that the patients in the group with high COC, but without P4P participation, had the lowest likelihood of retinopathy compared with those in the P4P participation group after propensity score matching. However, this result might be influenced by selection bias and is too perfect to not have the applied value in the empirical situation. Furthermore, we cannot exclude the possibility that physicians might drop patients from their P4P panel if they begin to show adverse effects from diabetes complications. This information cannot support the dataset we used, and more evidence is required from further studies. Finally, the quality of disease coding might have affected the estimation of the likelihood of developing retinopathy, and the results might have been underestimated.

Diabetes care requires a long-term relationship between patients and their care providers. For patients with type 2 diabetes who had low COC indicators, participation in a P4P program and/or following clinical guidelines was associated with the likelihood of developing retinopathy. In addition to encouraging patients to participate in P4P programs, health authorities might provide more incentives for providers or patients to regularly check and reward improved interpersonal relationships in diabetes control to reduce the risk of retinopathy.

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DISCLOSURE

The authors declare no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1 | The risk of retinopathy from Cox regression with time-dependent covariates in the full model compared with different cut-off point in 0.4 and 0.6.

Table S2 | The risk of retinopathy from Cox regression with time-dependent covariates in the full model compared with different cut-off point in 0.7 and 0.9.