Impact of Duration of Type 2 Diabetes Mellitus on Intermediate Outcomes in Patients Received Pay-for-Performance Shared Care in Taiwan

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Abstract

Background. It is not clear whether diabetes duration may influence the effect of pay-for-performance (P4P) shared care on patient outcomes. We aimed to investigate the associations between diabetes duration and intermediate outcomes in patients with type 2 diabetes mellitus (T2DM) who received P4P shared care in Taiwan.

Methods. We retrospectively identified patients with T2DM who were enrolled in the P4P program between 2014 and 2018. We divided the study population according to their duration of T2DM (<1 year, 1-10 years, >10 years). Patient outcomes were defined as changes in glycated hemoglobin (HbA1c), low-density-lipoprotein (LDL) cholesterol, renal function determined as estimated glomerular filtration rate (eGFR), and urine albumin-to-creatinine ratio (UACR) from baseline to 1-year follow-up. The associations between duration of T2DM and changes in these outcomes were analyzed.

Results. A total of 604 patients with T2DM were enrolled. Using patients with T2DM duration <1 year as the reference group, those with longer T2DM duration were more likely to have an increase in HbA1c and LDL cholesterol. There was no significant association between T2DM duration and eGFR change from baseline to 1-year follow-up. Nevertheless, patients with T2DM duration >10 years were more likely to have an increase in UACR, compared with the reference group.

Conclusion. We demonstrated a negative impact of T2DM duration on the effect of P4P program on HbA1c, LDL cholesterol, and UACR changes during 1-year follow-up.

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Introduction

The number of patients with type 2 diabetes mellitus (T2DM) is continuously increasing all over the world and in Taiwan[1,2]. The goal of treating patients with T2DM is to decrease risk of diabetes complications and improve quality of life[3]. The outcomes of patients with T2DM have been improved since the initiation of pay-for-performance (P4P) shared care program for diabetes care in Taiwan[4-6]. The improvements in patient outcomes may be partly attributed to the improvements in intermediate outcomes (glucose, blood pressure, and lipids control) during the same period[7,8].

T2DM is a progressive disease. Given the progressive decline in pancreatic β-cell function[9,10], the glycemic control of patients with T2DM may deteriorate overtime. This factor may contribute to an increase in risk of chronic complications associated with disease duration in these patients[11,12]. Despite the universal coverage of health care insurance in Taiwan, the quality of diabetes care remains suboptimal in a recent report[13]. The P4P shared care program has been associated with better diabetes outcomes[4-6], nevertheless, it is not clear whether T2DM duration associates with the patients' outcomes in the P4P shared care program.

Diabetes duration is linked to negative outcomes such as coronary atheroma burden, cardiovascular/microvascular complications, and mortality in type 2 diabetes. Research has shown that the risk of coronary heart disease death is higher in those with longer diabetes duration, even after accounting for other risk factors[14-17]. In addition, Ko et al. found that duration of diabetes affects the success of diabetes education programs. Patients with a shorter duration of diabetes showed better outcomes in self-care behaviors and glycemic control compared to those with longer diabetes duration. The study suggests that patients with longstanding type 2 diabetes may need more intensive and sustained reinforcement to achieve better results in managing their condition.[18]

Hence, understanding the potential associations between longer diabetes duration and increased risk is crucial in developing effective prevention and treatment strategies for individuals with T2DM. Therefore, this study aimed to investigate these associations in patients with T2DM who received P4P shared care in a regional hospital in central Taiwan.

Methods

We retrospectively identified patients with T2DM who were enrolled in the P4P program between 2014 and 2018 in our hospital. Patients who aged less than 18 years were excluded. A total of 1,346 patients had their first visit between October16, 2014 and December 31, 2018. Seven hundred and thirty patients were excluded for not having examination data in the first year. Out of the remaining patients, 616 had both their first visit date and yearly examination data available. Their first visit date ranged from November 6, 2014 to April 7, 2018. Seven patients with type 1 diabetes were excluded, leaving 609 patients. Five patients under 18 years of age were also excluded, leaving 604 patients in the final analysis.

To investigate the associations between diabetes duration and patient outcomes, only patients who had completed 1-year follow-up were included in our analyses. Patient outcomes were defined as changes at 1-year follow-up from baseline in glycated hemoglobin (HbA1c), low-density-lipoprotein (LDL) cholesterol, renal function determined as estimated glomerular filtration rate (eGFR), and urine albumin-to-creatinine ratio (UACR). This study was conducted in accordance with the Declaration of Helsinki. The study protocol was approved by the Institutional Review Board of Kuang Tien General Hospital, Taichung, Taiwan (approval number:10845).

We divided the study population according to their duration of T2DM (<1 year, 1-10 years, >10 years). The information on diabetes duration and relevant parameters, such as demographic characteristics and laboratory data (HbA1c, lipids profile, eGFR, and UACR) was recorded from the patients' electronic medical records. Changes

from baseline to 1-year follow-up in HbA1c, LDL cholesterol, eGFR, and UACR were considered as the intermediate outcomes.

Statistical analysis

Continuous data were presented as mean ± standard deviation (SD), and statistical differences among the diabetes duration groups were performed by one way ANOVA. Categorical data were presented as frequency (percentage) and statistical analyses were performed by the chi-squared test. Comparisons of the intermediate outcome measures (HbA1c, LDL cholesterol, eGFR and UACR) between baseline and 1-year follow-up were conducted using paired t test. The associations between changes in the outcome measures and duration of T2D were determined by linear regression analyses with adjustment for age, sex, and body mass index, and presented as β coefficient and 95% confidence interval (CI). All statistical analyses were performed by using SAS 9.4 (SAS Institute, Cary, NC), and statistical significance was set at a *P*-value <0.05.

Results

A total of 604 patients with T2DM were enrolled in this study. Table 1 shows the baseline characteristics of the study population by duration of T2DM. Patients with diabetes duration >10 years were older, had higher pre-meal blood glucose but lower total and LDL cholesterol levels, and lower eGFR with higher UACR, compared with those who had shorter duration of T2DM (Table 1).

Table 2 shows the changes in HbA1c, LDL cholesterol, eGFR, and UACR from baseline to 1-year follow-up according to duration of T2DM. The HbA1c and LDL cholesterol significantly improved at 1-year follow-up irrespective of the diabetes duration. However, patients with diabetes duration >10 years had a less improvement in HbA1c (p <0.001) and LDL cholesterol (p = 0.007), compared with those who had shorter duration of T2DM. The eGFR declined at 1-year follow-up in all the three groups, with no significant between-group difference in the eGFR changes from baseline (p = 0.10). The UACR significantly increased in patients

Table 1. Baseline characteristics of the study population by duration of type 2 diabetes mellitus

Variables	Duration of type 2 diabetes mellitus			P value
	<1 year	1-10 years	>10 years	
N	263	247	94	
Age, years	52.8 ± 13.6	57.6 ± 12.9	66.9 ± 10.6	<0.001
Male sex, %	127 (48.3)	121 (49.0)	33 (35.1)	0.053
Body mass index, kg/m^2	26.8 ± 4.9	26.6 ± 4.6	25.7 ± 4.0	0.13
Blood glucose before meals, mg/dl	153.6 ± 47.0	171.1 ± 57.3	œ188.9± 66.7	<0.001
HbA1c, %	9.5 ± 2.6	8.8 ± 2.3	9.0 ± 2.0	0.004
Total cholesterol, mg/dl	201.5 ± 65.9	186.5 ± 44.5	170.3 ± 35.9	<0.001
LDL cholesterol, mg/dl	117.3 ± 35.2	106.6 ± 35.7	92.6 ± 30.1	<0.001
HDL cholesterol, mg/dl	44.9 ± 11.9	44.2 ± 11.7	44.8 ± 11.5	0.80
Triglyceride, mg/dl	207.0 ± 395.8	179.6 ± 136.0	157.1 ± 124.2	0.28
eGFR, mL/min/1.73 m^2	107.5 ± 33.8	95.5 ± 37.3	72.0 ± 29.9	<0.001
UACR, mg/g	88.7 ± 418.0	225.0 ± 744.8	373.2 ± 748.0	<0.001

Values are mean ± SD or %. HbA1c, glycated hemoglobin. LDL, low-density lipoprotein. HDL, high-density lipoprotein. eGFR, estimated glomerular filtration rate. UACR, urine albumin-to-creatinine ratio.

Table 2. Changes in HbA1c, LDL cholesterol, eGFR, and UACR by known duration of T2DM

Variables	Known duration of T2DM			P value
	<1 year	1-10 years	>10 years	
HbA1c, %				
At baseline	9.5 ± 2.6	8.8 ± 2.3	9.0 ± 2.0	0.004
At 1-year follow-up	6.9 ± 1.2***	7.6 ± 1.5***	8.1 ± 1.4***	<0.001
Change from baseline	-2.6 ± 2.4	-1.2 ± 1.9	-0.9 ± 1.9	<0.001
LDL cholesterol, mg/dl				
At baseline	117.3 ± 35.2	106.6 ± 35.7	92.6 ± 30.1	<0.001
At 1-year follow-up	94.4 ± 25.7***	91.4 ± 25.8***	82.7 ± 23.2**	<0.001
Change from baseline	-22.9 ± 38.9	-15.1 ± 38.3	-10.0 ± 33.9	0.007
eGFR, mL/min/1.73 m^2				
At baseline	107.5 ± 33.8	95.5 ± 37.3	72.0 ± 29.9	<0.001
At 1-year follow-up	98.5 ± 26.3***	89.3 ± 33.4***	68.3 ± 28.8**	<0.001
Change from baseline	-9.0 ± 26.8	-6.2 ± 18.4	-3.7 ± 13.3	0.10
UACR, mg/g				
At baseline	88.7 ± 418.0	225.0 ± 744.8	373.2 ± 748.0	<0.001
At 1-year follow-up	85.9 ± 504.2	293.1 ± 981.2	549.5 ± 1216.3*	<0.001
Change from baseline	4.8 ± 246.6	75.2 ± 628.9	176.3 ± 791.0	0.03

Values are presented as mean ± SD. HbA1c, glycated hemoglobin. LDL, low-density lipoprotein. eGFR, estimated glomerular filtration rate. UACR, urine albumin-to-creatinine ratio. *P <0.01, **P <0.01, ***P <0.001 vs. baseline.

from baseline to 1-year follow-up in HbA1c, LDL cholesterol, eGFR, and UACR were considered as the intermediate outcomes.

Statistical analysis

Continuous data were presented as mean ± standard deviation (SD), and statistical differences among the diabetes duration groups were performed by one way ANOVA. Categorical data were presented as frequency (percentage) and statistical analyses were performed by the chi-squared test. Comparisons of the intermediate outcome measures (HbA1c, LDL cholesterol, eGFR and UACR) between baseline and 1-year follow-up were conducted using paired t test. The associations between changes in the outcome measures and duration of T2D were determined by linear regression analyses with adjustment for age, sex, and body mass index, and presented as β coefficient and 95% confidence interval (CI). All statistical analyses were performed by using SAS 9.4 (SAS Institute, Cary, NC), and statistical significance was set at a *P*-value <0.05.

Results

A total of 604 patients with T2DM were enrolled in this study. Table 1 shows the baseline characteristics of the study population by duration of T2DM. Patients with diabetes duration >10 years were older, had higher pre-meal blood glucose but lower total and LDL cholesterol levels, and lower eGFR with higher UACR, compared with those who had shorter duration of T2DM (Table 1).

Table 2 shows the changes in HbA1c, LDL cholesterol, eGFR, and UACR from baseline to

Table 3. Associations of type 2 diabetes mellitus duration with changes in clinical parameters

Independent variable: duration of type 2 diabetes	Univariate		Multivariatea	
	β coefficient (95% CI)	P value	β coefficient (95% CI)	P value
		Change in HbA1c		
<1 year	ref		ref	
1-10 years	1.37 (1.00, 1.75)	<0.001	1.28 (0.90, 1.66)	<0.001
>10 years	1.72 (1.21, 2.24)	<0.001	1.42 (0.87, 1.96)	<0.001
		Change in LDL-C		
<1 year	ref		ref	
1-10 years	7.78 (1.19, 14.37)	0.021	7.99 (1.29, 14.70)	0.020
>10 years	12.94 (4.00, 21.88)	0.005	13.59 (4.02, 23.16)	0.005
		Change in eGFR		
<1 year	ref		ref	
1-10 years	2.80 (-1.01, 6.60)	0.150	2.07 (-1.79, 5.92)	0.293
>10 years	5.31 (0.15, 10.48)	0.044	3.49 (-2.00, 8.99)	0.212
		Change in UACR		
<1 year	ref		ref	
1-10 years	70.40 (-26.91, 167.71)	0.156	65.76 (-32.87, 164.40)	0.191
>10 years	171.53 (41.81, 301.24)	0.010	172.74 (34.21, 311.27)	0.015

HbA1c, glycated hemoglobin. LDL-C, low-density lipoprotein cholesterol. eGFR, estimated glomerular filtration rate. UACR, urine albumin-to-creatinine ratio. aAdjusted for age, sex, and body mass index.

1-year follow-up according to duration of T2DM. The HbA1c and LDL cholesterol significantly improved at 1-year follow-up irrespective of the diabetes duration. However, patients with diabetes duration >10 years had a less improvement in HbA1c ($p < 0.001$) and LDL cholesterol ($p = 0.007$), compared with those who had shorter duration of T2DM. The eGFR declined at 1-year follow-up in all the three groups, with no significant between-group difference in the eGFR changes from baseline ($p = 0.10$). The UACR significantly increased in patients with diabetes duration >10 years. This group also had a significantly greater change from baseline in UACR (within-group $p < 0.01$).

Table 3 shows the associations of T2DM duration with changes from baseline to 1-year follow-up in the outcome measures. Using patients with diabetes duration <1 year as the reference group, those with longer diabetes duration were more likely to have an increase in HbA1c and LDL cholesterol. There was no significant association between diabetes duration and eGFR change from baseline to 1-year follow-up. Nevertheless, patients with diabetes duration >10 years were more likely to have an increase in UACR, compared with the reference group.

In our study, a positive beta coefficient indicates that an increase in diabetes duration (predictor variable) is associated with a smaller decrease in HbA1c (outcome variable). This means that patients with longer diabetes duration may have a smaller improvement in HbA1c compared to those with shorter diabetes duration. Our study found that patients with diabetes duration of 1-10 years and >10 years had significantly higher changes in HbA1c of 1.37% and 1.72%, respectively, compared to those with duration <1 year. This means that their HbA1c decreased less than patients with diabetes duration <1 year.

Discussion

In this study, we aimed to investigate the effect of T2DM duration on intermediate outcomes in patients who received P4P shared care in a regional hospital in central Taiwan. Our results demonstrate that patients with longer T2DM duration had less improvement in HbA1c and LDL cholesterol at 1-year follow-up, and were more likely to have an increase in UACR compared to patients with shorter T2DM duration. These findings are important because they suggest that patients with longer T2DM duration may require more intensive and individualized care to achieve optimal glycemic control and reduce the risk of long-term complications, which may not be fully addressed by P4P programs alone.

Furthermore, our study is the first to disclose the negative impact of T2DM duration on the effect of P4P programs in diabetes and chronic kidney disease care in Taiwan. Our results highlight the importance of personalized care and continuous evaluation of the effectiveness of P4P programs to improve patient outcomes. Our findings, if confirmed, may provide insight on the implementation and improvement of P4P programs for diabetes and chronic kidney disease care in Taiwan, and possibly other countries as well. This study underscores the need for healthcare professionals to take into account patients' T2DM duration when designing treatment plans and developing P4P programs to achieve better outcomes for patients with T2DM.

P4P program has been associated with improvements of outcomes in patients with T2DM in Taiwan. The improvements in patient outcomes included micro- and macro-vascular complications[4,5,19], as well as mortality[6,20]. Nevertheless, the effects of P4P program on intermediate outcomes (HbA1c, blood pressure, and lipids) were less studied[21]. Furthermore, it is not yet clear whether duration of diabetes has an effect on the outcome improvement with P4P program. In the context of universal health insurance coverage, duration of T2DM has been associated with an increase in healthcare cost in Taiwan 22. We demonstrated that patients with long duration of T2DM (>10 years) had less improvement in HbA1c and LDL cholesterol at 1-year follow-up, compared with those who had diabetes duration less than 1 year (Table 2 and Table 3). Our findings were consistent with previous reports[18,23] in which diabetes duration had a negative effect on HbA1c control. Although these findings could be partly explained by the progressive loss of pancreatic β-cell function in patients with T2DM[9,10], the similar impact of diabetes duration on LDL cholesterol control imply some other mechanisms might be involved. We suggest that the effects of P4P program on intermediate outcomes and long-term complications of T2DM may wane over time, especially when fixed standing diabetes care was provided repeatedly, rather than individualized and patient engagement care[24,25].

Similar scenario may be observed for the effect of P4P program on diabetes nephropathy. We found that patients with diabetes duration more than 10 years were more likely to have an increase in UACR at 1-year follow-up, compared with those who had diabetes duration less than 1 year (Table 2 and Table 3). This finding may be partly explained by the negative effect of prolonged diabetes duration and suboptimal HbA1c control. Again, we would like to raise the concern of the negative impact of diabetes duration on the effect of P4P program in diabetes care. Although the P4P program for chronic kidney disease care has been successfully implemented in Taiwan[26-29], patients with T2DM are an important subgroup among those with chronic kidney disease. To the best of our knowledge, this study is the first to disclose the negative impact of diabetes duration on the effect of P4P program. Our findings warrant further investigations, and if confirmed, may provide insight on the implementation and improvement of P4P program for diabetes and chronic kidney disease care in Taiwan[30].

There were several limitations in our study. First, we did not have patients who were not enrolled in the P4P program for comparison. Whether the impact of diabetes duration on the intermediate outcomes was specific to those who were enrolled in

the P4P program deserves further study. Second, we did not investigate the effect of diabetes duration on changes in blood pressure and body weight during the follow-up period.

Third, the authors acknowledge that our study did not include information on relevant medication use in our patients, which are important factors that may affect patient outcomes. Analyzing diabetes medications, lipid-lowering agents, RAAS blockade use, weight change, and other relevant factors simultaneously would provide a more comprehensive analysis. However, as we extracted data from the P4P shared care program for diabetes care database, we did not have access to detailed information on medication use in our patients. Furthermore, since our patients were followed up for several years, medication usage and dosages may have changed over time, making it challenging to provide a simple "yes" or "no" answer regarding medication use. Although we recognize this limitation, we believe that the patients in our hospital received consistent, guideline-based medical treatment, which may have mitigated the potential bias from this aspect.

Patients with shorter diabetes duration had greater changes in A1C or LDL-cholesterol during the 1-year follow-up. This may be attributed, in part, to physicians' more intensive medication adjustment efforts in the early stages of diabetes. Physicians may prioritize more aggressive treatment for patients with newly diagnosed diabetes to achieve optimal glycemic control and prevent long-term complications[31,32]. We recognize that current management guidelines can be complicated by clinical inertia and reverse inertia, which have resulted in over half of patients failing to meet glycemic targets. Although we believe that the patients in our hospital received consistent, guideline-based medical treatment, our study also suggests that treatment reverse inertia may exist in our patients[33-36].

Forth, as 730 out of 1346 patients were excluded due to the absence of examination data in the first year. This exclusion may have introduced a selection bias to our results. Finally, the relatively small study population was enrolled at a single regional hospital in central Taiwan. Our findings need to be confirmed in future studies with a large number of patients.

In conclusion, we demonstrated a negative impact of T2DM duration on the effect of P4P program on HbA1c, LDL cholesterol, and UACR changes during 1-year follow-up. Our findings, if confirmed, may provide insight on the implementation and improvement of P4P program for diabetes and chronic kidney disease care in Taiwan.

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