

The Association between Hypertension Comorbidity and Microvascular Complications in Type 2 Diabetes Patients: A Nationwide Cross-Sectional Study in Thailand

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Background: Type 2 diabetes mellitus (T2DM) is a global pandemic and its prevalence is rapidly increasing in developing countries, including Thailand. The most common comorbidity of T2DM is hypertension. T2DM with a hypertension comorbidity is likely to exacerbate the development of, or more severe microvascular complications. This study aims to determine the association between the hypertension comorbidity and microvascular complication among T2DM patients in Thailand.

Methods: The present study is a nationwide, multicenter, cross-sectional survey of T2DM outpatients across Thailand. Binary logistic mixed effect regression was used to investigate the effect of hypertension and other risk factors on the presence of microvascular complications. Imputation was used to investigate potential bias introduced by missing values.

Results: Of the 55,797 T2DM patients included in our sample, 55.35% were hypertensive. Prevalence of microvascular complication diagnosis in the last 12 months was higher in T2DM patients with hypertension than those without hypertension (12.12% vs. 9.80%, respectively). Patient with a hypertension comorbidity had 1.32 time the odds of developing microvascular complication (adjusted odds ratio [OR], 1.32; 95% confidence interval [CI], 1.20 to 1.46; $P < 0.001$). Older age, longer diabetes duration had 1.07 and 1.21 times the odds of developing microvascular complication, per 10 years (age) and 5 years (duration), respectively (OR_{age}, 1.07; 95% CI, 1.03 to 1.12; $P < 0.001$; and OR_{duration}, 1.12; 95% CI, 1.07 to 1.16; $P < 0.001$; respectively). Minimal bias was introduced by missing values, and did not influence to the magnitude of effect of hypertension on the presence microvascular complication.

Conclusion: Hypertension comorbidity is highly associated with microvascular complication among T2DM patients. Patients with T2DM and physicians should pay attention to blood pressure control.

Keywords: Diabetes mellitus, type 2; Hypertension; Microvascular complication; Thailand

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a global pandemic [1,2] and it is projected that 300 million people will have T2DM by 2025, worldwide [1]. Prevalence of T2DM is rapidly increasing in developing countries, in particular [3]. T2DM has a large impact on the quality of life, morbidity, mortality and health

expenditure [1]. One of the biggest burdens of T2DM is that of the chronic complications, that arise with T2DM progression. Chronic complications can be classified as macrovascular or microvascular.

Microvascular complications among T2DM patients are a consequence of prolonged hyperglycemia [4], and these complications include diabetic neuropathy, diabetic nephropathy

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and diabetic retinopathy. The prevalence of microvascular complications among T2DM patients is high, but has been shown to vary widely across populations [5-8]. For instance, a study in China reported prevalence of neuropathy, nephropathy, ocular lesions, and foot disease among T2DM patients to be 17.8%, 10.7%, 14.8%, and 0.8%, respectively [9]. Another study in Australia reported the prevalence of diabetic retinopathy among T2DM patients is 21.9% [10]. Prevalence of any microvascular in newly diagnosed T2DM in India is 30.2% [6].

Patients with T2DM frequently suffer with comorbidities, such as hypertension, obesity, and depression, and all have been established as common in T2DM patients [11-13]. The most common comorbidity associated with T2DM is hypertension. The prevalence of hypertension among T2DM patients varies across countries and is reported to range from 20.6% to 78.4% in the Southeast Asian region, and 9.7% to 70.4% in the African region [14].

It is well established that hypertension among patients with diabetes hastens the development and progression of microvascular complication due to increasing intracellular hyperglycemia [4,15,16]. For instance, a Spanish study reported the odds of developing microvascular complication among T2DM patients with hypertension is 2.43 times higher than that of those without hypertension [5]. Therefore, blood pressure control is highly important in preventing the development of microvascular complications among T2DM patients [17,18].

Several studies have investigated the blood pressure effect on macrovascular and microvascular complication among T2DM patients in Western countries [15,17,18]. Although some studies have examined long term vascular complications among patients with diabetes in Thailand [8,19], these studies were conducted on very specific clinical populations. No previous study has examined the effect of the hypertension comorbidity on microvascular complication in the general T2DM population in any Asia country. The objective of the present study is to determine the association between hypertension comorbidity and microvascular complication among patients with T2DM in Thailand.

METHODS

Study design and data source

The present study is a nationwide, multicenter, cross-sectional survey of T2DM outpatients across Thailand. All data were obtained from the Diabetes and Hypertension dataset, an ongoing

nationwide project, titled: "An assessment on quality of care among patients diagnosed with type 2 diabetes and hypertension visiting hospitals of ministry of public health and Bangkok metropolitan administration in Thailand, 2010-2012." This project is administered by the Medical Research Network of the Consortium of Thai Medical Schools (MedResNet) Thailand, under the sponsorship of the Thai National Health Security Office. Patients and hospitals were sampled using a proportional to size stratified cluster sampling approach, and then T2DM outpatients were proportionally sampled from the 602 participating hospitals across Thailand during the period April 1st to June 30th for both years 2011 to 2012.

A two stage stratified cluster, proportional to size sampling approach was used to select a nationally and provincially representative sample of diabetes patients in Thailand. The first stage was to ensure that the number and levels of hospitals were appropriately sampled across provinces to represent the diabetes population in Thailand. The second stage of cluster sampling was to ensure that the right mix of hospitals (levels) were sampled (given attendance patterns in Thai diabetes patients). Thailand has three levels of hospitals: regional hospitals (>500 beds), general (provincial; 200 to 500 beds) hospitals, and community hospitals, with this last group being further subdivided into large (80 to 120 beds), medium (60 beds), and small (10 to 30 beds) community hospitals. All regional and general hospitals in Thailand were included in our study, but only 456 (61.96% of the total 736) appropriately sized community hospitals were included. The 456 hospitals were made up of 10%, 20%, and 70% of large, medium, and small community hospitals, respectively, reflecting the size distribution of these hospitals throughout the community. Finally, once the list of participating hospitals was compiled, proportion to size sampling was performed to ensure the appropriate proportion of diabetes patients (based on national attendance patterns across hospital levels) were sampled at the five different levels of hospitals.

Patient information was retrospectively collected via medical records. Diabetes and Hypertension dataset, study protocols and case report forms are archived at the DAMUS (Data Archival for Maximum Utilization System) website [20]. The study was approved by the Ethical Review Committee for Research in Human Subjects Ministry of Public Health, Thailand, and the Khon Kaen University Ethics Committee for Human Research, Thailand. Informed consent was obtained from all patients.

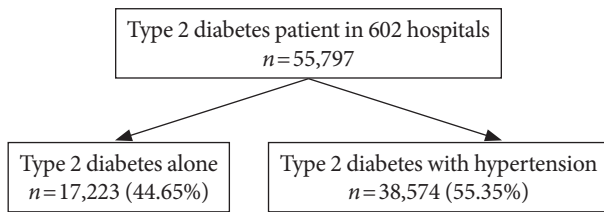


Fig. 1. Flow diagram of study sample.

Eligibility criteria

Patients with T2DM and receiving medical care in participating hospitals for at least 12 months were included in the present study. Patients with incomplete information in the key study variables (outcome and hypertension status) were excluded. After evaluating by eligibility, a total sample of 55,797 T2DM patients was considered (Fig. 1).

Outcomes

The outcome variable in the present study is microvascular complication diagnosis (+/–) in the last 12 months, which includes any of diabetic neuropathy, diabetic nephropathy, diabetic retinopathy, and renal insufficiency diagnosis (+/–) in the last 12 months. All microvascular complications were documented by medical records. Diabetic neuropathy was defined as the presence of symptoms and/or signs of peripheral nerve dysfunction in people with diabetes after the exclusion of other causes. Diabetic nephropathy was defined as serum creatinine level equal or greater than 2 mg/dL, or positive dipstick proteinuria, or the presence of random micro albuminuria/creatinine ratio greater than 30 mg/g. Diabetic retinopathy was diagnosed by detailed fundus examination, including either proliferative or background diabetic retinopathy diagnosed by an ophthalmologist. Renal insufficiency was defined by the reduction in estimated glomerular filtration rate (GFR): an estimated halving of GFR, and/or a 25 mL/min/1.73 m² decline in GFR from baseline.

Clinical and other risk factors

Hypertension comorbidity (+/–) is the main study effect of interest. Hypertension was defined as blood pressure exceeding 140 over 90 mm Hg (a systolic blood pressure above 140 mm Hg or a diastolic blood pressure above 90 mm Hg) [21], as previously diagnosed by a physician. Other continuous covariates considered include: (1) age, (2) diabetes duration, and clinical parameter during the last 12 months follow-up: (3) fasting plasma glucose (mmol/L); (4) serum creatinine (mmol/L); (5)

total cholesterol (mmol/L); (6) triglyceride (mmol/L); and (7) high density lipoprotein cholesterol (HDL-C mmol/L). Categorical covariates considered include: (1) glycosylated hemoglobin (HbA1c) treatment target (<7%, ≥7%); (2) blood pressure treatment target (blood pressure: <130/80, ≥130, or ≥80 mm Hg); (3) low density lipoprotein cholesterol treatment target (LDL-C; <100, ≥100 mg/dL; based on the American Diabetes Association 2012 guideline which is currently used in the Thai diabetes care system [22]); (4) previous macrovascular complication (diagnosis >12 months ago); and (5) previous microvascular complication (diagnosis >12 months ago); (6) diabetes medication (no treatment, oral hypoglycemic agents [OHAs], insulin, both OHAs, and insulin) and finally other covariates such as: health care coverage type, hospital type (regional, provincial, and community), smoking status (never, previous, and ongoing smoking), gender, and body mass index (BMI) class (classified <18.5, 18.5 to 22.9, 23 to 27.4, 27.5 to 32.4, 32.5 to 37.4, ≥37.5 kg/m² [23]).

Statistical analysis

Frequencies, means and standard deviations, were used to describe categorical and continuous variables, respectively. The effects of the hypertension comorbidity, along with other risk factors on the presence of macrovascular complication were investigated using binary logistic mixed effect regression. The potential clustering effect introduced by hospital and the multi-level nature of the data (hospital type is an upper level effect) were accounted for by using a mixed effect modeling approach. We investigated the potential bias introduced by missing values in the dataset using multiple iterative regression imputation. By comparing the difference between the magnitude of effects in the complete case and imputed data analyses, missing values bias could be gauged. Pooled estimates were generated across five imputed datasets and the global likelihood ratio test (was run using the methods outlined by Meng and Rubin [24] (1992). Purposeful selection of covariates was used to build the best model for the presence of microvascular complication [25]. Crude and adjusted odd ratios with 95% confidence interval (CI) and *P* value were used to represent the association between hypertension and other covariates with microvascular complication. All data analyses were conducted using the R statistical programming language (v.3.0.3) [26], the R library lme4 [27] was used for the mixed modeling, and the R library mi [28] was used for the multiple imputation.

Table 1. Sample characteristics for available cases^a

Characteristic	Number missing	Available cases	
		Hypertension (-)	Hypertension (+)
Microvascular complication, yes	0	1,687 (9.80)	4,677 (12.12)
Continuous covariates			
Age, yr	9	17,218 (56.1 ± 10.8)	38,570 (61.6 ± 10.2)
Diabetes duration, yr	2,674	16,502 (6.05 ± 4.35)	33,676 (6.95 ± 4.75)
Fasting plasma glucose, mmol/L	8,571	14,148 (8.7 ± 3.32)	32,898 (8.23 ± 3.02)
Serum creatinine, µmol/L	6,433	14,963 (83.07 ± 87.13)	34,401 (93.78 ± 88.58)
Total cholesterol, mmol/L	10,934	13,758 (4.87 ± 1.16)	31,105 (4.86 ± 1.19)
Triglyceride, mmol/L	9,112	14,280 (1.98 ± 1.17)	32,405 (1.97 ± 1.1)
HDL-C, mmol/L	13,587	12,805 (1.17 ± 0.33)	29,405 (1.18 ± 0.33)
Categorical covariates			
Female sex	0	12,256 (71.16)	26,747 (69.34)
Body mass index	4,029		
Underweight		752 (4.60)	1,066 (3.01)
Normal weight		4,881 (29.89)	8,313 (23.46)
Overweight		7,056 (43.20)	14,976 (42.26)
Obese I		2,988 (18.30)	8,471 (23.91)
Obese II		547 (3.35)	2,024 (5.71)
Obese III		108 (0.66)	586 (1.65)
Smoking	1,085		
None		15,215 (89.84)	34,499 (91.33)
Used to smoke		887 (5.24)	2,009 (5.32)
Ongoing smoking		834 (4.92)	1,268 (3.36)
Health care coverage	64		
Universal coverage		12,353 (71.78)	25,253 (65.55)
Government officer		2,273 (13.21)	7,159 (18.58)
Social security scheme		716 (4.16)	1,316 (3.42)
Other		1,868 (10.85)	4,795 (12.45)
Hospital type	3,287		
Regional		1,579 (9.57)	5,918 (16.43)
General		3,154 (19.12)	8,364 (23.22)
Community		11,760 (71.30)	21,735 (60.35)
Diabetes medication	923		
No medication		342 (2.01)	1,244 (3.28)
OHA		13,123 (77.27)	28,443 (75.07)
Insulin sensitizer		1,468 (8.64)	3,494 (9.22)
Both OHA and insulin		2,050 (12.07)	4,710 (12.43)
HbA1c treatment target, yes	14,089	3,624 (28.36)	10,505 (36.31)
Blood pressure treatment target, yes	667	8,870 (52.44)	12,519 (32.76)
LDL-C treatment target, yes	9,846	5,764 (40.94)	14,066 (44.13)
Previous macrovascular complication, yes	0	486 (2.82)	2,840 (7.36)
Previous microvascular complication, yes	0	1,672 (9.71)	5,992 (15.53)

Values are presented as number (%) or number (mean ± standard deviation) for continuous variables.

HDL-C, high density lipoprotein cholesterol; OHA, oral hyperglycemic agent; HbA1c, glycosylated hemoglobin; LDL-C, low density lipoprotein cholesterol.

^aPercentages have been rounded and may not total 100.

RESULTS

Basic sample characteristic

The study flow is shown in Fig. 1. Of the 55,797 T2DM patients included in our sample, 55.35% were hypertensive. Table 1 provides the main characteristics of the study sample. Prevalence of microvascular complication diagnosis in the last 12 months was higher in T2DM patients with hypertension than those without hypertension (12.12% vs. 9.80%, respectively). The mean age, diabetes duration, and serum creatinine in T2DM with hypertension were higher than those without hypertension, while mean total cholesterol, triglyceride, and HDL-C level were comparable between the two groups (Table 1). Prevalence of patients achieving HbA1c and LDL-C treatment target in hypertensive patients (36.31% and 44.13%, respectively) was considerably higher than non-hypertensive patients (28.36% and 40.94%, respectively). However, hypertensive patients tended to achieve the blood pressure treatment target less often compared to non-hypertensive patients (32.76% vs. 52.44%). Prevalence of both previous macrovascular and previous microvascular complications in hypertensive patients were higher than non-hypertensive patients. Perusal of Table 1 shows minimal difference between available cases and imputed data.

Microvascular complications and blood pressure levels

Table 2 gives the number and proportion of patients in various blood pressure classes and a prevalence estimate of microvascular complications for each of these groups. Perusal of Table 2 indicates that the prevalence of microvascular complications remains relatively stable from the normal blood pressure group (12.58%; 95% CI, 12.08 to 13.04) through to prehypertension group (12.93%; 95% CI, 12.30 to 13.59). However, the prevalence of microvascular complications was significantly higher for the stage 1 hypertension group (14.57%; 95% CI, 14.0 to

15.17). It is also likely that the prevalence is higher in the stage 2 hypertension patients, but the relatively small number of patients in this class leads to a wide 95% CI (16.51%; 95% CI, 12.71 to 21.13).

Risk factors and correlates of microvascular complications

The crude and adjusted estimates of the risk factors for microvascular complication are shown in Table 3. After adjusting for other covariates using multivariable binary mixed effect modeling, patient with the hypertension comorbidity had 1.32 time the odds of developing microvascular complication (adjusted odds ratio [OR_{adj}], 1.32; 95% CI, 1.20 to 1.46; $P < 0.001$).

In the final multivariable model, older T2DM patients and those with longer diabetes duration had 1.07 and 1.21 times the odds of developing microvascular complication, per 10 years (age) and 5 years (duration), respectively (OR_{age}, 1.07; 95% CI, 1.03 to 1.12; $P < 0.01$; and OR_{duration}, 1.12; 95% CI, 1.07 to 1.16; $P < 0.001$, respectively). Diabetes medication types were shown to be significantly associated with an increased microvascular complication. The odds of patients with insulin treatment and insulin with OHAs treatment were 2.71 and 1.83 higher to have microvascular complication compared to no medication (OR_{insulin}, 2.71; 95% CI, 2.02 to 3.64; and OR_{insulin with OHAs}, 1.83; 95% CI, 1.37 to 2.44, respectively).

The multivariable analysis also demonstrates that higher BMI class, lower hospital level, achievement of HbA1c and blood pressure treatment target, higher HDL-C, and previous microvascular complication were all shown to be associated with microvascular complication among patients with T2DM. For instance, previous microvascular complication were shown to be significantly associated with developing microvascular complications, with the odds of developing microvascular complications decreasing by 58% (OR_{adj}, 0.42; 95% CI, 0.37 to 0.48; $P < 0.001$).

Table 2. Number and percentage of patients in different blood pressure classes and the prevalence of microvascular complications in each group

Blood pressure classification	SBP, mm Hg	DBP, mm Hg	No. (%)	Prevalence of microvascular complications (95% CI) ^a
Normal	<120	and <80	18,445 (42.44)	12.58 (12.08–13.04)
Prehypertension	120–139	or 80–89	10,600 (24.39)	12.93 (12.30–13.59)
Stage 1 hypertension	140–159	or 90–99	14,094 (32.43)	14.57 (14.0–15.17)
Stage 2 hypertension	≥160	or ≥100	321 (0.74)	16.51 (12.71–21.13)

SBP, systolic blood pressure; DBP, diastolic blood pressure; CI, confidence interval.

^aBased on patients with non-missing values of both blood pressure and microvascular complications.

Table 3. Crude and adjusted odds ratios of factors associated with microvascular complication in complete case analysis

Effects	OR ^a	OR ^b	95% CI
Hypertension, yes	1.33 ^c	1.32 ^c	1.20–1.46
Age (in 10 years)	1.43 ^c	1.07 ^d	1.03–1.12
Body mass index		$\chi^2=896.54^e$, df=5	
Under weight	1.09	1.26 ^e	1.01–1.56
Over weight	0.93	1.01	0.91–1.11
Obese I	0.95	1.02	0.91–1.15
Obese II	0.90	0.92	0.76–1.12
Obese III	0.82	0.91	0.63–1.32
Hospital type		$\chi^2=769.19^e$, df=2	
General	0.88	0.95	0.64–1.39
Community	0.65 ^d	0.62 ^d	0.44–0.87
Health care coverage		$\chi^2=18.584^e$, df=3	
Government officer	0.94	0.96	0.86–1.07
Social security scheme	0.93	1.00	0.80–1.25
Other	1.16 ^d	1.02	0.88–1.18
Smoking		$\chi^2=62.888^e$, df=2	
Used to smoke	1.09	0.99	0.84–1.18
Ongoing smoking	1.14	1.21 ^e	1.01–1.46
Diabetes duration (in 5 years)	1.23 ^c	1.12 ^c	1.07–1.16
HbA1c treatment target, yes	0.75 ^c	0.86 ^d	0.78–0.94
Blood pressure treatment target, yes	0.89 ^c	0.91 ^c	0.84–0.99
FPG, mmol/L	1.04 ^c	1.02 ^d	1.01–1.03
Creatinine, $\mu\text{mol/L}^f$	1.002 ^c	1.003 ^c	1.002–1.003
Triglyceride, mmol/L	1.10 ^c	1.09 ^c	1.05–1.12
HDL-C, mmol/L	0.72 ^c	0.82 ^d	0.72–0.94
Diabetes medication		$\chi^2=286.4^e$, df=3	
OHA	0.03	0.97	0.74–1.26
Insulin sensitizer	2.92 ^c	2.71 ^c	2.02–3.64
Both OHA and insulin	2.05 ^c	1.83 ^c	1.37–2.44
Previous microvascular complication, yes	0.77 ^c	0.42 ^c	0.37–0.48
Female sex	0.92 ^d		
LDL-C treatment target, yes	0.96		
Total cholesterol	1.07 ^c		
Previous macrovascular complication, yes	1.07		

OR, odds ratio; CI, confidence interval; df, degrees of freedom; HbA1c, glycosylated hemoglobin; FPG, fasting plasma glucose; HDL-C, high density lipoprotein cholesterol; OHA, oral hyperglycemic agent; LDL-C, low density lipoprotein cholesterol.

^aCrude and adjusted odds ratios, ^bAdjusted odds ratios, ^c $P<0.001$, ^d $P<0.01$, ^e $P<0.05$, ^fRound to 3 decimals to show the 95% CI and P value.

Fig. 2 shows a comparison of the OR_{adj} and CIs results derived from the complete case and imputed data analyses. The results indicated minimal bias was introduced by missing val-

ues, and importantly, the significance of the hypertension effect to microvascular complication among patients with T2DM did not change. Fig. 2 does indicate that there were some changes

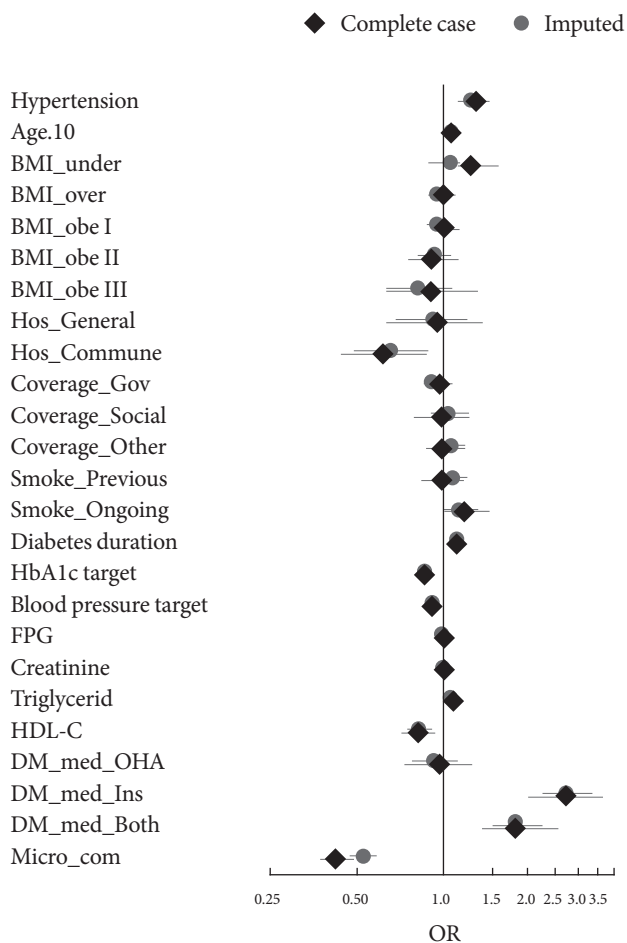


Fig. 2. Comparison between the complete case and imputed analyses results. BMI, body mass index; HbA1c, glycosylated hemoglobin; FPG, fasting plasma glucose; HDL-C, high density lipoprotein cholesterol; DM, diabetes mellitus; OHA, oral hyperglycemic agent; OR, odds ratio.

in the significance of some other effects. Importantly, the underweight BMI level effect could not be shown to be significant in the imputed data analysis.

DISCUSSION

Understanding the impact of the hypertension comorbidity along with other risk factors, is important in preventing T2DM microvascular complications. To the best of our knowledge, this is the first large nationwide study to assess the effect of the hypertension comorbidity on the presence of microvascular complications among T2DM patients in Southeast Asia, in general, and in Thailand, in particular. A region where T2DM prevalence is rapidly increasing [3,29,30].

The present study found that hypertension was indeed associated with the presence of microvascular complication among T2DM patients. Our findings confirm that the association between hypertension and microvascular complications observed in other populations [5] also occur in the Thai T2DM population. These results can be explained by the likelihood that hypertension leads to additional microvascular damage due to increasing intracellular hyperglycemia through upregulation of the glucose transporter 1 [4].

Even after adjusting for other covariates, the present study demonstrated that higher age and diabetes duration were both associated with the presence of microvascular complication among T2DM patients. It should be noted that these estimates are mutually adjusted; age has a significant effect above and beyond the effect of diabetes duration. The findings in present study are consistent with previous studies, which indicate age and diabetes duration are both independent risk factors in the development of microvascular complications among patients with T2DM [8,31]. However, another study [5] could not demonstrate an association between age and diabetes duration with microvascular complication among T2DM patients. This disparity might relate to the differences in the studies' protocols or populations.

The role of achieving treatment targets on prevention of T2DM complication is well established [32]. Our study confirms that achieving of HbA1c and blood pressure treatment targets are associated with lower risk of developing microvascular complication. It is noteworthy that our results show diabetes medication type and previous microvascular complication were significantly associated with developing microvascular complications. Those on diabetes medication were more likely to have microvascular complications, while previous microvascular complication appeared protective in preventing microvascular complication. This result can be explained by T2DM patients with more severe, or existing, microvascular complications will receive more aggressive treatment. Even though, at first glance, it appears medication may lead to an increase in the chance of microvascular complications, it is more likely that treatment is based on an individual lack of blood sugar control, which in turn, is responsible for increased likelihood of microvascular complications.

There were a number of limitations in the present study. Missing data, in particular, was of concern. Data were collected through medical records audit and incomplete records may be random, or associated with physician diligence. The extent of

missing data for the variables considered in this study is given in Table 1. The potential impact of information bias introduced by missing values was investigated using multiple imputation. The comparison between the complete case and imputed data analyses suggested minimal bias resulted from missing values (Fig. 2). Missingness had only a marginal impact on the effects of the covariates. Importantly, there was almost no impact on the association between hypertension and the presence of microvascular complication among patients with T2DM. Imputed data analysis results show only small changes in the magnitude of the effects, and the marginally narrower CIs, a likely result of higher estimate precision. Notably, the effect of underweight BMI level was non-significant in the imputed data analysis. However, the changes in the significance of the BMI effect does not relate to the main objective of this study: the association between hypertension and microvascular complications among T2DM patients.

Another limitation of our study was the cross-sectional nature of the sampling design. We attempted to address this by only considering microvascular complication diagnosed in the previous 12 months period, but this only provides partial evidence; only a cohort study can provide evidence of causal associations. Finally, there were limitations in the variables included (and omitted) in our data set. A number of important lifestyle and dietary variable were not recorded, nor conditions (other than hypertension), or the treatment patients may have been receiving for these conditions.

Despite the limitations of the present study, there are some major strengths. First, to date, no large nationwide, multicenter study has ever been conducted in Southeast Asian T2DM outpatients. Second, to the best of our knowledge, this is the first study of microvascular complication among T2DM patients which account for the clustering design artifact of hospital in such a multicenter study. Finally, the present study covers almost all the risk factors associated with microvascular complications reported in the literature. The estimates derived from our multivariable models account for the potential confounding effects of these risk factors. With these above strengths, the present study has confirmed the effect of the hypertension comorbidity on T2DM microvascular complications.

Our results indicate that hypertension was highly associated with microvascular complication. Blood pressure control is highly important in terms of preventing microvascular complication among patients with T2DM in Thailand. Patients with T2DM and physicians should be aware of the importance of

treatment and self-management of blood pressure, especially for T2DM patients with a hypertension comorbidity. Cohort studies should be conducted to investigate and confirm risk factors of microvascular complications in Asian populations, particularly in regards to the recurrence and co-occurrence of microvascular complications among patients with T2DM.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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