Medicine®

OPEN

Diabetes management in a Primary Care Network (PCN) of private general practitioners in Singapore
An observational study

Miyang Luo, BMed[a], Zhongxian Poh, MRCP, MMed[b], Gerald Koh, MBBS, PhD[a],
Tat Yean Tham, MBBS, GradDip OM[b,c], Winifred Lau, BE, MBA[d], Sue Anne Toh, MD, MSc[e],
Chin Kwang Chong, MBBS, GDFM[b], Lian Leng Low, MMed, MCl[f], Kavita Venkataraman, MBBS, PhD[a,*]

Abstract
A Primary Care Network (PCN) is a virtual network of general practitioners (GPs), sharing common resources and common clinical governance framework for effective chronic disease management. In this study, we analyzed the frequency of assessment as well as control of HbA1c, blood pressure (BP), and low-density lipoprotein (LDL) over time among adult patients with diabetes managed by a group of private GPs under PCN.

Data, including clinical measurements of HbA1c, BP, and LDL from 2012 to 2015, of 943 subjects at 9 GP clinics that piloted PCN in Singapore in 2012 was obtained from the chronic disease register for this analysis.

The total number of PCN patients increased from 371 in 2012 to 911 in 2015. The average HbA1c decreased from 7.5% in 2012 to 7.3% in 2015, with a significant yearly improving trend of −0.11% ($P < .001$). The trends in change for systolic BP and LDL were not statistically significant during the same follow-up period. Regular assessment of HbA1c decreased from 80% in 2012 to 55% in 2015. Such decreases were also found in BP and LDL assessments. We also found that receiving government subsidies under a national scheme was a major determinant for maintaining regular assessment, with patients so covered 3 to 20 times more likely to have regular assessments.

The PCN model can help improve care and clinical outcomes in adult patients with diabetes in the private primary care sector. Investing greater financial and human resources to augment service capacity and expanding subsidy coverage may be important to ensure the effectiveness, scalability, and sustainability of such a model of care.

Abbreviations: BP = blood pressure, CHAS = Community Health Assist Scheme, DALYs = Disability Adjusted Life-Years, DFS = diabetic foot screening, DRP = diabetic retinal photography, GEE = Generalized Estimating Equation, GP = general practitioner, HbA1c = glycated hemoglobin, IQR = interquartile range, LDL = low-density lipoprotein, OOP = out-of-pocket payments, PCN = Primary Care Network, SD = standard deviation.

Keywords: blood pressure, diabetes mellitus, HbA1c, LDL, primary care

1. Introduction

Diabetes mellitus is a growing public health problem in the world, with an estimated 415 million people affected globally in 2015,

and potentially rising to 642 million by 2040.[1,2] Diabetes in Singapore mirrors global trends, affecting 11.3% of the population aged 18 to 69 years.[3] It was the second leading cause of Disability Adjusted Life-Years (DALYs) in 2010,[4] with an estimated annual economic burden of over USD1 billion.[5] Most of the DALYs and cost from diabetes are due to long-term complications, for which glycemic, blood pressure (BP), and low-density lipoprotein (LDL) control are major determinants.[6–8]

The Singapore National Health Survey 2010 (NHS 2010) showed that 32% of diabetes patients had poor control (glycated hemoglobin HbA1c ≥ 8.0%).[3] While the survey did not stratify outcomes by site of care, most patients with diabetes are managed at the primary care level in Singapore.[9] In Singapore, primary care is provided through 18 public sector polyclinics and around 1500 clinics run by private general practitioners (GPs). According to the national Primary Care Survey, GPs are the main providers of primary care, accounting for 81% of all patient attendances, and a 55% market share of chronic disease care.[10] Traditionally, GPs in Singapore have operated in solo practices and do not have access to coordinated team based care and clinical data management support, unlike public sector polyclinics, which function as one-stop centers with medical, diagnostic, pharmacological, nursing, and some allied services. This has limited the capacity of GPs to provide chronic care effectively. There is also scarcity of data regarding the epidemiology and health outcomes for local diabetes patients that are managed in the private sector.

The Primary Care Network (PCN) is a model of care that supports the delivery of team-based primary health services, through a team of physicians, nurse counselors, care coordinators, and administrative assistants. Such networks have been established in Canada and New Zealand since the early 2000s, and have led to improved patient access to primary care and quality of care.[11,12] The first PCN in Singapore was started in 2012 by 9 local GP practices owned by a private group located in various parts of the country, in collaboration with the Agency for Integrated Care. The 2 key elements of this PCN are the provision of a mobile primary care team, as well as the creation of a chronic disease register for each participating GP clinic. The mobile team comprises of nurse counselors who provide counseling, diabetic foot screening (DFS), and care management; care coordinators who coordinate care for patients with chronic diseases including appointments, monitoring process indicators of care and supervising the maintenance of the chronic disease register; and administrative assistants who create and update patient records in the chronic disease register. The chronic disease register allows GPs to better monitor and track their patients' condition and care over time, as process indicators and care outcomes are documented in accordance with local clinical practice guidelines.

The effect of this PCN on diabetes care processes after a year of implementation has been previously reported.[13] However, there has been no description of the profile of patients enrolled, as well as an evaluation of the impact of the PCN model on care outcomes. Therefore, in this study, we examined the effect of the PCN model of care on the profile of patients enrolled, the care processes and clinical outcomes in patients with diabetes, managed in these GP practices over a 4-year time period, which may provide useful insights to the implementation of such care models among other private primary care providers both in Singapore and internationally.

2. Methods

2.1. Study population

The study population was identified from the chronic disease register in the 9 GP clinics enrolled in the first PCN in Singapore between 2012 and 2015. Patients were included into the register if their chronic diseases were managed by the particular clinic, based on review of clinical case notes for chronic disease diagnosis, and medication prescription and dispensing records of chronic disease medication. Both manual and electronic records were searched periodically for identification of eligible patients for inclusion. The inclusion criteria for this study were patients with diabetes aged 21 years and older, and being managed in any GP clinic for at least 6 months. Pregnant patients and those with gestational diabetes were excluded. Data were censored up to December 31, 2015. The study was approved by the National University of Singapore's institutional review board (NUS-IRB Reference Code: B-16-233), with a waiver of patient consent. Data were deidentified before analysis.

2.2. Data collection

Subjects followed standardized diabetes care and monitoring provided by their managing physician. Diabetes monitoring panels included 3- to 6-monthly HbA1c and BP measurements and 6- to 12-monthly lipid panels. Blood tests were sent to a private laboratory for analysis.

For patients with diabetes, the following variables were recorded in the chronic disease register: patient-related variables, including age, gender, ethnicity, height, date of first visit for diabetes management, smoking status, and type of funding, which was collected at the time of patient entry into the registry; disease-related variables, including diabetes duration which was calculated based on date of first visit for diabetes and diagnosis of hypertension and dyslipidemia which were collected at the time of patient entry into the registry; and clinical care measures, including: DFS and diabetic retinal photography (DRP), measured annually; weight and HbA1c, measured every 6 months; BP, measured 3 every months; and LDL, measured annually.

2.3. Statistical analysis

Variables were summarized using mean (standard deviation, SD) or median (interquartile range, IQR) for continuous variables and percentages for categorical variables. The control of HbA1c, BP, and LDL were categorized based on the median level during the study period according to recommended cut-off points in clinical guidelines.[14,15]

Diabetes management was categorized into optimal, moderate, and poor control using the following criteria: optimal control if HbA1c $\leq$ 7.0%, BP $\leq$ 140/90 mm Hg, and LDL $\leq$ 2.6 mmol/L; moderate control if 1 or 2 of the above targets were met; and poor control if none of the above targets were met.

Measurement frequency during the follow-up period was categorized as never (never measured), irregular (measured less frequently than once every year), and regular (at least once every year), based on the chronic disease register.

Patients' type of funding was categorized into none, Community Health Assist Scheme (CHAS) alone, Medisave alone, as well as CHAS and Medisave combined. CHAS is a national subsidy scheme introduced by the Singapore government that provides subsidies for medical care at participating GPs to lower- and middle-income citizens.[16] Medisave is a compulsory national saving scheme, where a part of the individual's income is automatically transferred into a Medisave account to meet future medical needs.[17] CHAS and Medisave can be used to cover medical expenses related to common chronic conditions, including diabetes, hypertension, and dyslipidemia.

Patients' characteristics and control of HbA1c, BP, and LDL in each year of follow-up (i.e., 2012–2015 yearly cohort) were also compared. Each yearly cohort was an open cohort, which consisted of patients from the study population who visited the GPs in that particular year of follow-up. P values were calculated using one-way ANOVA, Kruskal–Wallis, or Pearson's Chi-squared test, as appropriate.

Individual trends of HbA1c, Systolic BP, and LDL during follow-up were analyzed using Generalized Estimating Equation (GEE) models. Two models each were conducted with serial HbA1c, Systolic BP, or LDL measurements, using autoregressive correlation structure. Model 1 was the raw model with time in the PCN as the only independent variable, and Model 2 was the full model including age, gender, ethnicity, diabetes duration, hypertension, dyslipidemia, smoking, and type of funding in addition to time in the PCN. Patients with complete information on all adjusted variables were included in the GEE analysis (HbA1c n = 754; Systolic BP n = 847; LDL n = 734).

Multinomial logistic regression was used to identify patient characteristics associated with different measurement frequencies. Patients in the never measured group were used as the reference group. A backward stepwise model selection was

Table 1

Patient characteristics in the PCN.

	Baseline	2012	2013	2014	2015	*P*
N	943	371	652	823	911	
Age (mean, SD)	56.5 (12.50)*	57.8 (11.5)	56.7 (12.1)*	56.6 (12.5)	56.5 (12.5)	.35
Gender=female (%)	428 (45.4)	166 (44.7)	300 (46.0)	380 (46.2)	417 (45.8)	.97
Ethnicity (%)						.27
Chinese	680 (72.1)	271 (73.0)	457 (70.1)	595 (72.3)	660 (72.4)	
Malay	136 (14.4)	66 (17.8)	103 (15.8)	121 (14.7)	131 (14.4)	
Indian and others	127 (13.5)	34 (9.2)	92 (14.1)	107 (13.0)	120 (13.2)	
Diabetes duration (mean, IQR)	2.1 [0.4, 7.2]†	6.5 [3.3, 10.2]‡	3.5 [1.1, 8.6]§	2.4 [0.7, 7.6]‖	2.1 [0.4, 7.2]¶	<.001
Hypertension (%)	560 (59.4)	256 (69.0)	393 (60.3)	482 (58.6)	537 (58.9)	.004
Hyperlipidemia (%)	571 (60.6)	255 (68.7)	395 (60.6)	504 (61.2)	554 (60.8)	.04
Smoker (%)	170 (18.0)	66 (17.8)	122 (18.7)	154 (18.7)	168 (18.4)	.98
Type of funding (%)#						<.001
None	373 (39.6)	Not available	359 (55.1)	351 (42.6)	383 (42.0)	
CHAS	257 (27.3)	Not available	118 (18.1)	220 (26.7)	220 (24.1)	
Medisave	128 (13.6)	Not available	119 (18.3)	120 (14.6)	128 (14.1)	
CHAS and Medisave	185 (19.6)	Not available	56 (8.6)	132 (16.0)	180 (19.8)	

Baseline was defined as the date of first enrolment in the PCN model during 2012 to 2015. These 943 patients were re-grouped to each yearly cohort if they have visited GPs in the certain year according to their GP visiting records. *P*-value was calculated based on comparison of variables in 2012 to 2015.

CHAS = community health assist scheme.

* 1 missing.
† 24 missing.
‡ 17 missing.
§ 3 missing.
‖ 7 missing.
¶ 3 missing.
# CHAS was implemented in 2012, thus data were available since 2013.

conducted based on Akaike's Information Criterion from potential variables. Patients with complete information on all the adjusted variables were included in the analysis (n=918). Statistical significance was set as a *P*-value <.05. All statistical analyses were done with R version 3.3.2.

3. Results

3.1. Demographics and baseline characteristics

A total of 943 unique patients were included in this analysis. Their baseline characteristics at year of first joining PCN GP clinics are shown in Table 1 (mean age 56.5 years, 45.4% female, 72.1% Chinese). The median duration of diabetes was 2.1 years (IQR 0.4–7.2). 59.4% of patients had hypertension and 60.6% had dyslipidemia. Around 47% of patients received governmental subsidies through CHAS, and 33.2% utilized their Medisave account to pay for diabetes care.

To analyze the characteristics of patients managed in PCN over time, we re-grouped these patients by visit dates. The number of patients registered in the PCN increased 2.5 times, from 371 in year 2012 to 911 in year 2015 (Table 1). Thirty-two patients were lost to follow-up during the study period, and the yearly flow of patients in this open cohort is shown in Supplemental file 1, http://links.lww.com/MD/C572. The median duration of diabetes and the proportions of patients with concomitant hypertension and hyperlipidemia decreased between 2012 and 2015. While subsidy data was not available for patients in the year 2012, the proportion of patients receiving CHAS subsidies increased between 2013 and 2015.

3.2. Frequency of assessment and clinical outcomes over time (Table 2)

While the proportion of patients with DFS and DRP assessments were relatively stable during the 4 years, the proportions of

patients with HbA1c, BP, and LDL assessments each year were higher in 2012 and 2013 compared to subsequent years, though the absolute number of patients with these assessments increased over the years. Among those with assessments available, the median HbA1c decreased from 7.5% in 2012 to 7.3% in 2015, although the difference was not statistically significant. The median systolic and diastolic BP was stable over the years. However, smaller proportions of patients had optimal BP control in 2015 compared to 2012 (47.0% vs 58.2%, *P* = .009). The average median LDL was higher in 2013 to 2015 compared to 2012 (*P* < .001), and the proportion of patients with poor LDL control (>2.6 mmol/L) was lower in 2012 (*P* = .02).

Overall, 31.6%, 79.7%, and 36.7% of patients (n=943) achieved optimal glycemic (HbA1c ≤ 7.0%), BP (≤140/90 mm Hg) and LDL (≤2.6 mmol/L) control, based on the median of these measurements during the 4-year follow-up.

3.3. Trends of HbA1c, BP, and LDL (Table 3)

On analysis of serial HbA1c data points using GEE, there was significant improvement in HbA1c during the follow-up period after adjustment for confounders (*P* < .001). Younger age of diagnosis, smoking, and use of Medisave scheme alone were associated with increased HbA1c levels. Use of CHAS with or without Medisave was not associated with any significant HbA1c change. The trend of change for systolic BP and LDL was not statistically significant during the follow-up period after adjustment for confounders.

3.4. Factors associated with frequency of assessment

Having comorbidities, and utilizing Medisave and/or CHAS were associated with more frequent assessments of HbA1c, BP, LDL, DRP, and DFS on multinomial logistic regression. Longer

Table 2

Frequency of assessment and level of control of HbA1c, blood pressure, and LDL in each yearly cohort.

	Overall	2012	2013	2014	2015	P
N	943	371	652	823	911	
HbA1c assessed (n, %)	765 (81.1)	300 (80.9)	489 (75.0)	522 (63.4)	495 (54.3)	<.001
HbA1C (%, median, IQR)	7.5 [6.9–8.7]	7.5 [6.9, 8.5]	7.5 [6.8, 8.4]	7.50 [6.8, 8.5]	7.3 [6.8, 8.3]	.36
HbA1c control group (%)						.66
≤7.0%	242 (31.6)	101 (33.7)	161 (32.9)	191 (36.6)	181 (36.6)	
7.0–8.0%	254 (33.2)	96 (32.0)	162 (33.1)	160 (30.7)	167 (33.7)	
>8.0%	269 (35.2)	103 (34.3)	166 (33.9)	171 (32.8)	147 (29.7)	
Blood pressure assessed (n, %)	867 (91.9)	352 (94.9)	579 (88.8)	596 (72.4)	589 (64.7)	<.001
Systolic blood pressure (mm Hg, median, IQR)	130.0 [120.0–140.0]	130.0 [120.0, 140.0]	130.0 [120.0, 137.5]	130.0 [123.3, 139.7]	130.0 [122.5, 140.0]	.02
Diastolic blood pressure (mm Hg, median, IQR)	80.0 [70.0–82.0]	80.0 [70.0, 80.0]	80.0 [75.0, 82.5]	80.0 [73.9, 82.5]	80.0 [74.0, 83.0]	.95
Blood pressure control group (%)						.009
≤130/80 mm Hg	370 (42.7)	205 (58.2)	286 (49.6)	270 (45.4)	277 (47.0)	
130/80–140/90 mm Hg	321 (37.0)	89 (25.3)	185 (32.1)	194 (32.6)	191 (32.4)	
>140/90 mm Hg	176 (20.3)	58 (16.5)	106 (18.4)	131 (22.0)	121 (20.5)	
LDL assessed (n, %)	750 (79.5)	284 (76.5)	474 (72.7)	508 (61.7)	435 (47.7)	<.001
LDL (mmol/L, median, IQR)	2.8 [2.3–3.4]	2.6 [2.2, 3.1]	2.8 [2.3, 3.3]	2.8 [2.3, 3.4]	2.8 [2.2, 3.3]	.001
LDL control group (%)						.02
≤2.1 mmol/L	105 (14.0)	70 (24.6)	76 (16.0)	96 (18.9)	96 (22.1)	
2.1–2.6 mmol/L	170 (22.7)	80 (28.2)	127 (26.8)	122 (24.0)	100 (23.0)	
> 2.6 mmol/L	475 (63.3)	134 (47.2)	271 (57.2)	290 (57.1)	239 (54.9)	
Diabetes management (%)[*]						.14
Achieving all three targets	82 (11.3)	33 (13.1)	59 (13.0)	65 (13.4)	66 (16.5)	
Achieving 1 or 2 targets	562 (77.5)	208 (82.5)	362 (79.6)	380 (78.5)	295 (73.9)	
Not achieving any target	81 (11.2)	11 (4.4)	34 (7.5)	39 (8.1)	38 (9.5)	
Diabetic retinal photography assessed (n, %)	586 (62.1)	146 (39.4)	305 (46.8)	368 (44.7)	351 (38.5)	.003
Diabetic foot screening assessed (n, %)	566 (60.0)	139 (37.5)	285 (43.7)	332 (40.3)	323 (35.5)	.008

IQR = interquartile range, LDL = low-density lipoprotein.

[*] Targets of diabetes managements: HbA1c ≤ 7.0%, BP ≤ 140/90 mm Hg, and LDL ≤ 2.6 mmol/L.

Table 3

Trends in level of control and associated factors during follow-up.

	HbA1c[*]			Systolic blood pressure[†]			LDL[‡]		
	Estimate	Std. error	P	Estimate	Std. error	P	Estimate	Std. error	P
Model 1									
Time in PCN, y	−0.11	0.02	<.001	0.32	0.22	.15	−0.05	0.02	.02
Model 2									
Time in PCN, y	−0.11	0.02	<.001	0.18	0.22	.42	−0.03	0.02	.11
Age, y	−0.02	0.00	<.001	0.17	0.03	<.001	−0.01	0.00	<.001
Gender: female	0.10	0.11	.37	1.09	0.79	.17	0.01	0.07	.88
Ethnicity (ref. Chinese)									
Malay	0.26	0.14	.07	2.86	1.00	.004	0.18	0.09	.04
Indian and others	0.03	0.18	.88	1.40	1.29	.28	0.07	0.10	.48
Diabetes duration, y	0.01	0.01	.39	−0.02	0.08	.84	−0.02	0.01	<.001
Hypertension	−0.24	0.11	.03	5.40	0.75	<.001	0.01	0.06	.90
Hyperlipidemia	−0.21	0.11	.05	−0.52	0.77	.50	−0.11	0.07	.10
Smoking	0.46	0.15	.002	1.78	1.03	.09	0.06	0.09	.52
Type of funding (ref. none)									
CHAS	0.10	0.13	.44	1.26	0.98	.20	0.01	0.08	.86
Medisave	0.33	0.16	.04	−0.35	1.10	.75	0.16	0.10	.14
CHAS and Medisave	0.19	0.14	.17	−0.02	1.03	.99	−0.08	0.08	.33

CHAS = community health assist scheme, LDL = low-density lipoprotein.

The trends in level of control and associated factors were analyzed using Generalized Estimating Equation. Model 1 was the raw model with time as the only independent variable; Model 2 was the full model including age, gender, ethnicity, diabetes duration, hypertension, hyperlipidemia, smoking, and type of funding. Smoking, hypertension, and hyperlipidemia variables were categorized into "yes/no," with the "no" category as the reference group. Patients with complete information were included in the analysis.

[*] n = 754.

[†] n = 847.

[‡] n = 734.

Table 4

Factors associated with different measurement frequencies of HbA1c, BP, and LDL.

	Irregular vs never			Regular vs never		
	RRR	95% CI	P	RRR	95% CI	P
HbA1c						
Age	1.00	0.98–1.01	.63	0.98	0.96–0.99	.009
Diabetes duration	1.13	1.07–1.20	<.001	1.11	1.05–1.17	<.001
Hyperlipidemia	1.32	0.89–1.95	.18	1.85	1.24–2.75	.003
Type of funding (ref. none)						
CHAS	1.92	1.17–3.16	.01	4.49	2.74–7.35	<.001
Medisave	3.03	1.56–5.89	.001	4.45	2.28–8.7	<.001
CHAS and Medisave	6.30	2.58–15.39	<.001	20.27	8.41–48.86	<.001
Blood pressure						
Age	1.02	1.00–1.04	.12	1.00	0.97–1.02	.70
Hypertension	1.25	0.71–2.17	.44	1.71	0.99–2.97	.06
Hyperlipidemia	1.95	1.11–3.43	.02	2.81	1.61–4.90	<.001
Smoking	6.16	1.85–20.55	.003	4.15	1.24–13.85	.02
Type of funding (ref. none)						
CHAS	1.92	0.90–4.10	.09	6.06	2.90–12.67	<.001
Medisave	3.99	1.36–11.74	.01	7.23	2.50–20.95	<.001
CHAS and Medisave	7.83	1.03–59.51	.05	45.66	6.17–338.07	<.001
LDL						
Age	1.00	0.98–1.01	.73	0.98	0.97–1	.06
Ethnicity						
Malay	0.89	0.52–1.54	.69	0.93	0.53–1.62	.79
Indian	0.88	0.54–1.46	.63	0.48	0.26–0.86	.01
Diabetes duration	1.11	1.06–1.17	<.001	1.08	1.03–1.14	.004
Hyperlipidemia	1.22	0.84–1.78	.30	2.23	1.5–3.33	<.001
Type of funding (ref. none)						
CHAS	1.78	1.12–2.83	.01	3.24	2–5.24	<.001
Medisave	4.18	2.13–8.2	<.001	4.68	2.31–9.48	<.001
CHAS and Medisave	8.54	3.75–19.46	<.001	14.57	6.33–33.54	<.001
Diabetic retinal photography						
Age	0.98	0.96–0.99	<.001	0.97	0.95–0.98	<.001
Diabetes duration	1.12	1.08–1.16	<.001	1.01	0.96–1.06	.82
Hypertension	0.58	0.42–0.81	.001	0.87	0.57–1.32	.51
Hyperlipidemia	1.39	1.01–1.93	.05	1.54	1.02–2.32	.04
Type of funding (ref. none)						
CHAS	1.91	1.29–2.83	.001	3.83	2.26–6.47	<.001
Medisave	2.55	1.56–4.17	<.001	4.95	2.67–9.17	<.001
CHAS and Medisave	4.66	2.84–7.65	<.001	11.75	6.46–21.38	<.001
Diabetic foot disease						
Age	0.98	0.97–0.99	.002	0.97	0.95–0.98	<.001
Diabetes duration	1.12	1.08–1.16	<.001	1.01	0.96–1.07	.57
Hypertension	0.67	0.49–0.93	.02	0.95	0.62–1.45	.81
Type of funding (ref. none)						
CHAS	1.67	1.14–2.45	.009	3.90	2.25–6.76	<.001
Medisave	2.42	1.51–3.86	<.001	3.53	1.81–6.88	<.001
CHAS and Medisave	3.91	2.44–6.26	<.001	11.87	6.48–21.74	<.001

Multinomial logistic regression was used to identify patient characteristics associated with different measurement frequency. A backward stepwise model selection was conducted based on Akaike's Information Criterion from age, gender, ethnicity, diabetes duration, hypertension, dyslipidemia, smoking, and type of funding. Patients with complete information on all the adjusted variables were included in the analysis (n = 918).

CHAS = community health assist scheme, LDL = low-density lipoprotein, RRR = relative risk ratio.

duration of diabetes was associated with more frequent assessment of all measurements except BP. Individuals using CHAS and/or Medisave were 3 to 20 times more likely to have regular measurements compared to those who did not (Table 4).

Patients with CHAS and/or utilizing Medisave were older with higher proportions of female and Chinese ethnicity as compared to those without. They also had longer duration of diabetes and higher proportions of concomitant hypertension and dyslipidemia. (Supplemental file 2, http://links.lww.com/MD/C572).

4. Discussion

In this study of patients with diabetes, managed by a network of private general physicians supported by a mobile primary care team, the median HbA1c during a 4-year follow-up was 7.5%, with 31.6% having optimal control. The median systolic BP was 130 mm Hg, while the median LDL was 2.8 mmol/L. These results are comparable with previously published local data on diabetes management in patients managed in public institutions.[9,18–24]

There was a 2.5-fold increase in the number of patients under the PCN between 2012 and 2015. One major reason for this rapid increase in patient numbers could be the implementation of CHAS in 2012.[25] When first introduced in 2012, the scheme allowed subsidies for patients aged 40 years and above with a monthly household income per person of SGD 1500 or less. The criteria were subsequently modified in 2013 and 2014, to remove the age restriction and increase the income criteria to SGD 1800 or less. With these changes, around half of all Singaporean households are eligible for the scheme. These health system changes are reflected in the patient loads in the PCN, with an increase from 27% to 44% in the proportion of patients having CHAS subsidies, with or without the use of their Medisave medical savings. It is worth noting here that CHAS-subsidized patients were almost a decade older than nonsubsidized patients, with longer duration of diabetes and higher proportions of concomitant hypertension and dyslipidemia.

The key aim of the PCN was to improve chronic disease management; both care processes and care outcomes. A short-term analysis of diabetes process indicators in the PCN demonstrated significant improvement across all process indicators.[13] Our results, however, suggest that performance on process indicators over a longer period has been mixed, with fairly stable proportions of DRP and DFS assessments, but falling proportions of HbA1c, BP, and LDL measurements. It is probable that the rapidly increasing number of patients managed in this PCN since 2012 overwhelmed the mobile team's capacity to provide the relevant services, and/or track patients for these assessments in a timely manner. These results suggest the need for matching funding and human resources allocation to patient loads to ensure the sustained success and performance of the PCN model.

Another possible reason for the reduction in assessment frequency may be the reluctance of patients relying solely on out-of-pocket payments (OOP) for medical care to pay for ancillary services. We identified use of CHAS subsidies and Medisave savings as major determinants of regular assessments for HbA1c, BP, and LDL. The proportion with timely assessments among CHAS/Medisave patients was double that observed in OOP patients. Cost of care is a known determinant of care-seeking behavior, and reducing OOP expenditure for patients, through insurance and/or subsidies, has been shown to improve care in studies elsewhere.[26,27] Therefore, continuing and perhaps, increasing medical subsidies and care coverage may be beneficial in maintaining regular measurements of glycemic, BP, and lipid control in patients with diabetes managed by GPs. This is especially important given that CHAS patients achieved the same level of control, in spite of having longer disease duration and higher comorbidity burden.

On examining care outcomes, that is, control of HbA1c, BP, and LDL, we observed significant improvement in HbA1c levels over time, and stable levels of BP and LDL. This is commendable, given the progressive nature of diabetes, and in the context of the rapid increase in patient load in the GP clinics. This suggests that the PCN elements, including tracking of patient indicators over time, have had a meaningful impact on care in these patients. These results also serve as empirical evidence to support the development of such PCNs on a larger scale with financial and administrative help from the government.[28]

PCN models have been previously implemented in countries such as Canada and New Zealand, where the bulk of primary care services are government-run, -supported or -reimbursed.[11,12] Our study showcases a pilot PCN project among a purely private group of GPs with limited government support. Given the scarcity of data around this model of care in such settings, our work provides useful insights for the implementation of such care models in other private GPs both locally and internationally.

The limitations of our study included the short follow-up period and the analysis of a single network involving clinics run by the same group. Longer follow-up is needed to ascertain the long-term effects of PCN in terms of clinical outcomes such as diabetic complications, hospitalizations, and overall cost-effectiveness. This was the first PCN in Singapore. Currently, more such networks are being established and future studies will be helpful in examining the effects of different PCN models on diabetes outcomes in Singapore. In addition, the absence of medication data, as well as paucity of results from DRP and DFS screening in the chronic disease registry were other limitations that prevented the examination of factors such as complexity of the various chronic conditions and compliance to medications. There may also have been some underestimation of the duration of diabetes in our study as it was calculated from the date of first visit to the primary care physician for the management of diabetes.

5. Conclusions

These limitations notwithstanding, our findings suggest that the PCN is a promising model of primary care for diabetes as patients under the PCN experienced improved glycemic control improved over time, and stable BP and LDL control. However, there may be need to enhance or modify the support provided under the PCN based on the patient numbers, and to augment financial assistance schemes to ensure that all patients access ancillary care services at the appropriate intervals.

Author contributions

Conceptualization: Miyang Luo, Zhongxian Poh, Gerald Koh, Tat Yean Tham, Winifred Lau, Sue Anne Toh, Lian Leng Low, Kavita Venkataraman.
Data curation: Miyang Luo.
Formal analysis: Miyang Luo.
Funding acquisition: Kavita Venkataraman.
Investigation: Miyang Luo, Zhongxian Poh, Gerald Koh, Tat Yean Tham, Winifred Lau, Sue Anne Toh, Chin Kwang Chong, Lian Leng Low, Kavita Venkataraman.
Project administration: Zhongxian Poh, Kavita Venkataraman.
Resources: Gerald Koh, Tat Yean Tham, Winifred Lau, Sue Anne Toh, Chin Kwang Chong, Lian Leng Low.
Software: Miyang Luo.
Supervision: Kavita Venkataraman.
Validation: Zhongxian Poh, Kavita Venkataraman.
Visualization: Miyang Luo.
Writing – original draft: Miyang Luo, Zhongxian Poh.
Writing – review & editing: Miyang Luo, Zhongxian Poh, Gerald Koh, Tat Yean Tham, Winifred Lau, Sue Anne Toh, Chin Kwang Chong, Lian Leng Low, Kavita Venkataraman.

References

[1] IDF. *IDF Diabetes Atlas*. International Diabetes Federation; 2015.

[2] Zhang N, Yang X, Zhu X, et al. Type 2 diabetes mellitus unawareness, prevalence, trends and risk factors: National Health and Nutrition Examination Survey (NHANES). J Int Med Res 2017;45:594–609.

[3] National Health Survey 2010. Epidemiology and Disease Control Division, Ministry of Health, Republic of Singapore; 2011: Available at: http://www.moh.gov.sg/content/dam/moh_web/Publications/Reports/2011/NHS2010%20-%20low%20res.pdf. Accessed January 10, 2018.

[4] Phan TP, Alkema L, Tai ES, et al. Forecasting the burden of type 2 diabetes in Singapore using a demographic epidemiological model of Singapore. BMJ Open Diabetes Res Care 2014;2:e000012.

[5] Yoong J, May EP, Tan CS, et al. The Economic Cost of Diabetes in Singapore. SMDM Asia-Pacific Conference 2014; Singapore.

[6] Stratton IM, Adler AI, Neil HA, et al. Association of glycaemia with macrovascular and microvascular complications of type 2 diabetes (UKPDS 35): prospective observational study. BMJ (Clin Res Ed) 2000;321:405–12.

[7] Stettler C, Allemann S, Juni P, et al. Glycemic control and macrovascular disease in types 1 and 2 diabetes mellitus: meta-analysis of randomized trials. Am Heart J 2006;152:27–38.

[8] Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). UK Prospective Diabetes Study (UKPDS) Group. Lancet (London, England). 1998; 352:837–853.

[9] Heng BH, Sun Y, Cheah JT, et al. The Singapore National Healthcare Group Diabetes Registry—descriptive epidemiology of type 2 diabetes mellitus. Ann Acad Med Singapore 2010;39:348–52.

[10] Primary Care Survey 2010. Singapore: Ministry of Health; 2014.

[11] Hutchison B, Levesque J-F, Strumpf E, et al. Primary health care in Canada: systems in motion. Milbank Q 2011;89:256–88.

[12] Cumming J. Integrated care in New Zealand. Int J Integr Care 2011; 11 (Special 10th Anniversary Edition):e138.

[13] Chua LKL, Chong CK, Wee H-L, et al. Primary Care Network (PCN) as model of care for GP Chronic Disease Management. The Singapore Family Physician 2015;41: Home Care.

[14] American Diabetes Association. Standards of Medical Care in Diabetes —2015 Abridged for Primary Care Providers. Clinical Diabetes: A Publication of the American Diabetes Association. 2015;33:97–111.

[15] Diabetes Mellitus MOH Clinical Practice Guildlines 2014. Ministry of Health, Singapore; 2014. Accessed January 10, 2018.

[16] Community Health Assist Scheme. Available at: https://www.chas.sg/content.aspx?id=306. Accessed January 10, 2018.

[17] Medisave, available at: https://www.cpf.gov.sg/Members/Schemes/schemes/healthcare/medisave. Accessed January 10, 2018.

[18] Poh Z, Venkataraman K, Toh SE, Low LL. Glycaemic blood pressure and low density lipoprotein cholesterol control in adult patients with diabetes in Singapore: a review of Singapore literature over two decades. Ann Acad Med Singapore 2017;46:374–91.

[19] Toh MP, Heng BH, Sum CF, et al. Measuring the quality of care of diabetic patients at the specialist outpatient clinics in public hospitals in Singapore. Ann Acad Med Singapore 2007;36:980–6.

[20] Quah JHM, Liu YP, Luo N, et al. Younger adult type 2 diabetic patients have poorer glycaemic control: a cross-sectional study in a primary care setting in Singapore. BMC Endocr Disord 2013;13:18.

[21] Lee WR, Emmanuel S, Lim HS, et al. The status of diabetes mellitus in primary care institution and restructured hospitals in Singapore. Singapore Med J 2001;42:508–12.

[22] Low S, Chi LS, Yeoh LY, et al. Long-term diabetes outcomes in multi-ethnic Asians living in Singapore. Diabetes Res Clin Pract 2016;111:83–92.

[23] Ng TP, Goh LG, Tan Y, et al. Ethnic differences in glycaemic control in adult Type 2 diabetic patients in primary care: a 3-year follow-up study. Diabet Med 2005;22:1598–604.

[24] Tan NC, Barbier S, Lim WY, et al. 5-Year longitudinal study of determinants of glycemic control for multi-ethnic Asian patients with type 2 diabetes mellitus managed in primary care. Diabetes Res Clin Pract 2015;110:218–23.

[25] Community Health Assist Scheme. Available at: https://www.chas.sg.

[26] Nelson KM, Chapko MK, Reiber G, et al. The association between health insurance coverage and diabetes care; data from the 2000 Behavioral Risk Factor Surveillance System. Health Serv Res 2005;40:361–72.

[27] Schoen C, DesRoches C. Uninsured and unstably insured: the importance of continuous insurance coverage. Health Serv Res 2000;35(1 Pt 2):187–206.

[28] Primary Care Networks, Ministry of Health, Singapore. Available at: https://www.moh.gov.sg/content/moh_web/home/our_healthcare_system/Healthcare_Services/Primary_Care/primary-care-networks.html. Accessed January 10, 2018.