Social Science & Medicine 285 (2021) 114284

Contents lists available at ScienceDirect

Social Science & Medicine

journal homepage: www.elsevier.com/locate/socscimed

Longitudinal study of the earliest pilot of tiered healthcare system reforms in China: Will the new type of chronic disease management be effective?

Hongwei Hu, Hailun Liang, Hufeng Wang *

School of Public Administration and Policy, Renmin University of China, 59 Zhongguancun Street, Beijing, 100872, China

ARTICLE INFO

Keywords:
Tiered healthcare system
Integrated care model
Chronic disease
China

ABSTRACT

Background: In 2016, the tiered healthcare model featuring "specialists + general practitioners + health managers" in Xiamen was recognized by the Medical Reform Office of State Council and was promoted as a model to replace hospital-centric care with community-based care. This study evaluated the impact of the Xiamen's tiered healthcare system reform on health outcomes and healthcare spending among chronic disease patients.

Methods: Data were derived from Xiamen's electronic health record (EHR) and medical claims systems. The sample included 154,651 individuals with hypertension and 50,722 individuals with diabetes from Xiamen between 2012 and 2016. The dependent variables included rates of disease under control and total treatment costs. Patients were grouped by the types of chronic disease management: precision management, regular management, or without management. Kaplan-Meier, Cox survival analysis and PSM + DID method (Propensity score matching and difference-in-difference method) were used to compare the management outcomes by group.

Findings: The precision management group showed better clinical quality performance than the regular management group. Under-control disease rates in the precision management group showed a continuous improvement trend, while the regular management group showed a ceiling effect after ten months. Under-control rates in the precision management group increased over 40% for hypertension and over 30% for diabetes, higher than that increases found in the regular management group. Reform was also associated with consistent reductions in annual per capita total treatment costs across groups. The cost-savings in the precision management group between 2014 and 2016 was 381 Chinese yuan (CNY) for hypertension and 1117 CNY for diabetes, compared with the group without management.

Interpretation: The results in this study demonstrated the associations between tiered healthcare system reform and better clinical quality performance and improved treatment cost-saving. Developing methods to promote the policy and increase implementation are also important aspects of healthcare reform.

1. Introduction

1.1. Study background

Due to the excessive marketization orientation for the medical institutions in China during the past decades, primary health care facilities mainly including community health centres and their outpost clinics, and tertiary care facilities mainly including general hospitals and specialty hospitals, operate independently and compete for patients to make more profits. Due to upwardly concentrated allocation of medical resources among different levels of medical institutions, and the low trust in clinics and community health facilities, patients often seek care at higher level hospitals in China, even for routine chronic disease management. This led to the overload and shortage of medical resources in tertiary care facilities, as well as inefficiency in medical resources. How to scientifically guide the medical service supply and demand to improve the utilization efficiency of medical resources is an important challenge to China. Under the above circumstances, promoting comprehensive care services to treat frequently occurring and chronic diseases is critically important in China to avoid the excessive influx of patients to tertiary care facilities, furthermore, it is also crucial to shift the focus and resources towards lower levels of medical institutions, with an aim to provide citizens with public health and basic health services that are safe, effective, accessible, and affordable (WHO, 2015).

* Corresponding author. School of Public Administration and Policy Renmin University of China (RUC); Health Reform and Development Center RUC, 59 Zhongguancun Street, Beijing, 100872, China.
E-mail address: wanghufeng616@ruc.edu.cn (H. Wang).

https://doi.org/10.1016/j.socscimed.2021.114284
Received 1 June 2019; Received in revised form 21 July 2021; Accepted 29 July 2021
Available online 31 July 2021

In order to change the above unfavourable situation, in September 2015, the General Office of the State Council officially issued a policy, the "Guiding Opinions on Promoting and Developing the Tiered Healthcare System," (State Council General Office, 2015) which was the first policy containing guiding principles and goals for tiered healthcare system reforms in China. This policy emphasized two goals, "improving the tiered healthcare system with the shift to strong primary care" and "establishing and improving supporting mechanism." The tiered healthcare system reforms were regarded as the huge policy reform progress for chronic disease management; and they focused on improving the capabilities of chronic disease management among primary care facilities, and promoted healthcare equity and access to primary care services (World Bank Group, 2016a). Under the tiered healthcare system reforms, the use of primary health care facilities for routine chronic disease management could reduce the inefficiency of medical resources and improve the utilization efficiency of medical resources, as well as improve overall quality of medical services patients received (Li et al., 2017). In order to further promote the tiered healthcare system reforms, the "13th Five-Year Plan for Deepening the Healthcare System Reform" was issued at the beginning of 2017, and it designated "establishing a scientific and rational tiered healthcare system" as the first of five priorities. The importance of the tiered healthcare system reforms had become more prominent in China's medical reform practice.

1.2. Xiamen's model

Xiamen City, with a population of 3.92 million, is a sub-provincial city in Fujian Province on the southeast coast of China. Since 2012, Xiamen instituted a series of reform initiatives to achieve efficient allocation of medical resources, and to help the primary healthcare facilities to improve their capabilities, and to improve two-way referrals for chronic condition management. Reform approaches included upgrading primary healthcare infrastructures, health information technology modernization, re-designing incentives scheme for health care providers in community health centres, and expanding the essential drug list. In the process of tiered healthcare system reforms, the most important and featured initiative was the introduction of the "specialists + general practitioners + health managers" team-based care model for chronic disease management in 2014 in Xiamen, piloted among hypertension and diabetes patients. The model of "specialists + general practitioners + health managers" was the practical and implementable form of Xiamen's tiered healthcare system reform in practice, and it grounded in the theoretical support of Chronic Care Model (CCM) Innovative Care for Chronic Conditions (ICCC). In the model of "specialists + general practitioners + health managers", patients are assigned to a multidisciplinary team of three healthcare providers, consisting of a specialist from a tertiary hospital who was responsible for treating intractable diseases and designing treatment plans, a general practitioner from a health centre, and a health manager who usually was a trained nurse (Li et al., 2017). Patients could enjoy quality grassroots services instead of overwhelming a few big hospitals in the city for minor or chronic diseases. Xiamen's tiered healthcare system reforms, which were featured and mainly implemented with the model of "specialists + general practitioners + health managers", achieved great success in practice. By the end of 2015, the grassroots health services in Xiamen increased by 43.56%, and hypertension visits increased to 78% and diabetes visits increased to 95% in primary health care facilities; the number of general outpatient visits in tertiary hospitals decreased by 6.02%, meanwhile, the visits of hypertension and diabetes in tertiary hospitals decreased by an average of 22%; the waiting time for treatment in tertiary care facilities decreased from 40 min to less than 10 min (Yang and Chen, 2016). In 2016, Xiamen's model was praised by the Medical Reform Office of State Council and promoted country-wide as a representative model (see Fig. 1).

Along with the continuous exploration of chronic disease management practices, theoretical models that emphasize the integration of multiple influencing factors were developed and used as a theoretical basis for updated practice. Developed by Ed Wagner in 1996 (Wagner et al., 1996), the Chronic Care Model (CCM) is a multifaceted, evidence-based framework for enhancing care delivery by identifying essential components of the healthcare system that can be modified to support high-quality, patient-centred chronic disease management. The CCM provides a systematic approach to practice transformation.

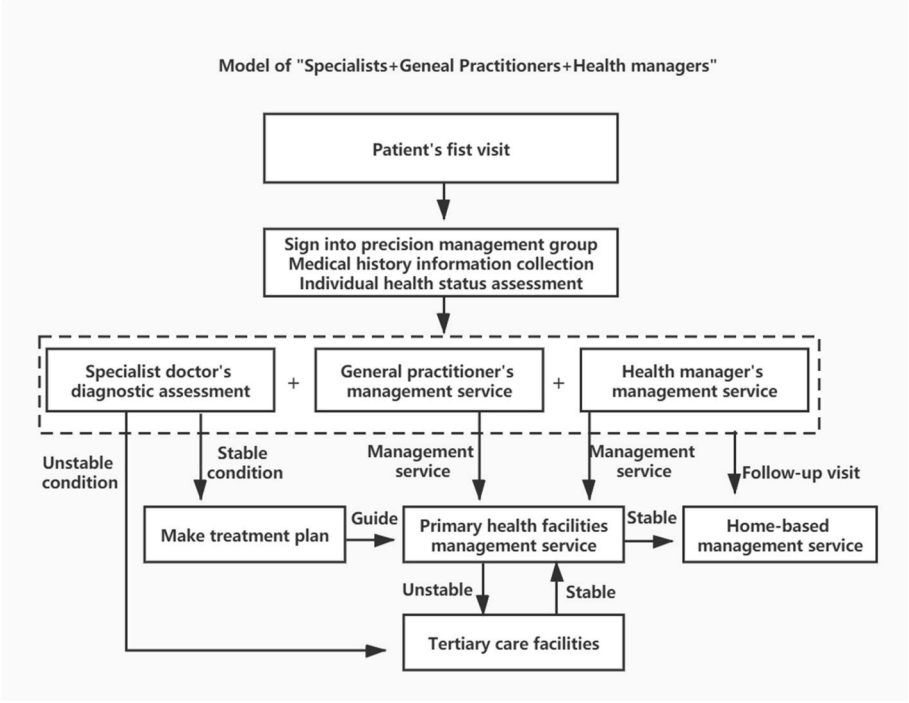

Fig. 1. Model of specialists + general practitioners + health managers.

Interrelated elements of the CCM include health systems, decision support, clinical information systems, patient self-management support, community resources, and delivery system design (Wagner et al., 1996). In 2002, the World Health Organization (WHO) described a new expanded framework, the Innovative Care for Chronic Conditions (ICCC) (WHO, 2002) that recognized a broader policy environment enveloping patients and their families, healthcare organizations, and communities. The policy environment encompasses legislation, leadership, policy integration, partnerships, financing, and allocation of human resources to allow communities and healthcare organizations to help patients and families with chronic condition management. The Xiamen's "specialists + general practitioners + health managers" team-based care model contributed to applying and refining these theoretical models in real world. For example, the team-based care model enhanced the continuity of care as well as the level of the patient self-management support. The triad team was more effective for managing each patient's health by using health education and routine clinical follow-up (Li et al., 2017).

The integration of healthcare services is the core of chronic disease management. In the Xiamen model, patients with chronic conditions are assigned to a team of three healthcare workers consisting of a specialist from a large hospital, a general practitioner from a community health centre, and a dedicated health manager. Together, the team is responsible for managing each patient's health problems through health education and routine clinical follow-ups. Xiamen's chronic disease management model expanded the existing classic chronic disease management models by including large hospital specialists and hospital-community integration in management, which contributed to improving chronic disease management in practice as well as to refining theoretical models.

1.3. Research question

As the earliest pilot city on the tiered healthcare system reforms in China, it is of great theoretical and practical value to evaluate the effectiveness of the tiered healthcare system reforms in Xiamen, which is featured and mainly implemented with the model of "specialists + general practitioners + health managers", for chronic disease management in the current China, the world's most populous country with a rapidly aging population corresponding with an onslaught of chronic diseases and associated risk factors. This study was the first in China to evaluate the effectiveness of the tiered healthcare system reforms based on large-scale micro-population data of whole sample with hypertension and diabetes in Xiamen, which is the earliest pilot city for China's tiered healthcare system reforms.

2. Methods

2.1. Data source and study sample

Data used in this study were compiled from the Xiamen's resident electronic health record (EHR) and medical claims systems between 2012 and 2016, with support from the Health Commission, Municipal Bureau of Medical Security, and the Disease Prevention and Control Centre of Xiamen city. The patients' data were linked by their unique identification number with their medical records, which were collected from medical organizations (medical institutions and pharmacies at all levels) in Xiamen, in order to construct a balanced panel data containing fully integrated health information, medical expenditures, and other related patient-level information. In this process, we obtained the full technical support from big data engineers employed by local government of Xiamen, in addition to the administrative support from these local departments. The data included the entire population of diabetes and hypertension patients in Xiamen, 154,651 individuals with hypertension and 50,722 individuals with diabetes. The basic sociodemographic information (gender, age, etc.) of all the patients with hypertension and diabetes diagnosed by various medical institutions at all levels in Xiamen, as well as the information on health status (the under-control rates for hypertension and diabetes) and medical treatment expenses of these patients, were included in this data. In reality, like other cities in China, the information about the patients with chronic disease was fragmented across different medical institutions and local departments in Xiamen.

The criteria for selecting hypertension and diabetes were based on "Chinese Guideline for the Management of Hypertension (2010)" (systolic blood pressure and diastolic blood pressure) and "China guideline for type 2 diabetes (2013)" (HbA1C value), which were widely used in China for screening hypertension and diabetes (Liu, 2011; Qin et al., 2015). The "specialists + general practitioners + health managers" model has been implemented quickly in the whole city Xiamen since 2014. However, every health facility could decide how to implement inside their facilities, such as partially applying the model among chronic disease patient population. Patients were allowed to choose whether participate in precision management group, regular management group or without management group.

The without management group consisted of patients who did not receive any chronic disease management. The regular management group consisted of patients who received normal care for chronic disease management in accordance with national guideline. The precision management group consisted of patients who received care from the multiple team of "specialists + general practitioners + health managers", in addition to regular chronic management.

2.2. Measures and statistical analysis

Our primary outcomes were the percentage of adults who have their chronic disease under control and total treatment costs at the person-year level. For health outcomes, we included hypertension control rates and diabetes control rates. Patients' total treatment costs were used to measure the whole healthcare spending on chronic diseases, which included total costs summed from various medical institutions (including medication costs from pharmacy departments inside medical institutions), and medication costs collected from pharmacies outside medical institutions. Disease-management group was the independent variable, and was categorized as precision management, regular management, or without management. Other patient characteristics were also selected as covariates in our analyses, including gender, age, residence, education, marriage, nationality, and political status. The descriptive analyses of these variables were shown in Tables 1 and 2.

Pre- and post-comparisons examined patients' health outcomes and costs before and after intervention implementation (e.g., precision management VS regular management). First, we provided the descriptive analyses of the sociodemographic and health-related characteristics of the three patient groups. Second, we analysed the trends in chronic disease control rates over 18 months after the intervention, using survival analysis to compare rates and trends between the precision management and regular management groups. Kaplan–Meier models were used to calculate survival rates and Cox proportional hazard regression models assessed the probabilities of certain health outcomes across the management groups. Moreover, Propensity score matching method and difference-in-difference method (PSM + DID) were employed in this study to minimize the possible estimation bias caused by the potential endogeneity (patients with more serious health status were more likely to participate in the precision management group), and to enhance the credibility and robustness of the estimation results about the intervention effects on health outcomes. Third, we calculated patients' total treatment costs. PSM + DID method was also used to compare the cost-savings among the three groups. PSM attempts to reduce the possible bias due to confounding variables that could be found in an estimate of the treatment effect obtained from simply comparing outcomes among units that received the treatment versus those that did not. DID calculates the effects of the independent variable on outcomes by comparing

Table 1
Hypertension sample description.

Variable	Total	Without Management	Regular Management	Precision Management
	Mean (S.D.)/ Distribution	Mean (S.D.)/ Distribution	Mean (S.D.)/ Distribution	Mean (S.D.)/ Distribution
Gender	Female 52.00% Male 48.00%	Female 52.11% Male 47.89%	Female 52.00% Male 48.00%	Female 51.32% Male 48.68%
age	57.84 (12.96)	55.71 (13.42)	60.02 (12.32)	61.23 (9.96)
Residence	Urban 87.49% Rural 12.51%	Urban 91.06% Rural 8.94%	Urban 85.27% Rural 14.73%	Urban 74.62% Rural 25.38%
Education	Illiteracy 3.85% Primary School 22.10% Junior High School 31.42% Senior High School 23.61% College Degree and Above 19.02%	lliteracy 2.91% Primary School 17.86% Junior High School 31.34% Senior High School 25.75% College Degree and Above 22.13%	Illiteracy 4.84% Primary School 25.82% Junior High School 31.46% Senior High School 21.71% College Degree and Above 16.16%	Illiteracy 5.20% Primary School 32.02% Junior High School 31.79% Senior High School 18.69% College Degree and Above 12.31%
Marriage	with spouse 80.82% without spouse 19.18%	with spouse 81.59% without spouse 18.41%	with spouse 79.61% without spouse 20.39%	with spouse 81.70% without spouse 18.30%
Nationality	Minority 0.92% Han Nationality 99.08%	Minority 0.88% Han Nationality 99.12%	Minority 0.95% Han Nationality 99.05%	Minority 1.02% Han Nationality 98.98%
Political Status	Non-party people 99.22% Party member 0.78%	Non-party people 99.26% Party member 0.74%	Non-party people 99.22% Party member 0.78%	Non-party people 98.91% Party member 1.09%
Baseline systolic blood pressure	135.80 (12.85)	–	134.95 (12.37)	141.16 (13.35)
Baseline diastolic blood pressure	81.57 (8.28)	–	81.40 (8.12)	83.14 (8.71)
N	154,651	81,801	60,678	12,172

Table 2
Diabetes sample description.

Variable	Total	Without Management	Regular Management	Precision Management
	Mean (S.D.)/ Distribution	Mean (S.D.)/ Distribution	Mean (S.D.)/ Distribution	Mean (S.D.)/ Distribution
Gender	Female 54.14% Male 45.86%	Female 54.35% Male 45.65%	Female 54.01% Male 45.99%	Female 53.57% Male 46.43%
age	59.92 (12.06)	58.51 (12.72)	61.28 (11.65)	62.11 (9.14)
Residence	Urban 91.56% Rural 8.44%	Urban 94.67% Rural 5.33%	Urban 90.61% Rural 9.39%	Urban 80.60% Rural 19.40%
Education	Illiteracy 3.40% Primary School 23.59% Junior High School 33.80% Senior High School 23.17% College Degree and Above 16.04%	Illiteracy 2.67% Primary School 19.60% Junior High School 33.79% Senior High School 25.39% College Degree and Above 18.55%	Illiteracy 4.12% Primary School 26.62% Junior High School 34.21% Senior High School 21.24% College Degree and Above 13.80%	Illiteracy 4.52% Primary School 32.22% Junior High School 32.67% Senior High School 19.05% College Degree and Above 11.54%
Marriage	with spouse 78.90% without spouse 21.10%	with spouse 79.24% without spouse 20.76%	with spouse 77.59% without spouse 22.41%	with spouse 81.21% without spouse 18.79%
Nationality	Minority 0.89% Han Nationality 99.11%	Minority 0.85% Han Nationality 99.15%	Minority 0.96% Han Nationality 99.04%	Minority 0.83% Han Nationality 99.17%
Political Status	Non-party people 99.21% Party member 0.79%	Non-party people 99.27% Party member 0.73%	Non-party people 99.18% Party member 0.82%	Non-party people 99.08% Party member 0.92%
Baseline HbA1C value	7.34 (1.90)	–	7.14 (1.78)	7.85 (1.95)
N	50,722	26,771	17,893	6058

the average change over time in the outcome variable for the interventions group, compared to the average change over time for the control group. All the variables mentioned above, as well as the variables indicating baseline health status (baseline blood pressure levels of hypertensive patients, and baseline HbA1C levels of diabetic patients), would be used as confounding variables in the matching process to estimate the propensity scores, which were used to match the patients from different two groups, through the matching methods such as kernel matching method. Patients from regular management group and patients from without management group would be matched with those from precision management group, respectively.

Health conditions of the patients from without management group could not be recorded in time due to the lack of chronic disease management service, the data limitation limited the comparison study between without management group and the other two groups in the section "Group differences in under-control rates and intervention efficacy" in this study. However, some previous studies had fully proved that patients with regular chronic disease management service had better under-control rates than those without any chronic disease management service (Liu, 2010; Ning et al., 2010). This was also supported by evidence from other countries (Kim et al., 2019). In fact, the chronic disease patients without any chronic disease management services have lower under-control rates than those with chronic disease management services, which is a social reality that could be widely observed. Therefore, this study aimed to prove patients from precision management group had higher under-control rates than those from regular management group based on survival analysis and PSM + DID method, and if that's the case, the patients from precision management group inevitably had higher under-control rates than those from without management group. All analyses were conducted with Stata/SE version 14.0 (StataCorp LP, College Station, TX). Two-tailed p-values less than or equal to 0.05 were considered statistically significant.

3. Results

3.1. Descriptive analysis results

Tables 1 and 2 showed the overall sociodemographic characteristics for the 154,651 hypertensive and 50,722 diabetic patients across the

three groups. In the hypertensive patients (Table 1), a greater proportion of patients were female (52%); more than 85% were urban residents; about 22.1% had a primary school education, 31.4% had a junior high school education, 23.6% had a senior high school education, and the remaining sample (19%) had higher level than a high school education. An overwhelming majority of patients were living with a spouse (80.8%), of Han ethnicity (99.1%), and without political membership (99.2%). Sociodemographic characteristics of the diabetic patients were showed in Table 2.

As for the baseline health status of the patients with hypertension and diabetes, there were significant group differences. Patients in precision management group had worse baseline health status than regular management group. For patients with hypertension from regular management group, the mean baseline systolic and diastolic blood pressures were 134.95 mm Hg and 81.40 mm Hg, respectively, while the mean baseline under-control rate was 0.77. For patients with hypertension from precision management group, the mean baseline systolic and diastolic blood pressures were 141.16 mm Hg and 83.14 mm Hg, respectively, while the mean baseline under-control rate was 0.53. Mean baseline HbA1C values in the diabetic patients were 7.14 and 7.85 in the regular management and precision management groups, respectively. Mean baseline under-control rates in the diabetic patients were 0.66 and 0.39 in the regular management and precision management groups, respectively

3.2. Group differences in under-control rates and intervention efficacy

Because only the patients in precision management group and regular management group had under-control records, comparison on under-control rates was only conducted between the two groups. Figs. 2 and 3 showed group differences of trends in hypertension control rates over 18 months post intervention. Although the precision management group had lower initial under-control rates, both groups showed comparable and constant improvements at 12 months, reaching control rates over 85%. Furthermore, at the 18_{th} month, the precision management group had higher control rates than the counterpart group (91% vs. 89%), while the regular management group showed a ceiling effect after ten months. Fig. 4 shows the Kaplan-Meier curve analysis results. Survival time was defined as the length of time between the beginning of intervention and when the disease was under control, with a total follow-up of 18 months. Results showed that the probability of achieving under-control status was higher in the precision management group, and patients achieved control faster than patients in the regular management group. Specifically, the median time to reach a 90% under-control rate was 3 months for the precision management group and 4.5 months for the regular management group. Results of the multivariate Cox

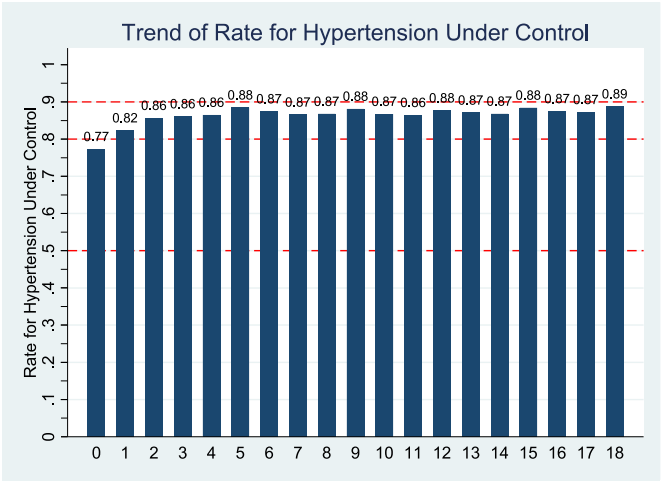

Fig. 2. Regular management group.

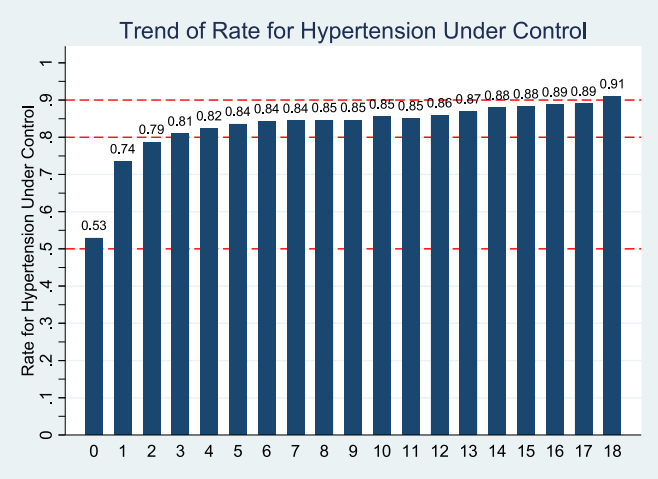

Fig. 3. Precision management group.

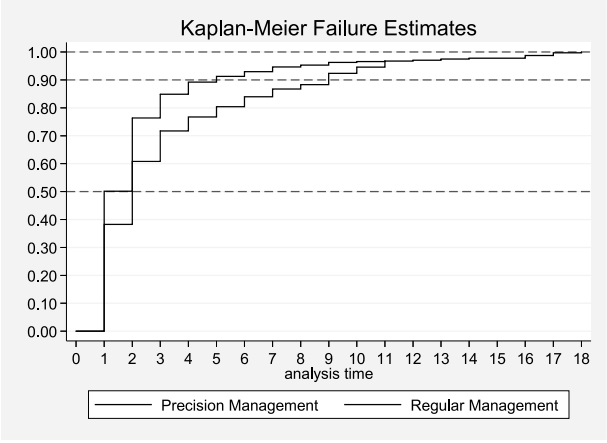

Fig. 4. K–M analysis comparison for hypertension under control.

Table 3
Cox Regression results.

	Hypertension			Diabetes		
	Haz. Ratio	Std. Err.	P > z	Haz. Ratio	Std. Err.	P > z
Precision Management	1.284	0.065	0.000	1.992	0.080	0.000
Male	0.938	0.047	0.198	1.026	0.022	0.236
Age logarithm	0.887	0.116	0.359	0.798	0.044	0.000
Rural	0.831	0.046	0.001	0.760	0.025	0.000
Education						
Primary School	0.951	0.083	0.563	1.034	0.057	0.544
Junior High School	0.820	0.079	0.040	1.038	0.057	0.501
Senior High School	0.835	0.090	0.096	1.060	0.061	0.313
College Degree and Above	0.800	0.096	0.063	1.050	0.064	0.420
Spousal Support	0.974	0.061	0.678	0.952	0.025	0.059
Han Nationality	1.122	0.376	0.731	1.088	0.114	0.419
Party Member	1.258	0.339	0.395	1.008	0.112	0.941
Baseline systolic blood pressure	0.980	0.002	0.000	–	–	–
Baseline diastolic blood pressure	0.986	0.002	0.000	–	–	–
Baseline HbA1C value	–	–	–	0.800	0.006	0.000
	LR chi2 (9) = 334.94 Prob > chi2 = 0.000			LR chi2 (9) = 1501.16 Prob > chi2 = 0.000		

regressions, shown in Table 3, further indicated that precision management improved the overall rate of under-control by 28% in the hypertensive patients.

Figs. 5 and 6 showed the trends in diabetes control rates over 18 months post intervention. The regular management group showed steadier improvement in the early months, with the precision management group showing relatively lower under-control rates at baseline; however, the precision management group showed greater progress over 18 months (80% vs. 79%), while the regular management group showed a ceiling effect after 6 months.

Results of the Kaplan-Meier curve analysis for diabetes management over the 18-month follow-up were shown in Fig. 7. The probability of the precision management group reaching under-control targets was higher than that of the regular management group, and the precision management group reached goals sooner, with an 80% under-control rate at 3 months for the precision management group and 5.5 months for the regular management group. Moreover, the multivariate Cox regression analysis indicated that precision management intervention improved the overall under-control rate by 99% in diabetic patients than the counterpart.

As a large-scale public policy experiment in real world, the endogeneity based on self-selection was inevitable in Xiamen's pilot work. Patients with more serious chronic disease were more likely to participate the precision group in reality, and this would lead to possible endogeneity. In order to reduce the possible estimation bias caused by the potential endogeneity, and to enhance the credibility and robustness of the estimation results, the method of PSM + DID was employed to evaluate the difference between precision management group and regular management group. The results were shown in Table 4.

As shown in Table 4, for patients with hypertension, the precision management group had over 40% higher under-control rate than that of the regular management group from 2014 to 2016; and for the patients with diabetes, the precision management group had over 30% higher under-control rate than their counterpart group in the same period. The comparison results showed in Table 4, based on multiple two-year comparison methods as well as multiple matching methods, strengthening the robustness and credibility of the conclusions in this study. The results indicated that Xiamen's tiered healthcare system reforms, which were featured and mainly implemented with the model of "specialists + general practitioners + health managers", had better effects on chronic disease management in practice.

3.3. Group differences in total treatment costs and intervention efficacy

The total treatment costs of different groups were shown in Table 5.

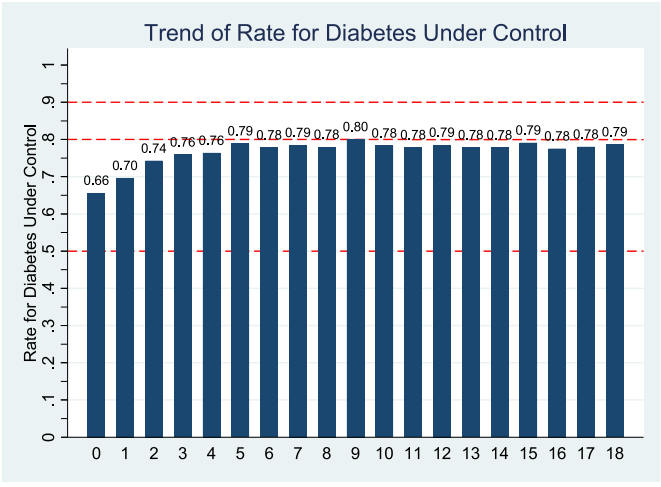

Fig. 5. Regular management group.

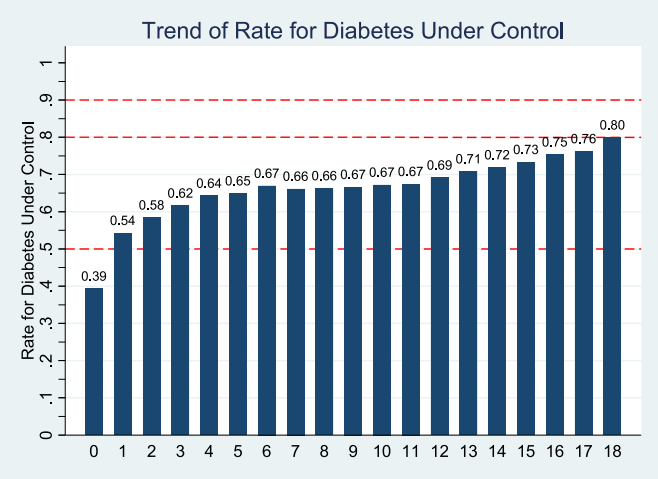

Fig. 6. Precision management group.

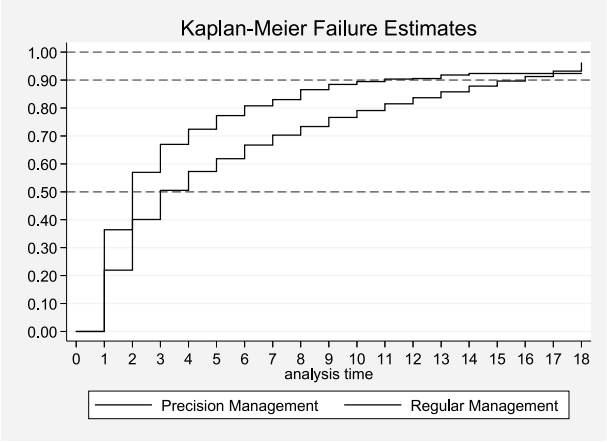

Fig. 7. K–M analysis comparison for diabetes under control.

Table 4
Treatment Effect for Patients with Chronic Diseases (Under-control rate).

	Precision Management VS Regular Management	
	2014–2015	2014–2016
Treatment for hypertension Group		
Nearest Neighbor 1:3 Matching	1.416***	1.407***
	(0.007)	(0.007)
Kernel Matching	1.133***	1.137***
	(0.004)	(0.004)
Treatment for Diabetes Group		
Nearest Neighbor 1:3 Matching	1.347***	1.333***
	(0.011)	(0.011)
Kernel Matching	1.122***	1.101***
	(0.009)	(0.009)

Notes: * 0.1 ** 0.05 *** 0.01 ; Standard Errors in parentheses; confounding variables are same with Table 3.

The differences on the treatment costs among the three groups were significant. Overall, treatment costs for both hypertension and diabetes gradually increased over this period, with precision management costs ranked the highest, followed by regular management and without management. For example, in 2016 the treatment costs of the precision management group for hypertension were around 300 CNY higher than costs for the regular management group, and around 800 CNY higher than costs for the without management group.

However, as shown in Table 6, patients of the precision management

Table 5
Expenditure of hypertension and diabetes (unit: CNY).

	Hypertension			Diabetes		
	Without Management	Regular Management	Precision Management	Without Management	Regular Management	Precision Management
2013	756.06	1108.14	1071.84	1078.24	2123.48	2243.20
2014	628.97	1007.70	1065.54	1097.04	2250.26	2551.44
2015	849.48	1291.91	1505.40	1261.99	2641.21	3425.38
2016	815.36	1337.15	1629.25	1443.80	3018.37	4017.74
Total	762.47	1186.23	1318.01	1220.27	2508.33	3059.44

Table 6
Treatment Effect for Patients with Chronic Diseases (Total direct treatment cost).

	Precision Management VS Regular Management		Precision Management VS Without Management	
	2014–2015	2014–2016	2014–2015	2014–2016
Treatment for hypertension Group				
Nearest Neighbor 1:3 Matching	−158.367*** (20.694)	−238.172*** (21.798)	−217.475*** (15.766)	−380.530*** (16.632)
Kernel Matching	−156.297*** (20.717)	−235.535*** (21.808)	−221.607*** (15.616)	−381.621*** (16.472)
Treatment for Diabetes Group				
Nearest Neighbor 1:3 Matching	−483.034*** (78.498)	−703.619*** (80.856)	−707.248*** (53.029)	−1117.247*** (54.917)
Kernel Matching	−482.945*** (77.403)	−698.321*** (79.939)	−710.806*** (51.368)	−1123.443*** (53.225)

Notes: * 0.1 ** 0.05 *** 0.01 ; Standard Errors in parentheses; confounding variables are same with Table 3.

group had significant lower annual average treatment costs, after the reduction of possible endogeneity based on PSM + DID analyses, indicating that Xiamen's tiered healthcare system reforms, which was featured and mainly implemented with the model of "specialists + general practitioners + health managers", had better cost-saving effects in practice. For instance, hypertensive patients' total treatment expenses of the precision management group from 2014 to 2016 were 238.172 CNY lower than that in the regular management group. Similarly, the total treatment expenses for diabetic patients from 2014 to 2016 in the precision management group were 1117.247 CNY lower than that in the without management group.

4. Discussion

4.1. Results and comparisons

The current study evaluated one of the supply side reforms that spearheaded the tiered service delivery system in practice. This study showed the effectiveness of the tiered healthcare system reforms in Xiamen, which was featured and mainly implemented with the model of "specialists + general practitioners + health managers", for the chronic disease management, based on the large-scale population data from Xiamen. The results provided valuable implications regarding the model's effects on improving chronic disease patients' health outcomes and reducing their healthcare costs in China, the world's most populous country with a rapidly aging population corresponding with an onslaught of chronic diseases and associated risk factors. Moving forward, the model will be expanded to more cities in China, preferentially to those with relatively high urbanization level and better medical service resources. The Chinese government and the World Bank announced a new initiative focused on expanding the tiered healthcare system reforms in Fujian province, which was an opportunity to expand the efficiency and quality of the healthcare system (World Bank Group, 2016b). Since 2016, policy makers and officials have come from 12 provinces and 58 cities to study Xiamen's tiered healthcare system model, strengthening the sustainability of Xiamen's practice and promoting it nationwide as an important reform model (WHO, 2018; Li et al., 2016; Kuang et al., 2015). Although this model requires local governments to increase the investment in medical resources which may increase local governments' financial burden, this model could bring huge benefits in health outcomes and in the reduction of healthcare burden for chronic patients. Furthermore, if we compare the benefits and costs based on the whole society rather than only on local governments' financial burden (fiscal revenue and expenditure), this model is actually cost-effective. From this point of view, therefore, this model would have good generalization in China if the local governments pay more attention to the cost-benefit comparison based on the whole society and the long-term period. However, more attention should be paid to the necessary conditions and crucial elements for the successful implementation of this model in other areas. From the practical experience of Xiamen's successful implementation of this model, at least two crucial elements were needed for the local governments to successfully implement this model. The first crucial element is the cost-benefit governance concept based on the whole society and long-term period. This governance concept could be regarded as the primary factor guiding local governments to implement this model successfully, although it would increase the financial burden of local governments directly. The second crucial element is the relative abundance of medical resources. The implementation of this model needs relatively abundant medical resources (precision management for chronic diseases needs more medical human resources), which are more likely to be concentrated in areas with higher urbanization level and better economic conditions. The above statements on the two crucial elements could provide key policy implication that this model would gradually expand from the areas with better medical resources and better governance concepts to other areas in China.

This study proved the effectiveness of the tiered healthcare system reforms in health improvement and cost-savings for chronic disease management based on the large-scale population data from Xiamen, and highlighted the importance of the integration of care provided by multidisciplinary teams for patients with chronic diseases given the difficulty of disease control. The findings in this study were in accordance with the previous researches. For example, Wang et al. (2018). found that multidisciplinary primary health-care teams helped to integrate different types of care in Shenzhen, with clearly defined roles for each team member and the flexibility to adjust roles based on patients' needs, thereby improving patients' care plan adherence and enhancing the performance of chronic disease management (Wang et al., 2018). A study by Shi et al. (2015b) showed that the implementation of a tiered healthcare delivery model in Henan was critical in guiding patients' healthcare seeking behaviour and associated with improved accessibility, continuity, coordination, and comprehensiveness of care, as well as with reducing health inequities and mitigating disparities for older patients with chronic conditions. A case-comparison design was used to study nine health care organizations in Guangzhou, Dongguan, and Shenzhen in China, and this study found that a tiered and well-organized primary care system could play a gatekeeping role and have the potential to provide reasonable levels of care to patients (Shi et al., 2015a).

4.2. Mechanism explanation

Regarding to the mechanism, as the earliest pilot city for tiered healthcare system reforms, Xiamen achieved the goal of "providing right care at the right place at the right time," (World Bank Group, 2016a) by integrating services and mobilizing resources, and thereby improving the efficiency of chronic disease management (Yu et al., 2017; Wang, 2017). The collaboration of multidisciplinary team members allowed specialists, general practitioners, and health managers to maximize their professional expertise. Specialists, who are responsible for determining the diagnosis and developing a treatment plan, may be able to see more patients with the support of general practitioners and health managers (Barber et al., 2014). General practitioners, who are responsible for implementing and monitoring healthcare plans, can assist by providing two-way referrals, and may improve their clinical expertise with the assistance of specialists from large hospitals. Health managers, who are responsible for health education and lifestyle interventions, can better maintain continuity of care via frequent patient contact, as well as reduce the workload of the specialists and general practitioners, thereby increasing their efficiency. By implementing the integrated care model, the multidisciplinary teams can handle more routine outpatient visits and chronic disease management tasks, and optimize resource allocation (Yip and Hsiao, 2014; Shi et al., 2015b). In particular, it allows a downward allocation of tertiary hospital-based resources toward community-based facilities, which in turn may help chronic disease patients receive high-quality care with lower costs (Shi et al., 2015a; Yan et al., 2016; Hu et al., 2016; Liang and Beydoun, 2019). Moreover, appropriately designed and tiered care delivery could enhance access, improve quality, and provide value to patients with chronic illness. The tiered healthcare system and multidisciplinary team can play a crucial role in providing culturally appropriate, timely and accessible care, supporting patient self-management, providing outreach to patients in the community, educating patients on the importance of lifestyle changes and adherence to their medication, and promoting continuity of care (Shi et al., 2015a). Through the collaboration mechanism of cross-level and multidisciplinary medical service workers (the triad team model), with the up and down flow of professional resources (the two-way referral systems) based on an tiered and well-organized healthcare system, the integrated, comprehensive, continuous and high-quality chronic disease management services could be produced and delivered in a timely and low cost manner. The successful practice of Xiamen's tiered healthcare system reforms further highlighted the importance and specific value of the tiered medical service delivery system as well as the integrated medical services in the medical supply side. Moreover, the model innovation as well as the fruitful practice conducted in Xiamen would provide practical support and inspiration for further improvement of the related theories of CCM and ICCC, and therefore better adapting to the chronic disease management practice in developing countries, especially for those where medical resources are highly imbalanced and upwardly concentrated.

4.3. Strengths and limitations

This study was the first in China to evaluate the effectiveness of the tiered healthcare system reforms based on large-scale micro-population data from all the patients with hypertension and diabetes in Xiamen, the earliest pilot city for China's tiered healthcare system reforms. This study was different from the previous studies, which were mostly conducted based on small sample size (or even limited cases), or only based on specific subgroup population (e.g., only including the elderly), or based on small experiments in hospitals. In addition, few of the previous studies were conducted on the large-scale data from the pilot cities of the tiered healthcare system reforms in China. A major strength and unique feature of the current study was the use of a comprehensive array of real-world datasets to evaluate the effects of tiered healthcare system reforms in a large city. This study is also one of the earliest evaluations of Xiamen's tiered healthcare system reforms, which piloted the model of "specialists + general practitioners + health managers" in Xiamen. Having data from all hypertensive and diabetes patients in the city made it possible to conduct a comprehensive evaluation of health reform effectiveness at the population level. Moreover, evaluating large-scale healthcare reforms has always been a challenge, especially in terms of how to measure policy effectiveness. Given the longitudinal data and survival analysis design of the study, we were able to investigate time-to-event outcomes that offered more information than simply whether or not an event occurred. Moreover, the use of proportional hazard models allowed us to derive consistent and efficient estimates of covariate effects, revealing meaningful patterns in the data. Finally, the use of PSM + DID methods in this study allowed us to minimize the possible estimation bias caused by the potential endogeneity, and to enhance the credibility and robustness of the estimation results.

Although this study had advantages mentioned above, there are also some limitations in this study. First, the task, collecting large-scale data from various medical institutions, pharmacies, and local departments in Xiamen, was too complex and difficult to limit the number of variables obtained in this process, although the data obtained were comprehensive to cover the total costs (outpatient and inpatient costs collected from various medical institutions, and medication costs collected from pharmacies) of all the patients with hypertension and diabetes in Xiamen. We cannot account for all the potential factors that may affect the outcome given the limitations of secondary data analysis, such as the unavailable variables of patients' complications and years with illness. Second, there was limited information about patients' self-reported indicators and lab test results, making it difficult directly to evaluate the quality of healthcare. Third, as a large-scale public policy experiment in real world, the endogeneity based on self-selection was inevitable in Xiamen's pilot practice. Although we employed the method of PSM + DID to minimize, to the greatest extent, the possible estimation bias caused by the potential endogeneity, this did not mean we had completely cleared the possible estimation bias. Fourth, this study could not conduct the comparison analyses between the without management group and the other two groups in survival analysis section due to the data limitation, because the hypertension or diabetes conditions of patients from without management group could not be recorded in time because of the lack of management services. However, this study proved that patients from precision management group had higher under-control rates than those from regular management group, therefore, the patients from precision management group inevitably had higher under-control rates than those from without management group, based on the underlying consensus showed in previous literatures that patients from regular management group had better health outcomes and higher under-control rates than those from without management group.

5. Conclusion

This study may help researchers and policy makers from other cities and regions observe the effectiveness and value of the tiered healthcare system reforms in Xiamen, which is featured and mainly implemented with the model of "specialists + general practitioners + health managers" for chronic disease management. The results demonstrated associations between the Xiamen model and better clinical quality performance and improved cost-savings. Our findings suggest that the tiered and well-integrated healthcare delivery system may serve as a strategy to enhance care for chronic disease patients. China's tiered healthcare delivery policy has a positive impact on chronic disease control, with the potential to promote the well-being of patients.

To sustain and improve the effects of the multidisciplinary team-based care model for chronic disease management, the roles of health managers and general practitioners should be further enhanced through standardized training and performance evaluation. Additionally, the model's effectiveness could be further improved by the use of advanced information technology, such as messaging apps and a resident's health

information website. This has been crucial to the sustainability and functioning of Xiamen's tiered healthcare system reforms. Moreover, methods for promoting and increasing the scale of policy implementation are an important part of the current reforms. Specialized reforms and careful study, guided by the coordinated efforts of central and local governments, will enable the translation of local successes into national policy, adapting them to other cities and regions. The success of Xiamen pilot may be useful for facilitating successful healthcare reforms in China and elsewhere.

Credit author statement

H Wang obtained the data and designed the study, H Hu preformed data analysis, H Liang wrote the manuscript.

References

Barber, S.L., Borowitz, M., Bekedam, H., Ma, J., 2014. The hospital of the future in China: China's reform of public hospitals and trends from industrialized countries. Health Pol. Plann. 29, 367–378. https://doi.org/10.1093/heapol/czt023.

Hu, R., Liao, Y., Du, Z., Hao, Y., Liang, H., Shi, L., 2016. Types of health care facilities and the quality of primary care: a study of characteristics and experiences of Chinese patients in Guangdong Province, China. BMC Health Serv. Res. 16 (335) https://doi.org/10.1186/s12913-016-1604-2.

Kim, H.S., Suh, Y., Kim, M.S., Yoo, B.N., Lee, E.J., Lee, E.W., Park, J.H., 2019. Effects of community-based primary care management on patients with hypertension and diabetes. Asia Pac. J. Publ. Health 31, 522–535. https://doi.org/10.1177/1010539519867797.

Kuang, L., Liang, Y., Mei, J., Zhao, J., Wang, Y., Liang, H., Shi, L., 2015. Family practice and the quality of primary care: a study of Chinese patients in Guangdong Province. Fam. Pract. 32, 557–563. https://doi.org/10.1093/fampra/cmv064.

Li, J., Wang, P., Kong, X., Liang, H., Zhang, X., Shi, L., 2016. Patient satisfaction between primary care providers and hospitals: a cross-sectional survey in Jilin province, China. Int. J. Qual. Health Care 28, 346–354. https://doi.org/10.1093/intqhc/mzw038.

Li, X., Li, Z., Liu, C., Zhang, J., Sun, Z., Feng, Y., Mei, J., Gu, C., Li, X., Yang, S., 2017. Evaluation of the three-in-one team-based care model on hierarchical diagnosis and treatment patterns among patients with diabetes: a retrospective cohort study using Xiamen's regional electronic health records. BMC Health Serv. Res. 17, 779. https://doi.org/10.1186/s12913-017-2705-2.

Liang, H., Beydoun, M.A., 2019. Modifiable health risk factors, related counselling, and treatment among patients in health centers. Health Soc. Care Community 27, 693–705. https://doi.org/10.1111/hsc.12686.

Liu, X.L., 2010. Discussion on the standardized management and its efficacy of chronic disease in a community, tianjin. Chine. J. Preven. Control Chronic Disease. 18, 416–417 (In Chinese).

Liu, L.S., 2011. 2010 Chinese guidelines for the management of hypertension. China. J. Cardiovas. Disease. 39, 579–615 (In Chinese).

Ning, S., Wang, Y., Chen, Q., Yang, S., Liang, W., 2010. Community management of patients with hypertension and diabetes in Beijing. Chin. J. Public Health 26, 900–901 (In Chinese).

Qin, Y., Pan, X., Su, J., Yang, J., Du, W., Zhang, N., Gu, S., Su, M., Miao, C., Shen, C., Wu, M., 2015. Concurrent control of blood glucose, pressure, lipids, and body mass in patients with type 2 diabetes and comparison with the 2013 Chinese guidelines: a cross-sectional study. Lancet 386. https://doi.org/10.1016/S0140-6736(15)00581-4.

Shi, L., Lee, D.-C., Liang, H., Zhang, L., Makinen, M., Blanchet, N., Kidane, R., Lindelow, M., Wang, H., Wu, S., 2015a. Community health centers and primary care access and quality for chronically-ill patients – a case-comparison study of urban Guangdong Province, China. Int. J. Equity Health 14, 90. https://doi.org/10.1186/s12939-015-0222-7.

Shi, L., Makinen, M., Lee, D.C., Kidane, R., Blanchet, N., Liang, H., Li, J., Lindelow, M., Wang, H., Xie, S., Wu, J., 2015b. Integrated care delivery and health care seeking by chronically-ill patients - a case-control study of rural Henan province, China. Int. J. Equity Health 14, 98. https://doi.org/10.1186/s12939-015-0221-8.

State Council General Office, 2015. Guidance of the General Office of the State Council on Promoting Multi-Level Diagnosis and Treatment System. http://www.gov.cn/zhengce/content/2015-09/11/content_10158.htm. (Accessed 17 January 2019).

Wagner, E.H., Austin, B.T., Von Korff, M., 1996. Organizing care for patients with chronic illness. Milbank Q. 74, 511–544. https://doi.org/10.2307/3350391. (Accessed 17 January 2019).

Wang, L.Y., 2017. County integrated healthcare organization, China solution of rural health. Chin. Stud. 6, 161–166. https://doi.org/10.4236/chnstd.2017.63015.

Wang, X., Sun, X., Birch, S., Gong, F., Valentijn, P., Chen, L., Zhang, Y., Huang, Y., Yang, H., 2018. People-centred integrated care in urban China. Bull. World Health Organ. 96, 843–852. https://doi.org/10.2471/BLT.18.214908.

World Bank Group, 2016a. Deepening Health Reform in China: Building High-Quality and Value-Based Service Delivery. https://openknowledge.worldbank.org/handle/10986/24720. (Accessed 17 January 2019).

World Bank Group, 2016b. Building High-Quality and Value-Based Service Delivery Policy Summary. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/800911469159433307/deepening-health-reform-in-china-building-high-quality-and-value-based-service-delivery-policy-summary. (Accessed 17 January 2019).

World Health Organization, 2002. Innovative Care for Chronic Conditions-Building Blocks for Action. https://www.who.int/chp/knowledge/publications/icccreport/en/. (Accessed 17 January 2019).

World Health Organization, 2015. China Country Assessment Report on Aging and Health. Geneva. http://apps.who.int/iris/bitstream/handle/10665/194271/9789241509312_eng.pdf?sequence=1. (Accessed 17 January 2019).

World Health Organization, 2018. China Multidisciplinary Teams and Integrated Service Delivery across Levels of Care. https://www.who.int/docs/default-source/primary-health/case-studies/china.pdf. (Accessed 17 January 2019).

Yan, F., Tang, S., Zhang, J., 2016. Global implications of China's healthcare reform. Int. J. Health Plann. Manag. 31, 25–35. https://doi.org/10.1002/hpm.2252.

Yang, S., Chen, L., 2016. Chronic diseases first, Co-management of doctors of three kinds and reform of hierarchic diagnosis and treatment benefiting masses of people. Modern Hospital Manag. 14, 2–6 (In Chinese).

Yip, W., Hsiao, W., 2014. Harnessing the privatisation of China's fragmented health-care delivery. Lancet 384, 805–818. https://doi.org/10.1016/S0140-6736(14)61120-X.

Yu, W., Li, M., Nong, X., Ding, T., Ye, F., Liu, J., Dai, Z., Zhang, L., 2017. Practices and attitudes of doctors and patients to downward referral in Shanghai, China. BMJ Open 7, e012565. https://doi.org/10.1136/bmjopen-2016-012565.