Developing the Risk-Adjusted Capitation Payment for Patients with Diabetes Mellitus in China: Results from Administrative Data in Tianjin

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BACKGROUND

- Capitation, paying healthcare providers a fixed fee based on each participant in a health plan for the provision of services, is commonly applied with chronic disease management like diabetes mellitus (DM) in China, can encourage healthcare providers to proactively manage patients' health and thereby control costs[1,2].
- Risk-adjusted capitation, which uses individual information to calculate the expected cost, adjusts the capitation payment to reflect patients' relative health needs and costs, so as to better regulate healthcare providers[3,4].
- Given that capitation is relatively new in China, especially for risk-adjusted capitation, it's a need how to design payment schemes.

OBJECTIVE

- To develop the risk-adjustment capitation model for DM patients in China, and to further simulate the financial impact on healthcare insurance and healthcare providers.

METHODS

Stage I Identifying the study population

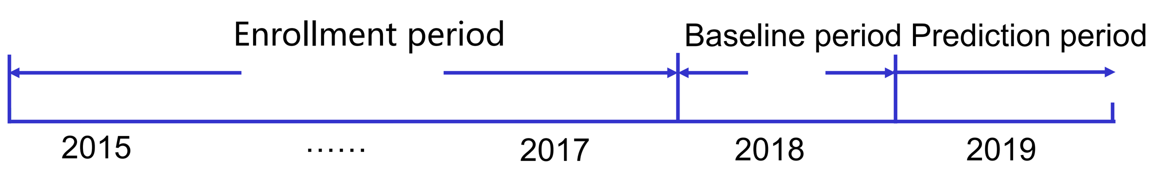
Data source

- Data were obtained from the Tianjin Basic Medical Insurance Database (2015-2019).
  - ✓ This database contains enrollment, health care service and medication prescription claims of beneficiaries who registered in the 'Outpatient Specific Diseases' program in Tianjin, one of the municipalities in China, from 2015 to 2019.

Study population

- DM registered adult patients before 2018, who had continuous enrollment and ≥1 outpatient specific diseases claim with a primary diagnosis of DM (ICD code E10-E14) both in 2018 and 2019.

Study period



Stage II Descriptive analyses

Measures

- Patients' baseline characteristics and the economic burden was estimated.
  - ✓ Sociodemographic characteristics included age, sex, basic medical insurance type and occupation in 2018.
  - ✓ Disease characteristics included 17 DM complications and 17 Charlson comorbidities during 2018.
    - ➢DM complications included 8 categories and 17 subcategories of macrovascular, microvascular and metabolic complications.
  - ✓ DM-related healthcare resource utilization and costs in 2019.

Stage III Developing risk-adjusted models

- Prospective risk-adjusted models are conducted using 5 sets of risk-adjusters in 2018 combined with 4 econometric methods to predict individuals' DM-related outpatient and total spending in 2019.

Risk-adjusters

- ✓ Risk-adjusters 1: age, sex
- ✓ Risk-adjusters 2: Risk-adjusters 1+17 DM complications
- ✓ Risk-adjusters 3: Risk-adjusters 1+17 Charlson comorbidity
- ✓ Risk-adjusters 4: Risk-adjusters 2+10 Charlson comorbidity (duplicate DM complications were excluded)
- ✓ Risk-adjusters 5: Risk-adjusters 4+ 36 DM complications interaction(generated by 9 DM complications pairwise interaction)

Econometric models

- ✓ the Ordinary Least Squares Model (OLS)
- ✓ the OLS log-transformation Model (OLS log-transformation)
- ✓ the Generalized Linear Model (GLM-Gamma log-link, GLM-Poisson log-link)

Stage IV Evaluating the predictive performance

- In-sample and out-sample predictive performance was evaluated based on the whole sample and the simulated external sample, which was generated by the cross-validation method.

METHODS (Cont'd)

Measures

- Pseudo $R^2 = 1 - \frac{\sum_i^n (y_i - \hat{y}_i)^2}{\sum_i^n (y_i - \bar{y})^2}$ Pseudo $R^2_{adj} = 1 - \left(1 - \text{Pseudo } R^2\right)\frac{n-1}{n-k-1}$
- Mean Absolute Error (MAE)= $\frac{\sum_i^n |y_i - \hat{y}_i|}{n}$
- Root Mean Squared Error (RMSE)= $\sqrt{\frac{\sum_i^n (y_i - \hat{y}_i)^2}{n}}$

Stage V Simulation study

- Based on the best-fit model, the financial impacts of implementing different risk-adjusted capitation payments (R-CAP) on healthcare insurance and providers were estimated compared with fee-for-service (FFS) or unadjusted capitation payment (CAP).

Payment method

- ✓ $R\text{-}CAP_1$: 2019 risk-adjusted predicted cost
- ✓ $R\text{-}CAP_2$: 2019 risk-adjusted predicted cost + the bottom-up approach (set the minimum and maximum payment at the 20th and the 80th percentile excluding the highest 5% of cases)
- ✓ $R\text{-}CAP_3$: 2019 risk-adjusted predicted cost + FFS for 5% highest and 25% lowest patients

Measures

- ✓ $Ratio_{FFS}$= payment in $R\text{-}CAP_i$ / FFS
- ✓ $Ratio_{CAP}$= payment in $R\text{-}CAP_i$ / CAP

RESULTS

- 241,120 eligible DM patients were identified, the mean age was 63.6 (11.1) years old, with 46.7% being females. The mean CCI was 2.5 (1.9), and about 74.5% had DM complications, of which the top three diseases in frequency were cardiovascular disease (68.4%), neuropathy (53.3%) and renal disease (48.6%) (**Table 1**).
- The DM-related total spending for the DM patients was *RMB19,069.9*, of which outpatient spending was *RMB14,758.5* in 2019.

Table1. Baseline characteristics of the DM patients, 2018

Baseline characteristics	DM patients(N=241,120)	
	Mean/n	SD/%
Sociodemographic characteristics[n(%)]		
Mean age	**63.6**	**11.1**
Female	**112,712**	**46.7%**
Basic medical insurance type		
UEBMI	186,546	77.4%
URRBMI	55,574	22.6%
Occupation		
employees	50,779	21.1%
retirees	135,767	56.3%
unemployees	54,503	22.6%
students	71	0.0%
Disease characteristics[mean/n(SD/%)]		
CCI	**2.5**	**1.9**
DM complications		
Cardiovascular disease	164,943	**68.4%**
Coronary heart disease	146,127	60.6%
Angina	17,094	7.1%
Myocardial infarction	1,120	0.5%
Chronic heart failure	8,398	3.5%
Arrhythmia	15,351	6.4%
Cerebrovascular disease	16,210	6.7%
Stroke	10,646	4.4%
Transient ischemic attacks	4,789	2.0%
Other CVD	2,745	1.1%
Peripheral vascular disease	90,025	37.3%
Foot disease	14,170	5.9%
Renal disease	117,199	**48.6%**
Diabetic nephropathy	102,266	42.4%
Chronic nephritis	5,512	2.3%
Nephrotic syndrome	39,375	16.3%
Renal failure	32,930	13.7%
Retinopathy	76,246	31.6%
Neuropathy	128,527	**53.3%**
Metabolic complications	905	0.4%
With no above DM complications	37,302	**15.5%**

*UEBMI, Urban Employee Basic Medical Insurance; URRBMI, Urban and Rural Residents Basic Medical Insurance; CCI, Charlson Comorbidity Index; DM, Diabetes Mellitus; CVD, Cerebrovascular Disease.
*The 9 DM complications in blue will generate 36 disease interaction terms.

- **Figures 1 and 2** showed the relationship between age, sex, and DM complications variables and DM-related outpatient spending.
  - ✓ Individual characteristics of age and sex are correlated with DM-related outpatient spending, though not in a linear relationship.
  - ✓ The presence or absence of DM complications also significantly affected DM-related outpatient spending, except for acute onset cerebrovascular disease and metabolic complications.

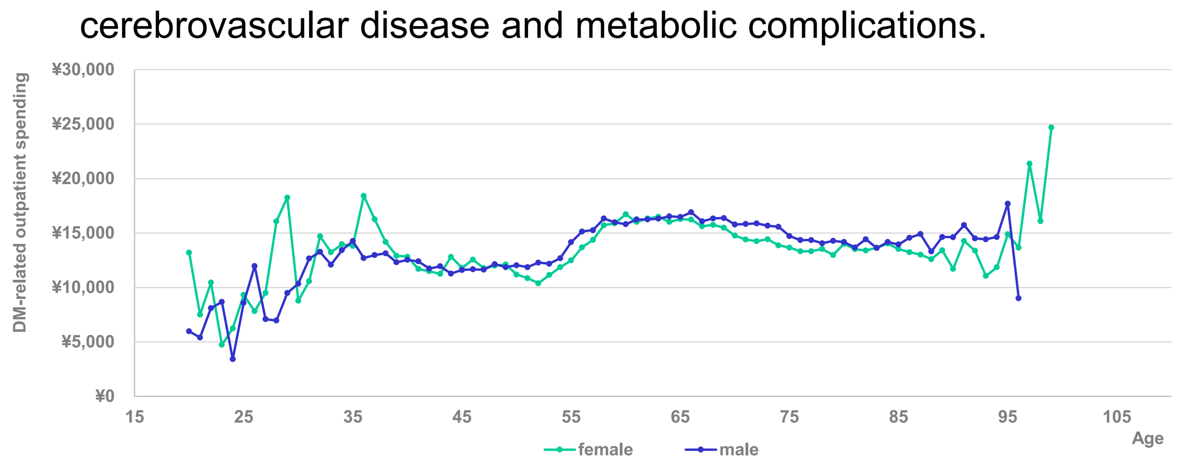


Figure1. DM-related outpatient spending by age and sex, 2019

RESULTS (Cont'd)

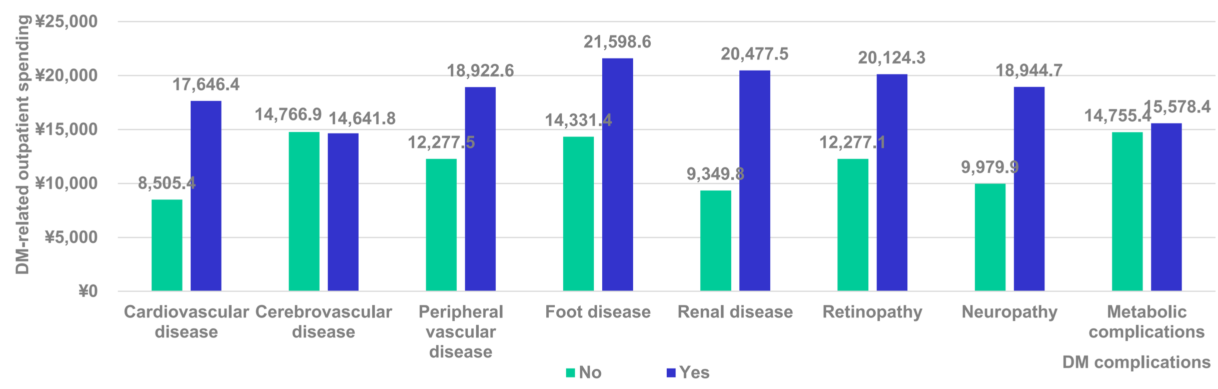


Figure2. DM-related outpatient spending by DM complications, 2019

- The out-sample prediction performance was less than but close to the in-sample performance, indicating that there is little overfitting. The best-fit model was the combination of risk-adjusters 5 with OLS, in-sample and out-sample R^2_{adj} were 30.48% and 30.30%(**Table 2**).

Table2. Predictive performance of risk-adjusted models

	In-sample predictive performance			Out-sample predictive performance		
	Pseudo R^2_{adj}	MAE	RMSE	Pseudo R^2_{adj}	MAE	RMSE
OLS						
Risk-adjusters 1	0.0138	8,938	12,997	0.0129	8,939	12,996
Risk-adjusters 2	0.2937	6,828	11,000	0.2927	6,829	10,999
Risk-adjusters 3	0.2236	7,488	11,532	0.2225	7,489	11,532
Risk-adjusters 4	0.2973	6,790	10,971	0.2962	6,792	10,971
Risk-adjusters 5	**0.3048**	**6,751**	**10,912**	**0.3030**	**6,753**	**10,913**
OLS log-transformed						
Risk-adjusters 1	0.0101	8,945	13,022	0.0092	8,946	13,020
Risk-adjusters 2	0.2430	7,113	11,387	0.2420	7,114	11,386
Risk-adjusters 3	0.2061	7,534	11,662	0.2051	7,535	11,660
Risk-adjusters 4	0.2421	7,095	11,394	0.2409	7,097	11,394
Risk-adjusters 5	**0.2771**	**6,882**	**11,127**	**0.2754**	**6,885**	**11,127**
GLM-Gamma log-link						
Risk-adjusters 1	0.0138	8,938	12,997	0.0129	8,939	12,996
Risk-adjusters 2	0.2728	6,972	11,161	0.2717	6,973	11,160
Risk-adjusters 3	0.2197	7,494	11,561	0.2187	7,495	11,560
Risk-adjusters 4	0.2740	6,949	11,151	0.2728	6,951	11,151
Risk-adjusters 5	**0.2971**	**6,790**	**10,973**	**0.2953**	**6,793**	**10,974**
GLM-Poisson log-link						
Risk-adjusters 1	0.0138	8,938	12,997	0.0129	8,939	12,996
Risk-adjusters 2	0.2851	6,895	11,066	0.2840	6,897	11,066
Risk-adjusters 3	0.2236	7,486	11,532	0.2224	7,487	11,533
Risk-adjusters 4	0.2878	6,864	11,045	0.2865	6,866	11,046
Risk-adjusters 5	**0.3027**	**6,767**	**10,929**	**0.3007**	**6,770**	**10,931**

*MAE, Mean Absolute Error; RMSE, Root Mean Squared Error; OLS, the Ordinary Least Squares Model; GLM, the Generalized Linear Model

- The blended payment scheme that combined risk adjustment and partial FFS ($R\text{-}CAP_3$) generated fewer financial fluctuations, in which $ratio_{FFS}$ and $ratio_{CAP}$ were 0.99 and 1.20 for total healthcare insurance, ranged from 0.69 to 1.17 and 0.96 to 1.35 for different districts, respectively(**Table 3**).

Table3. Potential financial impact of risk-adjusted models

NO.	FFS	CAP	$R\text{-}CAP_1$			$R\text{-}CAP_2$			$R\text{-}CAP_3$		
	2019 actual outpatient spending (million)	Payment (million)	Payment (million)	$Ratio_{FFS}$	$Ratio_{CAP}$	Payment (million)	$Ratio_{FFS}$	$Ratio_{CAP}$	Payment (million)	$Ratio_{FFS}$	$Ratio_{CAP}$
1	600.8	471.7	558.7	0.93	1.18	521.6	0.87	1.11	603.5	1.00	1.28
2	581.7	465.3	515.4	0.89	**1.11**	493.5	0.85	**1.06**	522.4	0.90	1.12
3	386.0	310.6	364.8	0.95	1.17	339.4	0.88	1.09	401.5	1.04	1.29
4	373.5	301.0	392.2	1.05	1.30	344.7	0.92	1.15	406.6	1.09	**1.35**
5	366.6	313.9	358.6	0.98	1.14	336.8	0.92	1.07	366.5	1.00	1.17
6	339.9	216.9	242.5	**0.71**	1.12	237.0	**0.70**	1.09	233.6	**0.69**	1.08
7	270.8	249.9	346.2	1.28	1.39	337.3	1.25	1.35	315.8	**1.17**	1.26
8	214.0	181.0	212.9	1.00	1.18	201.1	0.94	1.11	224.4	1.05	1.24
9	81.5	70.3	105.5	1.29	**1.50**	102.3	1.25	1.45	90.0	1.10	1.28
10	68.3	66.6	82.6	1.21	1.24	83.3	1.22	1.25	73.4	1.07	1.10
11	67.5	72.5	98.1	1.45	1.35	107.6	1.59	1.48	73.5	1.09	1.01
12	62.5	60.8	75.0	1.20	1.23	83.3	1.33	1.37	60.8	0.97	1.00
13	59.4	56.6	71.9	1.21	1.27	74.8	1.26	1.32	62.0	1.04	1.10
14	32.7	35.8	51.6	**1.58**	1.44	54.1	1.65	1.51	38.1	1.17	1.07
15	28.5	30.2	44.4	1.56	1.47	47.4	1.67	**1.57**	32.9	1.16	1.09
16	24.9	28.4	38.2	1.53	1.34	42.9	**1.72**	1.51	27.1	1.09	**0.96**
Total	**3,558.6**	**2,931.4**	**3,558.6**	**1.00**	**1.21**	**3,407.1**	**0.96**	**1.16**	**3,532.3**	**0.99**	**1.20**

*FFS, Fee-For-Service; CAP, Capitation; R-CAP, Risk-adjusted Capitation.

LIMITATIONS

- First, in terms of model construction, this study currently compares the performance of two types of disease grouping methods, DM complications and Charlson comorbidity, it is worthwhile to explore more models that are applicable to China.
- Second, with regard to the generalization of the results, there may be limitations in generalizing the results of this study to the national level and to the entire disease population, studies with larger samples and more diseases can be explored.

CONCLUSIONS

- A capitation payment that adjusts for age, sex, and complications, especially those related to DM, performs better in predicting future DM-related costs.
- Blended payment schemes that combined risk adjustment and partial FFS are more conducive to healthcare insurance payment reform and chronic disease management.

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