Supplementary materials

Quantifying the Financial Impact of Overuse in Primary Care in China: A Standardised Patient Study

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1.1 Field Settings

This Standardised Patients (SPs) audit study was conducted in a capital city in northwest China. The capital city has a population of over 8.8 million in an area of more than 9,983 km², and 73.43% of residents of the capital city lived in urban areas in 2017. The per capita Gross Regional Product (GRP) was 71,357 CNY (10,747 USD, PPP by the annual average exchange rate in 2016) at the end of 2016. The residents mainly live in 7 districts of the capital city. All 63 community health centres in the 7 districts were selected for the study.

1.2 SP training

The SPs were recruited from the local community to make sure that they were similar to the actual patients commonly diagnosed by primary care providers. We announced the recruitment online via WeChat (an app similar to WhatsApp). The recruitment requirement included:
- ➢ The participants should be in reasonably good physical condition.
- ➢ Physicians and other health-related professionals were excluded from recruitment.
- ➢ The participants should be in their 40s (for the case of asthma) or 50s (for the case of unstable angina).

We received 20 completed applications in 2017, and of those, 14 attended the interview. SPs were chosen following four basic criteria:
- ➢ Time availability for training and SPs medical visits.
- ➢ Residence in the capital city over 5 years and speaking the local language fluently.
- ➢ A reasonable level of intelligence, critical thinking, memory ability and communication are essential.
- ➢ Excellent acting skills are preferred.

Finally, 10 SPs (8 females and 2 males) were selected to participate in this study in 2017.

First, 10 SPs were randomly assigned to 2 disease cases (asthma and unstable angina). Then SPs participated in a 3-day training before visiting hospitals and physicians. The training was conducted by a team consisting of professors, medical experts and our team members.
- ➢ Details of assigned diseases and scripts were explained to the SPs and recordings of incognito interactions between SPs and physicians obtained from our pilot study were presented to the SPs.
- ➢ Role-playing and one-on-one training methods were used to further develop the scripts, help them understand and memorise the scripts and portray the cases.
- ➢ The training on principles of how to respond to physician questions that were not listed in the scripts and how to avoid invasive examinations (e.g., blood tests).
- ➢ Peer evaluation was used to improve SPs' acting performance. SPs' acting performance was required to be as similar to the specific disease script as possible. Also, within each disease group, SPs' acting performance should be at a highly comparable level.

We repeated the audit study in 2018. We had 6 out of the 10 initial SPs available to participate in the program. We recruited 2 additional SPs (out of 6 applications) in 2018 following the same standard. All in all, 8 SPs (7 females and 1 males) were selected to participate in this study in 2018.

Overall, we recruited 18 person-years SPs, among which 15 were females, and 3 were males.

1.3 SP scripts

Panel A For Asthma
Name, gender, age, staff
Reason for visit: wheezing, cough
State of consultation: a little sluggish, a little tired, dry cough occasionally
Main complaint: intermittent wheezing and coughing for 2 years, recurrence in the last week, worsening
History of present illness

1. Shen Tao, male, 40 years old, on November 15, 1977, lived in XXXX Street, XXXX District, and his phone number was XXXXXXXXXXX.

2. Liu Mei, female, 40 years old, 40 years old on November 15, 1977, lives in XXXX Street, XXXX District, and her phone number is XXXXXXXXXXX.

3. 2 years ago, I had a fever and cough after catching a cold. I still coughed after the fever subsided, but there was no sputum. At the same time, I felt wheezing. I had a "squeaking" sound and felt suffocated. No palpitation and other discomforts. It happened once in about 3 or 4 months, but after a 15-minute break, it relieved slowly, so I haven't seen it in the CHC or taken medicine.

4. The disease seems to be related to the cold air. It is usually severe in autumn. Sometimes I feel uncomfortable when I enter an air-conditioned room. I usually cough first, and soon start to pant.

5. The weather has suddenly become cold in the past week. After the cold, I have coughing and wheezing. It is light during the day and heavy at night. Basically, I don't have enough breath every day, and I feel a little wheezing on the second floor. Intermittent wheezing, a little cough, no fever, no sputum, no palpitation, no leg swelling, no chest pain, no hemoptysis. It takes about 15 minutes for each attack to be particularly uncomfortable, and it takes about 2 hours before and after it to completely heal, and I feel that my whole body is weak.

6. In the past 2 years, I feel that my physical strength is not as good as before, and I feel short of breath after playing a long time. Eating is ok. There is no change in weight. There is no problem with urine.

Past history

I started to change allergic rhinitis 7.5 years ago, sneezing, runny nose during the attack, and taking "Chlorpheniramine" in severe cases can be cured. No other diseases, no history of drug allergy. No surgical trauma. No smoking and alcohol addiction.

Personal history and family history

8. Born locally and went to school until graduation. Unmarried, my mother has allergic rhinitis, which is more serious than me, and sometimes she has to spray "hormones" into her nose. Father is healthy.

Panel B For Unstable Angina

Name, gender, 50, sales

Reason for visit: chest pain

State of consultation: a little sluggish, with chest pain

Main complaint: intermittent chest pain for 1 year, worsening in the last 1 week

1. Wang Junqiang, male, 50 years old, November 15, 1967, lives in XXX Street, XX District, and his phone number is XXXXXXXXXXX.

2. Zhao Feng, 50 years old, November 15, 1967, lives in X Street, XXX District, and his phone number is XXXXXXXXXXX.

3. Daily life is irregular, eating and sleeping are not punctual. When busy, there is no time to eat and sleep for a few hours. I usually like to smoke, one pack of cigarettes a day for 8 years. I like to drink when I go out to eat with my friends and have drunk it for 5 years (the above symptoms are the description of SP for boys, if SP is for girls, they don't smoke, but they often drink because of the nature of work).

4. Gradually, I feel a little overwhelmed by my body. A year ago, I occasionally experienced chest pains when I was working and angry, about once a month or two, but after resting for about three to five minutes, the pain gradually disappeared.

5. But the pain occurred once every four days on the last Wednesday, and it also occurred during rest. When it hurts, I feel dizzy, sweating, fatigue, and short of breath. Now it takes 20 minutes to gradually relieve the pain. Just two days ago, when he was resting, he had chest tightness and severe chest pain. Because the pain was so severe this time, he was going to see the doctor.

6. Except that blood sugar is a bit high, the body has no other diseases. Usually, the taste is heavier when you eat, and you eat more salt.

7. My elder brother, had similar symptoms. The rest of the family is healthy.

1.4 SP visits

SPs visited our sample CHCs in late August 2017 and 2018. Four SPs were randomly assigned and independently visited each CHC (2 SPs portraying unstable angina and the other 2 SPs portraying asthma). To avoid being detected by physicians, SPs who presented the same disease could not visit the same CHC within 7 days after his/her first visit.

Generally, in CHCs, patients need to schedule an appointment onsite and pay a fixed consultation fee. Then they can visit general physicians directly and can choose a physician at this stage. However, in this study, we required SPs to visit the first physician in the first office as though they were an ordinary patient.

The procedure for the SPs to collect data for the study include:
- The whole interaction between SPs and clinicians based on the informed consent signed by CHCs and physicians, using a hidden voice recording device.
- The diagnoses of each visit. SPs were required to ask providers directly whether a diagnosis was given or not.
- The SPs were required to purchase the medications prescribed by physicians or obtain a prescription to collect data about drugs dispensed and the fees charged.
- An exit survey after leaving the medical visit including all information on the process, diagnosis, treatment, and a rating of the physicians.
- The student instructors double-checked the recording together with SPs immediately after the visit, thus, SPs could clarify to enumerators what was taking place.

Based on reports from SPs, none of them were recognised as SPs by physicians either in 2017 or 2018.

1.5 Guidelines for unstable angina and asthma

Checklist Items for Asthma

Panel A Inquiry Items

Item Order	Item	Recommend Item (N=13)	Essential Item (N=5)
1	The time of last attack [Essential]	1	1
2	Progression of disease [Essential]	1	1
3	Means of mitigation [Essential]	1	1
4	Triggers or circumstances of attack [Essential]	1	1
5	Degree or duration of attack [Essential]	1	1
6	Problems with breathing	1	0
7	Time of first attack	1	0
8	Wheezing (breathing sound)	1	0
9	Cold and fever	1	0
10	To produce phlegm (in the throat)	1	0
11	Family medical history	1	0
12	Other diseases	1	0
13	Medical history during childhood	1	0

Panel B Medical Examination Items

Item Order	Item	Recommend Item (N=7)	Essential Item (N=4)
1	Auscultation of chest or back [Essential]	1	1
2	Pulmonary ventilation function test [Essential]	1	1
3	Bronchodilation test (reversible airway test) [Essential]	1	1
4	Physical examination	1	1
5	Chest X-ray	1	0
6	Blood test	1	0
7	Percussion: Percussive percussion with both lungs	1	0

Checklist Items for Unstable Angina

Panel A inquiry Items

Item Order	Type	Item
1	The area	The pain location [Essential]
2		The pain type [Essential]
3	Nature of the pain	The degree of the pain [Essential]
4		Radiating pain [Essential]
5	The triggers	When the pain starts while doing something [Essential]
6	Means of mitigation	Means of pain relief [Essential]
7		Duration of the pain [Essential]
8	Time	Earliest onset time
9		Time of last attack
10		Short of breathing
11	Associated symptoms	Nausea and vomiting
12		Sweat
13	Frequency of attack	Frequency of attack
14		Disease risk factors (i.e., blood glucose, blood pressure, blood lipids)
15	Risk factors	Habits（dietary, smoking, drinking）
16		Family history

Panel B Medical Examination Items

Item Order	Type	Item
1	EKG	EKG [Essential]
2	Coronary check	Coronary artery examination [Essential]
3	Blood pressure	Blood pressure
4	Pulse	Pulse
5	Auscultation	Auscultation (chest and back)
6	Temperature	Temperature

	Unstable Angina	Asthma
Diagnosis	1. Correct diagnosis Angina; Myocardial infarction 2. Partially correct diagnosis, for example Heart disease 3. Incorrect diagnosis Myocardial ischemia, neuralgia, menopausal syndrome, myocarditis, cervical spondylosis, chest congestion, swelling in chest.	1. Correct diagnosis Asthma 2. Partially correct diagnosis, for example Allergies; Breathing problem 3. Incorrect diagnosis Heart disease, cold, coronary heart disease, respiratory infection, myocardial ischemia, acute pharyngitis, mycoplasma infection.
Treatment	1. Correct treatment Aspirin, clopidogrel/ or other anti-platelet agents, referral. 2. Unnecessary or harmful, for example Antibiotics, ginkgo oral liquid, Naoxintong capsule, oral electrolyte solution, psychiatric medication, theophylline	1. Correct treatment Bronchodilators, theophylline, inhaled or oral corticosteroids, leukotriene inhibitors, inhaled anticholinergic 2. Unnecessary or harmful, for example Aspirin, compound liquorice tablet, erythromycin, lung-nourishing semifluid extract, ginkgo oral liquid, cephalosporin

Table S1 Descriptive statistics

	No.	%
Public vs. private		
Public hospitals	414	84.15
Private hospitals	78	15.85
Physician competence		
Low competence	275	55.89
High competence	217	44.11
Case		
Unstable angina	245	49.8
Asthma	247	50.2
Physician gender		
Female physician	268	54.47
Male physician	224	45.53
Patient gender		
Female patient	411	83.54
Male patient	81	16.46
Physician age		
Junior	152	30.89
Senior	340	69.11

Table S2 Distribution of unnecessary items among hospitals, physicians, and patients

Panel A

| | (1) | | | (2) | | | (3) | | |
| | Total overuse | | | Overuse of tests | | | Overuse of drugs | | |
	Mean	(95% CI)	p-value	Mean	(95% CI)	p-value	Mean	(95% CI)	p-value
Overall	0.7215	(0.6818, 0.7613)		0.5467	(0.5026, 0.5909)		0.2805	(0.2407, 0.3203)	
Public vs. Private									
Public hospitals	0.7174	(0.6739, 0.7609)	0.636	0.5314	(0.4832, 0.5796)	0.115	0.2947	(0.2506, 0.3388)	0.106
Private hospitals	0.7436	(0.6458, 0.8414)		0.6282	(0.5200, 0.7364)		0.2051	(0.1147, 0.2955)	
Physician competence									
Low	0.8109	(0.7644, 0.8574)	<0.001	0.6291	(0.5718, 0.6864)	<0.001	0.2800	(0.2267, 0.3333)	0.978
High	0.6083	(0.5430, 0.6736)		0.4424	(0.3760, 0.5088)		0.2811	(0.2210, 0.3412)	
Disease									
Angina	0.5796	(0.5175, 0.6417)	<0.001	0.3633	(0.3028, 0.4238)	<0.001	0.3265	(0.2675, 0.3855)	0.024
Asthma	0.8623	(0.8192, 0.9055)		0.7287	(0.6730, 0.7844)		0.2348	(0.1817, 0.2879)	
Physician gender									
Female	0.7351	(0.6820, 0.7881)	0.464	0.5784	(0.5190, 0.6377)	0.123	0.2724	(0.2189, 0.3259)	0.662
Male	0.7054	(0.6454, 0.7653)		0.5089	(0.4432, 0.5747)		0.2902	(0.2305, 0.3499)	
Patient gender									
Female	0.7226	(0.6792, 0.7661)	0.904	0.5231	(0.4746, 0.5716)	0.018	0.3139	(0.2688, 0.3589)	<0.001
Male	0.7160	(0.6170, 0.8151)		0.6667	(0.5631, 0.7702)		0.1111	(0.0421, 0.1801)	
Physician age									
Junior	0.6842	(0.6099, 0.7585)	0.217	0.5066	(0.4266, 0.5865)	0.231	0.3026	(0.2292, 0.3761)	0.465
Senior	0.7382	(0.6913, 0.7851)		0.5647	(0.5118, 0.6176)		0.2706	(0.2232, 0.3180)	
N	492			492			492		

Note: The presence of overuse was coded 1 and the absence was 0. Therefore, the mean denotes the overuse rate in this study. The Chi-square test was used to examine statistical significance.

Panel B

| | Unnecessary items | | | Unnecessary tests | | | Unnecessary drugs | | |
	Mean	S.D.	p-value	Mean	S.D.	p-value	Mean	S.D.	p-value
Overall	1.879	1.060	[1, 7]	1.662	0.877	[1, 6]	1.594	0.761	[1, 5]

Public vs. Private									
Public hospitals	1.855	1.063	0.342	1.614	0.817	0.057	1.607	0.767	0.600
Private hospitals	2.000	1.043		1.878	1.092		1.500	0.730	
Physician competence									
Low competence	1.888	1.103	0.835	1.653	0.887	0.831	1.753	0.861	0.005
High competence	1.864	0.987		1.677	0.864		1.393	0.556	
Case									
Unstable angina	1.796	1.075	0.228	1.719	1.033	0.452	1.275	0.449	<0.001
Asthma	1.934	1.049		1.633	0.790		2.034	0.878	
Physician gender									
Female physician	1.888	1.106	0.852	1.677	0.852	0.733	1.534	0.783	0.328
Male physician	1.867	1.004		1.640	0.913		1.662	0.735	
Patient gender									
Female patient	1.838	1.034	0.104	1.609	0.846	0.050	1.550	0.718	0.010
Male patient	2.086	1.174		1.870	0.972		2.222	1.093	
Physician age									
Junior	1.885	1.117	0.948	1.740	0.979	0.353	1.348	0.482	0.007
Senior	1.876	1.038		1.630	0.834		1.717	0.843	

Note: [x, y] indicates the range of the variable from its minimum x to its maximum y. Analysis of variance (ANOVA) was used for continuous variables.

Table S3 Adjusted association using regressions

	(1) Overuse	(2) Overuse of tests	(3) Overuse of drugs	(4) Unnecessary items	(5) Unnecessary tests	(6) Unnecessary drugs
Male patient	-0.001	0.106*	-0.199***	0.232	0.368***	-0.211
	[-0.110, 0.108]	[-0.019, 0.232]	[-0.328, -0.070]	[-0.050, 0.514]	[0.121, 0.614]	[-0.775, 0.352]
Male physician	-0.004	-0.048	0.041	-0.045	0.013	0.046
	[-0.076, 0.068]	[-0.141, 0.044]	[-0.034, 0.115]	[-0.300, 0.210]	[-0.242, 0.267]	[-0.163, 0.255]
Private hospital	0.040	0.104*	-0.089*	0.206	0.372***	-0.075
	[-0.064, 0.144]	[-0.011, 0.219]	[-0.195, 0.016]	[-0.057, 0.470]	[0.102, 0.642]	[-0.393, 0.243]
High competence	-0.077*	-0.068	0.030	0.014	-0.038	-0.085
	[-0.164, 0.011]	[-0.159, 0.024]	[-0.071, 0.132]	[-0.206, 0.234]	[-0.261, 0.186]	[-0.347, 0.177]
Senior physician	0.011	0.007	-0.031	-0.080	-0.136	0.134
	[-0.078, 0.100]	[-0.108, 0.122]	[-0.101, 0.039]	[-0.315, 0.154]	[-0.379, 0.107]	[-0.094, 0.362]
Asthma	0.242***	0.297***	-0.043	0.170	-0.104	0.686***
	[0.162, 0.321]	[0.220, 0.373]	[-0.138, 0.051]	[-0.072, 0.412]	[-0.358, 0.150]	[0.417, 0.955]
N	491	491	491	355	269	138
LR test of alpha=0				1.00	1.00	1.00

Note: Logistic and negative binomial regressions were performed by adjusting for day of week, month, year, and county fixed effect. The table reports marginal effects and 95% confidence intervals in brackets. We also report the p-value of the *LR test of alpha=0* to test for the presence of over-dispersion. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table S4 Distribution of health care expenditure

Medical expenditure (CNY)	Overall		Non-overuse group		Overuse group		P-value
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
By total overuse							
Total cost	35.00	41.26	11.43	19.24	44.10	43.84	<0.001
Test cost	19.09	29.04	7.51	7.49	23.56	32.81	<0.001
Drug cost	15.21	29.26	3.40	13.49	19.77	32.28	<0.001
By overuse of tests							
Total cost	35.00	41.26	28.23	35.74	40.61	44.63	<0.001
Test cost	19.09	29.04	7.37	7.38	28.80	35.94	<0.001
Drug cost	15.21	29.26	19.77	30.71	11.43	27.47	0.002
By overuse of drugs							
Total cost	35.00	41.26	24.61	33.77	61.64	46.59	<0.001
Test cost	19.09	29.04	21.66	31.67	12.47	19.44	0.002
Drug cost	15.21	29.26	2.50	11.01	47.81	35.59	<0.001

Note: Analysis of variance (ANOVA) was used for continuous variables to test the difference across the group of not having overuse and the group of having overuse.

Table S5 Financial impact of overuse

Panel A: Extensive margin using health care expenditure

	(1) Total cost	(2) Test cost	(3) Drug cost	(4) Total cost	(5) Test cost	(6) Drug cost	(7) Total cost	(8) Test cost	(9) Drug cost
Overuse	27.390*** [17.353,37.427]	14.319*** [6.968,21.669]	12.934*** [5.892,19.976]						
Overuse of tests				6.962 [-3.558,17.483]	16.725*** [10.320,23.131]	-8.704** [-15.268,-2.141]			
Overuse of drugs							39.416*** [29.015,49.817]	-5.079* [-10.920,0.761]	43.007*** [35.470,50.544]
N	492	492	492	492	492	492	492	492	492
Adjusted R^2	0.30	0.32	0.23	0.23	0.34	0.22	0.36	0.28	0.52

Panel B: Extensive margin using log of health care expenditure

	(1) Total cost	(2) Test cost	(3) Drug cost	(4) Total cost	(5) Test cost	(6) Drug cost	(7) Total cost	(8) Test cost	(9) Drug cost
Overuse	1.178*** [0.739,1.617]	0.588*** [0.201,0.976]	1.003*** [0.570,1.437]						
Overuse of tests				0.145 [-0.276,0.565]	0.720*** [0.390,1.050]	-0.667*** [-1.043,-0.291]			
Overuse of drugs							1.631*** [1.202,2.060]	-0.284 [-0.737,0.168]	3.071*** [2.736,3.406]
N	492	492	492	492	492	492	492	492	492
Adjusted R^2	0.33	0.26	0.27	0.25	0.27	0.25	0.38	0.24	0.67

Panel C: Intensive margin using health care expenditure

	(1) Total cost	(2) Test cost	(3) Drug cost	(4) Total cost	(5) Test cost	(6) Drug cost	(7) Total cost	(8) Test cost	(9) Drug cost
Unnecessary items	10.751*** [4.576, 16.926]	3.403* [-0.167, 6.972]	7.497*** [2.495, 12.499]						
Unnecessary tests				4.682 [-4.661, 14.024]	5.711* [-0.763, 12.184]	-1.108 [-7.707, 5.490]			
Unnecessary drugs							16.115* [-0.511, 32.741]	7.990* [-1.098, 17.078]	10.313* [-0.576, 21.203]
N	355	355	355	269	269	269	138	138	138
Adjusted R^2	0.33	0.37	0.30	0.29	0.33	0.12	0.29	0.10	0.39

Panel D: Intensive margin using log health care expenditure

|	(1) Total cost	(2) Test cost	(3) Drug cost	(4) Total cost	(5) Test cost	(6) Drug cost	(7) Total cost	(8) Test cost	(9) Drug cost
Unnecessary items	0.209** [0.031, 0.386]	0.031 [-0.187, 0.249]	0.383*** [0.180, 0.586]						
Unnecessary tests				0.023 [-0.339, 0.384]	0.163 [-0.150, 0.476]	-0.121 [-0.440, 0.198]			
Unnecessary drugs							0.205 [-0.241, 0.650]	0.234 [-0.250, 0.717]	0.132 [-0.317, 0.581]
N	355	355	355	269	269	269	138	138	138
Adjusted R^2	0.30	0.26	0.34	0.36	0.25	0.18	0.23	0.36	0.41

Note: Covariates include physician gender and age. County, hospital, day of week, year, case, and patient fixed effect were controlled for in the regression. Robust standard errors were clustered at the community health centre level; 95% confidence intervals in brackets; *10% significance level. **5% significance level. ***1% significance level.

Table S6 Predicting the probability of correct diagnosis

	(1) dy/dx	95% CI
Male physician	-0.046	[-0.161, 0.069]
Visit time		
21049.day	0.060	[-0.243, 0.362]
21052.day	0.215	[-0.089, 0.520]
21053.day	0.093	[-0.259, 0.445]
21054.day	-0.040	[-0.228, 0.149]
21055.day	0.092	[-0.209, 0.394]
21056.day	0.114	[-0.244, 0.471]
21057.day	-0.041	[-0.540, 0.458]
21059.day	0.000	[0.000, 0.000]
21395.day	-0.166	[-0.435, 0.102]
21396.day	-0.058	[-0.343, 0.226]
21397.day	0.137	[-0.157, 0.431]
21398.day	-0.150	[-0.563, 0.264]
21399.day	0.015	[-0.347, 0.377]
21402.day	-0.258***	[-0.427, -0.089]
21403.day	0.008	[-0.262, 0.279]
21404.day	0.081	[-0.268, 0.430]
21405.day	-0.186	[-0.537, 0.164]
21406.day	-0.027	[-0.568, 0.513]
SP ID		
2.spcode1	-0.106	[-0.402, 0.191]
3.spcode1	0.007	[-0.248, 0.263]
4.spcode1	-0.162	[-0.383, 0.060]
5.spcode1	-0.088	[-0.293, 0.117]
6.spcode1	-0.422***	[-0.626, -0.218]
7.spcode1	-0.596***	[-0.768, -0.424]
8.spcode1	-0.425***	[-0.655, -0.196]
9.spcode1	-0.361***	[-0.576, -0.145]
10.spcode1	-0.453***	[-0.601, -0.305]
12.spcode1	-0.138	[-0.379, 0.103]
18.spcode1	-0.420***	[-0.600, -0.240]
N	481	
Pseudo R^2	0.296	

Note: County, hospital and case fixed effects were controlled for in the regression. Robust standard errors were clustered at the community health centre level; 6 SPs participated in our survey both in 2017 and 2018, and thus we have 12 unique SP IDs controlled for in the regression models; 95% confidence intervals in brackets; *10% significance level. **5% significance level. ***1% significance level.

Figure S1 Physician competence and health care expenditure
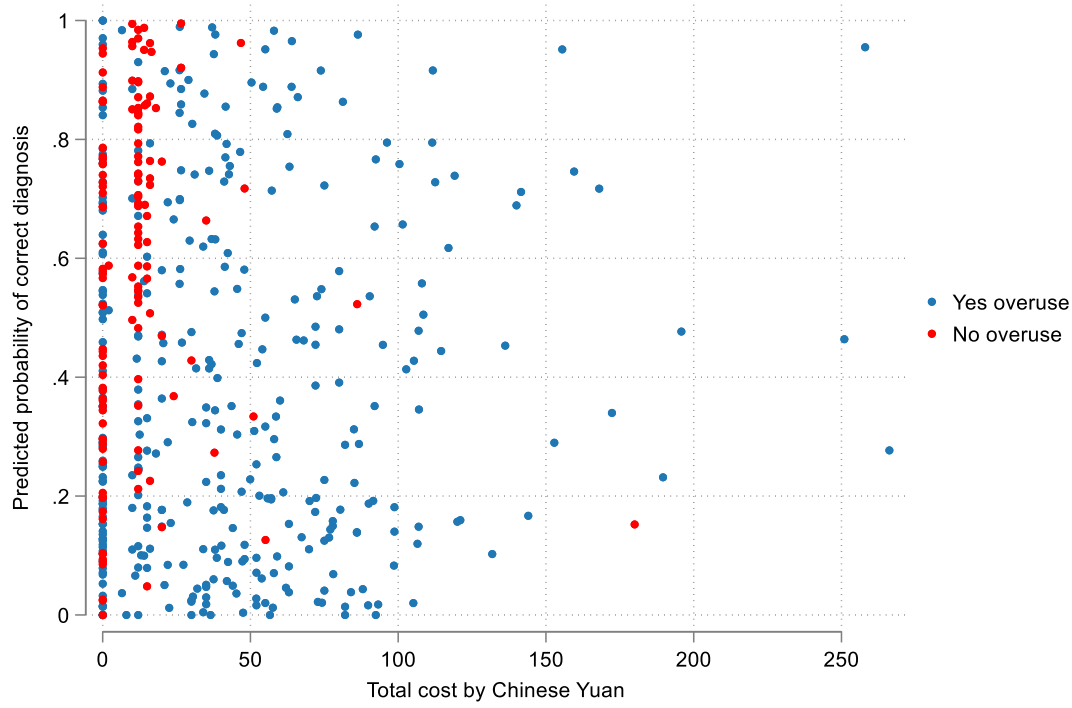
Note: The predicted probability of correct diagnosis was estimated using a logistic regression.