

# Keeping Up With Guideline Recommendations: Does Patient Volume Matter in Diabetes Care?

Yi-Chun Chen, MS; Shou-Hsia Cheng, PhD; and Chi-Chen Chen, PhD

The association between service volume and health care outcomes was first presented by Luft and colleagues in 1979.<sup>1</sup> Many empirical studies have supported the positive association between higher service volume and better health care outcomes, especially for surgical procedures performed in hospitals.<sup>1-5</sup> In 1989, a study on the association between nonsurgical service volume and quality of care emerged.<sup>6</sup> The majority of outcome variables in previous studies were measured by mortality.

Along with the development of evidence-based medicine in the 1990s, clinical practice guidelines for specific diagnoses or procedures have been proposed.<sup>7</sup> Adherence to guideline recommendations has been regarded as a measure of quality of care<sup>8</sup> and has been incorporated into volume-outcome research as an outcome measure.<sup>9</sup> For example, guideline adherence has been employed in volume-outcome studies for pneumonia, diabetes, myocardial infarction, and sepsis.<sup>9-13</sup> Unfortunately, there are no consistent findings about the association between service volume and guideline adherence for nonsurgical services.<sup>5,10-19</sup>

For diabetes care, in the past decade, 6 studies investigated the association between service volume and guideline adherence; 3 of them showed a positive association,<sup>10,14,19</sup> whereas the other 3 did not.<sup>11,15,18</sup> In addition, glycemic level control by prescribed medication is one of the critical tasks of diabetes care. Previous studies did not explore the relationship between physicians' patient volume and the likelihood of prescribing guideline-recommended antihyperglycemic agents.

Metformin was recommended as the preferred initial pharmacologic agent for the treatment of type 2 diabetes in the 2005 International Diabetes Federation (IDF) Global Guideline for type 2 diabetes.<sup>20</sup> In 2006, the American Diabetes Association (ADA) and the European Association for the Study of Diabetes recommended metformin as the initial antidiabetic intervention in their Consensus Statement for Management of Hyperglycemia in Type 2 Diabetes.<sup>21</sup> These 2 guidelines are the main references for Taiwanese doctors in treating diabetes.

The introduction of a new clinical guideline is regarded as an innovation in medical care.<sup>22,23</sup> The current study employed

## ABSTRACT

**OBJECTIVES:** To examine the association between service volume and guideline adherence via multiyear observations.

**STUDY DESIGN:** Repeated cross-sectional study.

**METHODS:** This study employed nationwide claims data from Taiwan's National Health Insurance scheme and identified patients with newly diagnosed type 2 diabetes from 2001, 2005, and 2009; a new prescription guideline for diabetes care was introduced in 2006. Physician service volume was measured by the number of total outpatients with diabetes. The outcome variable indicated whether a patient was receiving metformin, the guideline-recommended antihyperglycemic agent, at the index date.

**RESULTS:** Patients visiting physicians who had high or medium volumes of patients with diabetes were more likely to receive metformin than patients visiting physicians who had low volumes; the odds ratios (ORs) were 2.48 [95% CI, 2.03-3.04] and 1.76 [95% CI, 1.45-2.13], respectively. Patients with newly diagnosed diabetes in 2009 and 2005 were more likely to receive metformin than their counterparts in 2001, with ORs of 12.00 [95% CI, 11.19-12.86] and 2.44 [95% CI, 2.30-2.59], respectively. We also found that patients who visited younger physicians, physicians with fewer practice years, physicians practicing in large-scale hospitals, or physicians practicing in urban areas were more likely to receive metformin than their counterparts.

**CONCLUSIONS:** In the process of implementing a new practice guideline for treating patients with diabetes, physicians with higher patient volumes are more likely to adhere to the guideline recommendation.

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multiple years of data (2001, 2005, 2009) with a repeated cross-sectional design to examine the relationship between patient volume and guideline adherence in the process of diffusion of a new practice guideline in Taiwan.

## MATERIALS AND METHODS

### Study Design

To minimize the influence of patients' health-related confounders and to control physician factors other than physicians' service volume related to the patients' receipt of guideline-recommended services, we conducted a repeated cross-sectional study to explore the association between physicians' patient volume and the likelihood that the patients with newly diagnosed diabetes received the guideline-recommended initial antihyperglycemic agent.

### Data Sources

We used Taiwan's National Health Insurance (NHI) claims data obtained from the National Health Research Institutes of Taiwan. The NHI scheme is a universal social insurance that covers all residents in Taiwan. Nearly 93% of health care providers are contracted with the NHI. There were 2 major databases used in this study: the Longitudinal Cohort of Diabetes Patients (LHDP) and a diabetes-specific NHI claims database. In the LHDP database, nationally representative patients with newly diagnosed diabetes were identified annually from 1999 to 2010. Diabetes-specific NHI claims data contained all claim records with diabetes diagnosis or antihyperglycemic agents from 1999 to 2010. These 2 databases consisted of records of the patients' detailed information, such as outpatient visits, hospital admissions, medications, and laboratory tests. Other NHI databases used in the study included the registry of beneficiaries, the registry of contracted medical facilities, the registry for medical personnel, and the registry for board-certified specialists. According to the privacy protection requirement, the identification numbers of the participants were scrambled and could not be identified by the researchers. Information concerning geographic regions came from the Population of Townships and Districts in the Monthly Bulletin of Interior Statistics. This study was approved by the Institutional Review Board of National Taiwan University Hospital (201312029w).

### Study Population

The LHDP database consists of subjects who first received a diagnosis of type 2 diabetes (*International Classification of Diseases, Ninth Revision, Clinical Modification* code 250.x0 or 250.x2 [excluding type 1 diabetes code 250.x1 or 250.x3]) every year, and this study selected subjects in the 2001, 2005, and 2009 cohorts for analysis. Study subjects were eligible for inclusion if they (1) were at least 18 years old on the index date (the date the first diabetes diagnosis code appeared

## TAKEAWAY POINTS

- ▶ This study suggests that in the process of diffusion of a new practice guideline for treating patients with new-onset diabetes, physicians with higher patient volumes are more likely to adhere to the new guideline recommendation.
- ▶ This study also found that younger physicians practicing in large-scale institutions or urban areas are more likely to adhere to new practice guidelines.
- ▶ To facilitate the diffusion of new practice guidelines, policy makers should develop strategies that promote the distribution of new guideline information to older physicians and those practicing in rural and small-scaled institutions.

in the NHI claims data); (2) received a single oral antihyperglycemic agent, either metformin or another antihyperglycemic agent, at the index date; and (3) had no insulin prescription at the index date. The observation period for this study spanned 1 year after the index date for each patient. A total of 73,234 patients were included in the analysis (24,115 patients in 2001; 24,505 patients in 2005; and 24,614 patients in 2009).

### Variables of Interest

**Dependent variable.** The main dependent variable is whether the newly diagnosed patient received metformin, which was the 2006 guideline-recommended medicine in Taiwan, as the antihyperglycemic agent at the index date. Additionally, we included the test of glycated hemoglobin (A1C) as another dependent variable, which was listed in the guideline before 2000.<sup>24</sup> We defined a patient as receiving guideline-recommended regular A1C testing if they received the test at least 2 times in the year after the index date.<sup>25-33</sup>

**Independent variable.** The main independent variable was a physician's service volume, measured by the number of total outpatients with diabetes for each physician every year. The service volume was categorized into 3 groups: low (bottom one-third), medium (middle one-third), and high (top one-third). This study included 2 dummy variables to represent the time fixed effect (year 2005 and year 2009), with 2001 as the reference group. The time fixed effect was used to observe the adoption trend of the IDF/ADA guideline recommendation over time.

### Covariates

Several confounding factors were incorporated in the regression models. These variables included characteristics of the health care providers and patients. The characteristics of the physicians were gender, age group (< 35, 35-44, 45-54, and ≥ 55 years), practice years (< 1, 1-4, 5-9, and ≥ 10 years), specialty (endocrinologist and nonendocrinologist), accreditation level of the practicing institution (medical center hospital, regional hospital, district hospital, and community clinic) and location (rural vs urban area) of the practicing institution. Rural-urban status was classified according to the population density of the zip code of the practice location. The zip codes in the bottom two-thirds of the population density (approximately 30% of total population) in Taiwan were defined as rural areas in this study. In the regression model, we

also incorporated interaction terms of the practice location and physician service volume to examine the heterogeneous effects of physician service volume on metformin receipt and regular A1C tests between urban and rural area.

The characteristics of the study patients included in the analysis were sex, age group (18-44, 45-54, 55-64, and  $\geq 65$  years), income level, and modified Charlson Comorbidity Index (CCI) score. The income levels of subjects were calculated according to their NHI enrollment status and premium collected. For those who were self-employed or employees, the NHI enrollment premium equaled their reported salaries. For veterans and their families, the premium was estimated by the retirement pension provided by the Veterans Affairs Council. For subjects in other NHI enrollment categories, the premium was estimated by the average income of the cities/counties in which they lived. The income level, approximated by the NHI premium, was divided into low and high groups with a cutoff point at the 18th group from the NHI Payroll Bracket, approximately NT\$34,800. The modified CCI scores were included as a confounding factor,<sup>34,35</sup> which was calculated based on D'Hoore's method<sup>36</sup> and was divided into 3 groups (0, 1, and  $\geq 2$ ). To ensure the accuracy of a patient's chronic condition status, only those diagnoses appearing at least 3 times in a patient's annual claims record after the initial visit were included in the calculation of the CCI score.

### Statistical Analysis

As certain potentially unobserved characteristics of health care providers could affect the choice of the initial oral glucose-lowering agent, such as the physician's practice style, a random intercept logistic regression model was used to investigate the association between physicians' patient volumes and their patients' receipt of guideline-recommended services while considering the effects of patient clustering according to the diabetes care physician. For the random intercept effect, we calculated the intraclass correlation coefficient, which represents the proportion of variance accounted for by the physician level. The unit of analysis was patients. The analyses were performed by using Stata version 14.2 (StataCorp LLC).

## RESULTS

In the 3 study years, 2001, 2005, and 2009, the number of patients with newly diagnosed type 2 diabetes taking 1 oral antihyperglycemic agent increased steadily from 24,115 to 24,614 (Table 1). Men accounted for 52.5% to 53.6% of the study subjects, and patients 55 years and older accounted for more than half of the study subjects. Approximately 73.9% to 76.9% of the patients had no comorbidities at the index visit.

Table 1 also shows the characteristics of the physicians who provided services to the study subjects at the index visits. A total of 6558, 7227, and 7445 physicians were identified in 2001, 2005, and 2009, respectively. In 2001, the majority of physicians were approximately 35 to 54 years old and had practiced for less than 5 years. In the 3 study years, most of the physicians practiced in

community clinics (45.7%, 51.8%, and 51.3%, respectively), and only a small number of physicians had specialty training in endocrinology, ranging from 0.4% to 1.7%.

For patients with newly diagnosed diabetes with oral antihyperglycemic agents, the overall percentage receiving metformin for treatment at the index visit was 22.1%, 34.7%, and 60.0% in 2001, 2005, and 2009, respectively. Patients visiting physicians with a higher diabetes patient volume were more likely to receive metformin compared with their counterparts in the 3 study years (Figure). For example, in 2009, 68.0% of the patients who visited physicians with high diabetes patient volumes received metformin, whereas 46.6% of the patients who visited physicians with low diabetes patient volumes received metformin. In addition, the Figure shows that patients visiting physicians practicing in urban areas were consistently more likely to receive metformin than their counterparts in rural areas in the 3 years.

Similarly, the overall probability of patients with newly diagnosed diabetes to receive guideline-recommended A1C tests gradually increased from 2001 to 2009. Patients who visited physicians with a higher diabetes patient volume were more likely to receive regular A1C tests compared with their counterparts in the 3 study years. Patients who visited physicians practicing in urban areas were more likely to receive A1C tests than their counterparts in rural areas in the 3 years.

Table 2 shows the bivariate association between the characteristics of the physicians and patients and the likelihood of receiving metformin or A1C tests. We observed that patients visiting physicians with high or medium service volume were more likely to receive metformin at the index visit than patients visiting physicians with low service volume (45.3%, 34.6%, and 29.5%, respectively). Patients visiting physicians practicing in urban areas were more likely to receive metformin than those in rural areas (41.0% vs 32.8%). Other characteristics of the physicians associated with their patients' receipt of metformin were being female, age younger than 35 years, being an endocrinologist, and practicing in a medical center or regional hospital. On the other hand, patients who were female, were younger than 44 years, and had a high income level were also more likely to receive metformin than others.

The physicians' characteristics associated with their patients' receipt of guideline-recommended A1C tests were higher patient volume, practicing in urban area, being female, age younger than 35 years, being an endocrinologist, and practicing in a medical center or regional hospital. On the other hand, patients who were male, were younger than 64 years, had high income, and were without comorbidity were more likely to receive guideline-recommended A1C tests.

Table 3 shows the results of the random intercept logistic regression models. Patients visiting physicians with high or medium diabetes patient volume were more likely to receive metformin than patients visiting physicians with low diabetes patient volume after controlling for potential confounding factors; the odds ratios (ORs) were 2.48 (95% CI, 2.03-3.04) and 1.76 (95% CI, 1.45-2.13), respectively.

We also found that patients visiting physicians in urban areas were more likely to receive metformin than their counterparts in rural areas (OR, 1.67; 95% CI, 1.39-2.00). When using the rural–low volume group as the reference in the model, we found the regression coefficients of the 2 interaction terms were both negative and statistically significant (both ORs, 0.73). In addition, compared with patients visiting older physicians ( $\geq 55$  years), patients visiting younger physicians were more likely to receive metformin at the index visit, with ORs ranging from 1.13 (95% CI, 1.02-1.25) to 2.33 (95% CI, 2.02-2.70). Similarly, patients visiting physicians who had been practicing for 4 or fewer years were more likely to receive metformin than those patients visiting physicians who had been practicing for more than 10 years (OR, 1.18; 95% CI, 1.08-1.30).

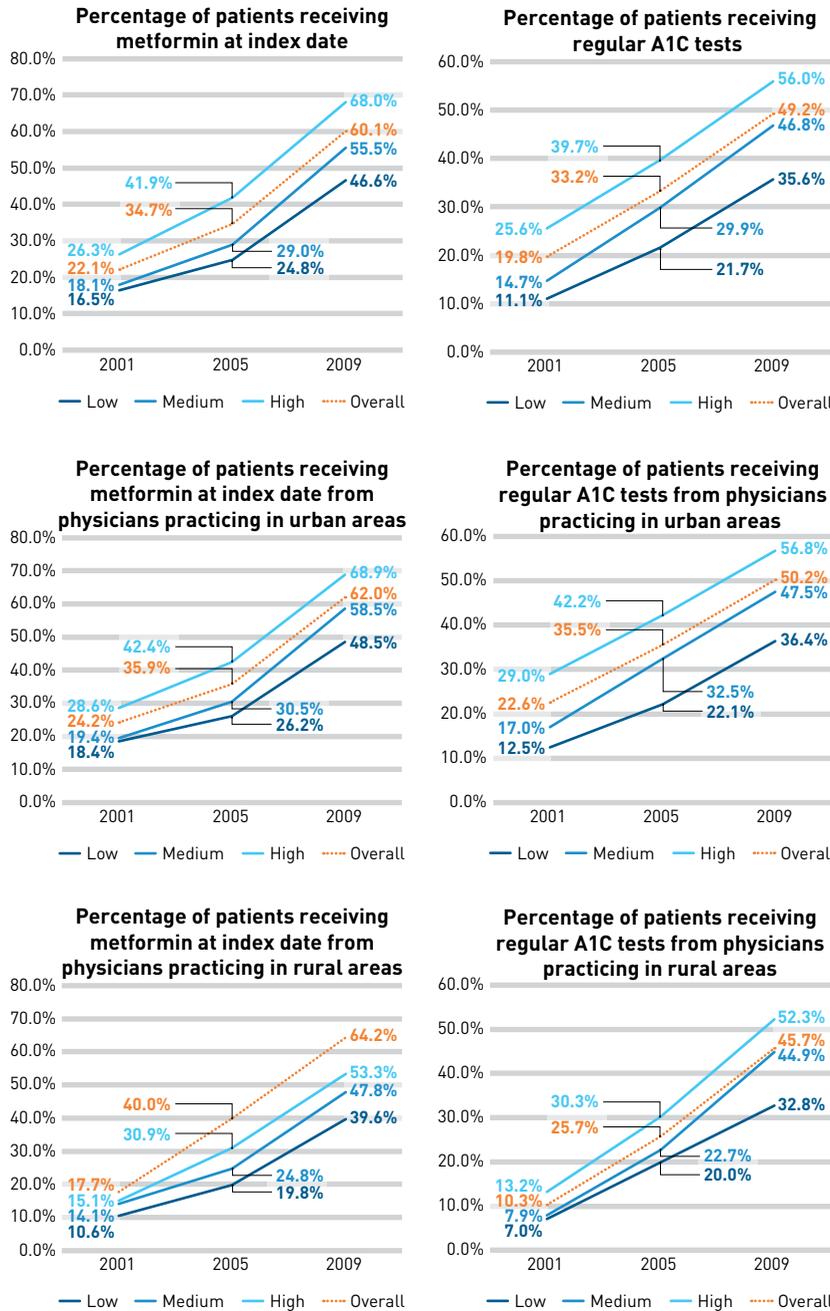
Regarding the level of health care institutions, compared with patients visiting physicians in community clinics, patients visiting physicians in district hospitals, regional hospitals, and medical center hospitals were more likely to receive metformin at the index visits, with ORs of 1.19 (95% CI, 1.07-1.33), 1.40 (95% CI, 1.26-1.55), and 1.53 (95% CI, 1.35-1.73), respectively. Finally, the year effect showed that patients with newly diagnosed diabetes in 2009 and 2005 were more likely to receive metformin than their counterparts in 2001, with ORs of 12.00 (95% CI, 11.19-12.86) and 2.44 (95% CI, 2.30-2.59), respectively.

The association between the characteristics of the physicians and the likelihood of patients' receiving guideline-recommended A1C tests was similar to the results of receiving metformin. For instance, patients visiting physicians with high and medium patient volume were more likely to receive regular A1C tests, with ORs of 1.65 (95% CI, 1.44-1.90) and 1.34 (95% CI, 1.17-1.54), respectively, compared with patients visiting low-volume physicians. Patients visiting physicians in urban areas were more likely to receive regular A1C tests than their counterparts in rural areas (OR, 1.22; 95% CI, 1.07-1.38). Finally, the year effect showed that patients with newly diagnosed diabetes in 2009 and 2005 were more likely to receive regular A1C tests than their counterparts in 2001, with ORs of 5.06 (95% CI, 4.80-5.33) and 2.36 (95% CI, 2.24-2.48), respectively (Table 3).

**TABLE 1.** Characteristics of the Patients and Their Physicians in This Study

	2001		2005		2009	
	n	%	n	%	n	%
<b>Physician characteristics</b>						
Total	6558	100.0	7227	100.0	7445	100.0
Diabetes patient volume						
Low	2162	33.0	2384	33.0	2445	32.8
Medium	2208	33.7	2413	33.4	2514	33.8
High	2188	33.4	2430	33.6	2486	33.4
Practice location						
Rural	1391	21.2	1628	22.5	1633	21.9
Urban	5167	78.8	5599	77.5	5812	78.1
Gender						
Male	6125	93.4	6615	91.5	6658	89.4
Female	433	6.6	612	8.5	787	10.6
Age group in years						
< 35	971	14.8	904	12.5	945	12.7
35-44	2979	45.4	2822	39.1	2379	32.0
45-54	1800	27.5	2267	31.4	2594	34.8
$\geq 55$	808	12.3	1234	17.1	1527	20.5
Practice years						
< 1	1975	30.1	2206	30.5	1651	22.2
1-4	2267	34.6	1710	23.7	2103	28.3
5-9	1346	20.5	2036	28.2	1347	18.1
$\geq 10$	970	14.8	1275	17.6	2344	31.5
Specialty						
Endocrinologist	25	0.4	92	1.3	126	1.7
Nonendocrinologist	6533	99.6	7135	98.7	7319	98.3
Accreditation level of the practicing institution						
Medical center hospital	1051	16.0	1010	14.0	1089	14.6
Regional hospital	1264	19.3	1309	18.1	1549	20.8
District hospital	1248	19.0	1167	16.2	988	13.3
Community clinic	2995	45.7	3741	51.8	3819	51.3
<b>Patient characteristics</b>						
Total	24,115	100.0	24,505	100.0	24,614	100.0
Gender						
Male	12,648	52.5	12,930	52.8	13,204	53.6
Female	11,467	47.6	11,575	47.2	11,410	46.4
Age group in years						
$\leq 44$	4332	17.9	4490	18.3	4237	17.2
45-54	6843	28.4	7005	28.6	7098	28.8
55-64	5872	24.4	6080	24.8	6544	26.6
$\geq 65$	7078	29.4	6930	28.3	6735	27.4
Income level						
Low	18,871	78.3	19,382	79.1	19,183	77.9
High	4421	18.3	4875	19.9	5258	21.4
Missing	823	3.4	248	1.0	173	0.7
Charlson Comorbidity Index score						
0	17,812	73.9	18,680	76.2	18,927	76.9
1	4767	19.8	4402	18.0	4116	16.7
$\geq 2$	1536	6.4	1423	5.8	1571	6.4

**FIGURE.** Likelihood of Patients With New-Onset Type 2 Diabetes Receiving Guideline-Recommended Services in the 3 Study Years by Urban and Rural Areas



A1C, glycated hemoglobin.

## DISCUSSION

The majority of previous studies investigating the volume-outcome relationship used a cross-sectional design; the present study employed a multiyear observational design to examine the volume-outcome relationship while considering the diffusion of new practice guidelines for treating patients with new-onset diabetes.

We examined the guideline-recommended antihyperglycemic agent and regular A1C testing in the analysis. Findings from this study showed that a higher service volume was associated with a higher probability of patients receiving guideline-recommended services for both initial antihyperglycemic agents and regular A1C tests. This positive finding is consistent with those of several previous studies on diabetes care.<sup>10,19</sup> We suggest that physicians who see a larger number of patients with diabetes are more attentive to guideline updates and are more willing to adhere to the new guideline recommendations.

The likelihood of patients receiving guideline-recommended services was associated with not only physicians' diabetes patient volume but also the physicians' practice locations, ages, practice years, and practice institutions. Patients visiting physicians practicing in urban areas were more likely to receive guideline-recommended services than in rural areas. Patients visiting younger physicians and physicians who practice at large-scale teaching hospitals were more likely to receive guideline-recommended services.

According to diffusion of innovations theory, "motivations and time of adoption can be predicted by each adopter's structural position in the network of advice-seeking and advice-giving relationships that tie a social system." Additionally, "resource-rich communities with greater concentrations of professionals exhibit greater capacity to acquire and make use of innovations."<sup>37</sup> These interpretation might explain our findings: We believe that physicians practicing in urban areas or in large-scale teaching hospitals were more likely to receive the most updated guideline information than their counterparts in rural areas or at small institutions. Similarly, junior physicians might have just finished their training in teaching hospitals; they may have been more likely to learn the most updated guideline information than senior physicians.

Another interesting finding was the negative effect of the interaction terms of the service volume and practice location on patients' receipt of metformin. This means that the effect of service volume on patients' receipt of metformin is less influential in urban areas than in rural areas, given that the overall metformin receipt rate was higher in urban areas. We suggest that the innovation information (guideline revision) reached urban clinicians faster

**TABLE 2.** Factors Associated With Patients Receiving Guideline-Recommended Services (N=73,234)

	Receiving metformin		Receiving other single oral antihyperglycemic agent		P	Receiving regular A1C tests				P
	n	%	n	%		Yes		No		
						n	%	n	%	
<b>Physician characteristics</b>										
Diabetes patient volume					<.001					<.001
Low	4250	29.5	10,159	70.5		3316	23.0	11,093	77.0	
Medium	7281	34.6	13,790	65.5		6484	30.8	14,587	69.2	
High	17,106	45.3	20,648	54.7		15,227	40.3	22,527	59.7	
Practice location					<.001					<.001
Rural	5448	32.8	11,154	67.2		4481	27.0	12,121	73.0	
Urban	23,189	41.0	33,443	59.1		20,546	36.3	36,086	63.7	
Gender					<.001					<.001
Male	25,461	38.0	41,468	62.0		22,088	33.0	44,841	67.0	
Female	3176	50.4	3129	49.6		2939	46.6	3366	53.4	
Age group in years					<.001					<.001
<35	4088	48.6	4319	51.4		3422	40.7	4985	59.3	
35-44	11,802	38.6	18,751	61.4		10,585	34.6	19,968	65.4	
45-54	9200	38.1	14,947	61.9		8151	33.7	16,023	66.3	
≥55	3547	35.1	6553	64.9		2869	28.4	7231	71.6	
Practice years					<.001					<.001
<1	7282	39.0	11,414	61.1		6349	34.0	12,347	66.0	
1-4	8283	38.8	13,080	61.2		7276	34.1	14,087	65.9	
5-9	6511	37.2	11,010	62.8		5730	32.7	11,791	67.3	
≥10	6561	41.9	9093	58.1		5672	36.2	9982	63.8	
Specialty					<.001					<.001
Endocrinologist	953	55.9	753	44.1		1037	60.8	669	39.2	
Nonendocrinologist	27,684	38.7	43,844	61.3		23,990	33.5	47,538	66.5	
Accreditation level of practicing hospital					<.001					<.001
Medical center	4875	47.5	5386	52.5		4669	45.5	5592	54.5	
Regional hospital	7383	48.1	7983	52.0		6343	41.3	9023	58.7	
District hospital	4619	36.7	7954	63.3		4359	34.7	8214	65.3	
Community clinic	11,760	33.6	23,274	66.4		9656	27.6	25,378	72.4	
<b>Patient characteristics</b>										
Gender					<.001					<.001
Male	14,459	37.3	24,323	62.7		13,601	35.1	25,181	64.9	
Female	14,178	41.2	20,274	58.9		11,426	33.2	23,026	66.8	
Age group in years					<.001					<.001
≤44	5659	43.4	7390	56.6		4546	34.8	8503	65.2	
45-54	8056	38.5	12,890	61.5		7673	36.6	13,273	63.4	
55-64	7183	38.8	11,313	61.2		6684	36.1	11,812	63.9	
≥65	7739	37.3	13,004	62.7		6124	29.5	14,619	70.5	
Income level <sup>a</sup>					<.001					<.001
Low	21,938	38.2	35,498	61.8		18,920	32.9	38,516	67.1	
High	6317	43.4	8237	56.6		5837	40.1	8717	59.9	
Charlson Comorbidity Index score					.224					.002
0	21,767	39.3	33,652	60.7		19,132	34.5	36,287	65.5	
1	5114	38.5	8171	61.5		4393	33.1	8892	66.9	
≥2	1756	38.8	2774	61.2		1502	33.2	3028	66.8	
Onset year					<.001					<.001
2001	5327	22.1	18,788	77.9		4763	19.8	19,352	80.3	
2005	8512	34.7	15,993	65.3		8144	33.2	16,361	66.8	
2009	14,798	60.1	9816	39.9		12,120	49.2	12,494	50.8	

A1C, glycated hemoglobin.

<sup>a</sup>Due to 1024 missing values, the variable "income level" left 71,990 valid counts.

**TABLE 3.** Factors Associated With Patients Receiving Guideline-Recommended Services in a Random Intercept Logistic Regression Model

	Receiving metformin			Receiving regular A1C tests		
	OR	95% CI	P	OR	95% CI	P
<b>Physician characteristics</b>						
Diabetes patient volume (reference: low)						
Medium	1.76	1.45-2.13	<.001	1.34	1.17-1.54	<.001
High	2.48	2.03-3.04	<.001	1.65	1.44-1.90	<.001
Practice location (reference: rural)						
Urban	1.67	1.39-2.00	<.001	1.22	1.07-1.38	.002
Diabetes patient volume*practice location (reference: low volume-rural)						
Medium volume-urban	0.73	0.59-0.91	.005	1.14	0.98-1.33	.097
High volume-urban	0.73	0.59-0.91	.005	1.09	0.94-1.27	.261
Gender (reference: male)						
Female	1.56	1.33-1.82	<.001	1.29	1.17-1.41	<.001
Age group in years (reference: ≥ 55)						
<35	2.33	2.02-2.70	<.001	1.59	1.44-1.76	<.001
35-44	1.44	1.29-1.62	<.001	1.31	1.21-1.41	<.001
45-54	1.13	1.02-1.25	.016	1.18	1.10-1.27	<.001
Practice years (reference: ≥ 10)						
< 1	1.18	1.07-1.30	.001	1.02	0.95-1.09	.649
1-4	1.18	1.08-1.30	<.001	0.99	0.92-1.05	.685
5-9	1.08	0.99-1.17	.075	0.97	0.91-1.04	.372
Specialty (reference: nonendocrinologist)						
Endocrinologist	1.06	0.86-1.30	.572	1.57	1.35-1.84	<.001
Accreditation level of practicing institution (reference: community clinic)						
Medical center hospital	1.53	1.35-1.73	<.001	1.67	1.54-1.81	<.001
Regional hospital	1.40	1.26-1.55	<.001	1.36	1.26-1.45	<.001
District hospital	1.19	1.07-1.33	.002	1.23	1.14-1.33	<.001
<b>Patient characteristics</b>						
Gender (reference: male)						
Female	1.34	1.28-1.40	<.001	1.02	0.99-1.06	.203
Age group in years (reference: ≥ 65)						
≤44	1.23	1.15-1.31	<.001	1.18	1.12-1.25	<.001
45-54	1.04	0.98-1.10	.194	1.35	1.29-1.42	<.001
55-64	1.00	0.94-1.06	.898	1.31	1.25-1.38	<.001
Income level (reference: low)						
High	1.14	1.08-1.20	<.001	1.19	1.14-1.24	<.001
Charlson Comorbidity Index score (reference: ≥ 2)						
0	1.08	0.98-1.18	.113	1.16	1.07-1.25	<.001
1	1.07	0.97-1.18	.193	1.07	0.99-1.17	.100
Onset year (reference: 2001)						
2005	2.44	2.30-2.59	<.001	2.36	2.24-2.48	<.001
2009	12.00	11.19-12.86	<.001	5.06	4.80-5.33	<.001

A1C, glycated hemoglobin; OR, odds ratio.

and easier than rural clinicians and thus might shorten the difference in the rates of prescribing metformin among the 3 service volume groups of physicians. On the other hand, the effect of the interaction terms of the service volume and practice location on patients' receipt of regular A1C tests was not statistically significant. The A1C test had been recommended by the ADA since 1989 and so was not "new" in diabetes care in the years addressed by our study; therefore, physicians' adoption of regular A1C tests might be less affected by practice location. In addition, receiving A1C tests depended not only on the physicians' adherence to guidelines but also on patient-side factors such as access to care or compliance.

Regarding the use of metformin for patients with new-onset diabetes in Taiwan, we found that the metformin receipt rate increased from 22.1% in 2001 to 34.7% in 2005. After the new practice guidelines were introduced in 2006, the metformin receipt rate increased to 60.0% in 2009. The guideline adoption seems to have been faster in Taiwan than in the United States.<sup>38-40</sup> One possible explanation is that the single payer in Taiwan (ie, the NHI) had implemented a pay-for-performance program for diabetes care since 2001 to promote adherence to practice guideline recommendations and more physicians had participated in the program over time.<sup>41</sup> In addition, compared with the United States, Taiwan is a small geographic area with a smaller number of physicians. We might expect that the dissemination of new guideline information would be faster and easier in Taiwan. At the individual level, the rate of metformin recipients increased more significantly in the physician groups with high and medium service volume than the group with low service volume. Physicians of younger age and with fewer practice years also had a greater increase in percentage of metformin recipients than older and senior physicians ([eAppendix](#) [available at [ajmc.com](#)]).

**Limitations**

Limitations of this study should be mentioned. The classification of rural-urban area according to population density might be arbitrary. Also, a physician practicing in an urban area might see patients from a nearby rural area. However, the possible misclassification may only weaken the

association between the patient's receipt of guideline-recommended services and the physician's practice location. Additionally, due to the features of the single-payer system in Taiwan, findings from this study might not be generalized to other health systems.

## CONCLUSIONS

This study suggests that in the process of diffusion of a new practice guideline for treating patients with new-onset diabetes, physicians with higher patient volumes are more likely to adhere to the new guideline recommendation. This study also found that younger physicians practicing in large-scale institutions and in urban areas are more likely to adhere to new practice guidelines. To facilitate the diffusion of new practice guidelines, policy makers should develop strategies that promote the distribution of new guideline information to older physicians and those practicing in rural and small-scaled institutions. ■

**Author Affiliations:** Department of Health Care Administration, Chang-Jung Christian University (YCC), Tainan, Taiwan; Institute of Health Policy and Management, College of Public Health (YCC, SHC), and Population Health Research Center (SHC), National Taiwan University, Taipei, Taiwan; Department of Public Health, College of Medicine, Fu Jen Catholic University (CCC), New Taipei City, Taiwan.

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**Address Correspondence to:** Shou-Hsia Cheng, PhD, National Taiwan University, 17 Xu-Zhou Rd, Taipei, Taiwan 100. Email: shcheng@ntu.edu.tw.

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**eAppendix.** Physicians' Characteristics and the Percentage of Their Patients Receiving Metformin by Year

	Receiving metformin				Change in percentage of metformin recipients from 2005 to 2009
	2005		2009		
	N	%	N	%	
DM patient volume					
Low	1219	24.8	2272	46.6	21.8
Medium	2043	29.0	4011	55.6	26.6
High	5250	41.9	8515	68.0	26.1
Practice location					
Rural	1745	30.9	2858	53.3	22.3
Urban	6767	35.9	11940	62.0	26.2
Gender					
Male	7605	33.9	13015	59.1	25.3
Female	907	44.6	1783	68.6	24.0
Age groups, years					
<35	1184	46.9	2032	76.5	29.6
35-44	3818	36.5	5209	63.0	26.5
45-54	2616	31.9	5292	57.0	25.1
55+	894	26.9	2265	51.5	24.6
Practice years					
<1	2496	36.9	3296	65.9	29.0
1-4	2150	36.1	4309	62.9	26.8
5-9	2401	32.4	2875	59.1	26.6
10+	1465	33.5	4318	54.7	21.2
Specialty					
Endocrinologist	242	37.9	579	69.5	31.6
Non-endocrinologist	8270	34.7	14219	59.8	25.1
Accreditation level of the practicing institution					
Medical center hospital	1473	45.2	2401	70.0	24.8
Regional hospital	2022	42.8	3854	67.9	25.1
District hospital	1530	35.8	2093	60.5	24.7
Community clinic	3487	28.5	6450	53.5	25.1