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Exploring geographic variation of and influencing factors for utilization of four diabetes management measures in Swiss population using claims data

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ABSTRACT

Introduction Four strongly recommended diabetes management measures are biannual glycated hemoglobin (HbA1c) testing, annual eye examination, kidney function examination, and low-density lipoprotein (LDL) testing in patients below 75 years. We aimed to describe regional variation in the utilization of the four measures across small regions in Switzerland and to explore potential influencing factors.

Research design and methods We conducted a cross-sectional study of adult patients with drug-treated diabetes in 2014 using claims data. Four binary outcomes represented adherence to the recommendations. Possible influencing factors included sociodemographics, health insurance preferences, and clinical characteristics. We performed multilevel modeling with Medstat regions as the higher level. We calculated the median odds ratio (MOR) and checked spatial autocorrelation in region level residuals using Moran's I statistic. When significant, we further conducted spatial multilevel modeling.

Results Of 49 198 patients with diabetes (33 957 below 75 years), 69.6% had biannual HbA1c testing, 44.3% each had annual eye examination and kidney function examination, and 55.5% of the patients below 75 years had annual LDL testing. The effects of health insurance preferences were substantial and consistent. Having any supplementary insurance (ORs across measures were between 1.08 and 1.28), having supplementary hospital care insurance (1.08–1.30), having chosen a lower deductible level (eg, SFr2500 compared with SFr300: 0.57–0.69), and having chosen a managed care model (1.04–1.17) were positively associated with recommendations adherence. The MORs (1.27–1.33) showed only moderate unexplained variation, and we observed inconsistent spatial patterns of unexplained variation across the four measures.

Conclusion Our findings indicate that the uptake of strongly recommended measures in diabetes management could possibly be optimized by providing further incentives to patients and care providers through insurance scheme design. The absence of marked regional variation implies limited potential for improvement by targeted regional intervention, while provider-specific promotion may be more impactful.

Significance of this study

What is already known about this subject?

- Better adherence to clinical guidelines and recommendations could increase clinical outcomes of patients with diabetes.
- Little is known about the utilization and its regional variation of recommended measures in diabetes management.

What are the new findings?

- In a healthcare system with mandatory health insurance, choosing a lower deductible level, choosing a managed care model, and having supplementary insurance were associated with better adherence.
- Unexplained variation after adjusting for possible influencing factors was not pronounced, and inconsistent spatial patterns were observed across different measures.

How might these results change the focus of research or clinical practice?

- The findings imply a potential to optimize the utilization of recommended healthcare services by providing further incentives through insurance scheme design.

INTRODUCTION

Diabetes is one of the most common chronic diseases. The global prevalence in adults over 18 years was 8.5% (around 422 million) in 2014, and deaths directly caused by diabetes were estimated at 1.6 million in 2016.[1] In Switzerland, an estimated 500 000 persons suffer from the condition, which is responsible for around 2% of all deaths.[2] Diabetes can be treated and its complications delayed through various measures, including constant medical care, restricted diet, physical activity, and regular screening.[3]

A variety of clinical guidelines on diabetes management have been developed nationally

and internationally to improve outcomes. The Swiss Society of Endocrinology and Diabetology (SGED) has developed "The criteria for good disease management of Diabetes in primary care" in 2013 and revised it in 2017.[4] The American Diabetes Association, the European Society of Cardiology, and the European Association for the Study of Diabetes report and annually adapt clinical guidelines on diabetes as well.[5 6] Some recommendations on diabetes management are crucial and consistently present in almost all clinical guidelines, for instance, biannual glycated hemoglobin (HbA1c) testing, annual eye examination, and low-density lipoprotein (LDL) testing. Studies have shown strong evidence that the complications of diabetes could be reduced through managing risk factors such as increased HbA1c, LDLs, and blood pressure.[7–9] It has also been reported that adherence to clinical guidelines had a positive influence on clinical outcomes including mortality and hospitalizations.[10–12]

In the present study, we used four strong standard recommendations included in most diabetes clinical guidelines, that is, patients with diabetes should undergo (1) at least two HbA1c tests per year, (2) at least one eye examination per year, (3) at least one kidney function examination per year, and (4) at least one LDL test per year (only in patients below 75 years). One study in Switzerland using health insurance claims data for the years 2011–2013 reported overall adherence to these recommendations but did not perform an in-depth assessment of drivers of utilization or geographic variation.[13] Generally, few studies have investigated the adherence to clinical recommendations on diabetes management.

Various factors may affect the utilization of healthcare services for diabetes, including characteristics of patients, healthcare providers, health insurance, and regions. This could result in geographic variation in utilization. Such variation in utilization may be unwarranted, which would to some extent reflect unequal access.[14] The four diabetes recommendations are clear and based on high-quality evidence, and the corresponding management measures are not preference sensitive.[15] Moreover, access to healthcare in general and the four measures in particular is very good in Switzerland. Therefore, we expected little unexplained variation after adjusting for possible influencing factors in the present case.[16]

The aims of this study were to (1) investigate the utilization levels of the above-defined strongly recommended measure in diabetes management, (2) explore potential factors influencing utilization, and (3) assess the regional variation in utilization of the four measures across small regions in Switzerland.

MATERIALS AND METHODS

Study population

We used health insurance claims data provided by the Helsana Group, one of the largest health insurance companies in Switzerland. The Helsana database underlying this study included mandatory health insurance claims from around 1.2 million people, covering 15% of the Swiss population. Adults (older than 18 years) enrolled with Helsana who were prescribed any diabetes medication (the Anatomical Therapeutic Chemical code was used to identify diabetes medications) between January 1, 2014 and December 27, 2014 were analyzed. We excluded enrollees with incomplete insurance coverage in 2014 or not surviving until the end of 2014, patients living outside Switzerland, asylum seekers, Helsana employees, patients with incomplete address information, and patients living in nursing homes with lump-sum reimbursement. Since diagnosis information was not available for outpatient services, we could not distinguish between type 1 and type 2 diabetes.

Basic health insurance (covering a federally defined benefit package) is mandatory in Switzerland and private insurance companies are obliged to offer it to anyone irrespective of their health status. Mandatory health insurance includes appropriate and cost-effective inpatient and outpatient health services. A variety of annual deductibles (300–2500 Swiss Francs (SFr)) can be chosen, and selecting a higher deductible leads to a lower premium. Enrollees can also choose between standard and managed care models, where the latter require a specific general practitioner or telemedicine provider as the first contact when a new health problem arises, hence are cheaper.[17 18] In addition to mandatory health insurance, a variety of supplementary health insurance products can be bought, for instance, supplementary hospital care insurance which allows for hospitalization in semiprivate/private wards.[17]

Outcome and explanatory variables

We differentiated the participants according to whether they received diabetes medication between January 5, 2013 and December 31, 2013 (prevalent cases if they received it, incident cases if they did not). The date of the first prescription of any diabetes medication in 2014 (incident cases) or January 1, 2014 (prevalent cases) was considered as the index date for each participant. The following 360 days were regarded as the assessment period, which was used to define if the recommendations were being adhered to.

We defined binary outcome variables for the four measures under study: in the assessment period, (1) at least two HbA1c tests, (2) at least one eye examination (ophthalmologist visit was used as a proxy of eye examination), (3) at least one kidney function examination (ie, serum creatinine and/or albuminuria test), and (4) at least one LDL test (or total cholesterol+high-density lipoprotein (HDL)+triglycerides test) for patients below 75 years.[19]

The explanatory variables included (1) sociodemographics, including age, gender, language region, purchasing power index per household, and urban/rural residence; (2) health insurance preferences, including having both mandatory and supplementary insurance, having supplementary hospital care insurance, standard

or managed care model, and choice of annual deductible; and (3) clinical characteristics, including number of comorbidities (pharmaceutical cost groups were used to deduce chronic morbidity based on drug use)[20] and incident or prevalent diabetes treated with oral medication or insulin. In addition, a region-level variable—ophthalmologist density per 10 000 inhabitants—was used specifically for the study of eye examinations.

Geographic unit

We used Medstat regions as the geographic units for regional variation analysis. Medstat regions (n=705) are defined by the Swiss Federal Statistical Office to reflect hospital catchment areas in a way that they are large enough to provide anonymity for each person hospitalized in Switzerland.[21] Each patient's residence was assigned to the corresponding Medstat region in the claims data.

Statistical analysis

First, we performed a descriptive analysis of study population's characteristics. We distinguished between all eligible patients and the subpopulation below 75 years, relevant for the assessment of LDL testing.

Second, we mapped out the raw utilization rates of the four measures across Medstat regions to show their geographic distribution. We checked spatial autocorrelation of regional utilization rates by computing the global Moran's I statistic.[22] Moran's I measures the correlation of a variable with itself through space, with a value range from −1 to 1. Moran's I values very close to 0 suggest the studied variable is randomly distributed through space. If Moran's I is positive with p value <0.05, it indicates that neighboring regions are more similar than distant regions, and vice versa if Moran's I is negative with p value <0.05.

Third, we performed multilevel multivariable logistic regression for each measure, with patients as the lower-level units and Medstat regions as the higher-level units. Decisions on inclusion of explanatory variables were based on the deviance information criterion.[23] We included age as a quadratic term to allow for non-linear relationships. The Medstat region-level variable of ophthalmologist density per 10 000 inhabitants was included in the model for eye examination. To estimate the degree of random variation in the multilevel models, we calculated the median odds ratio (MOR) at the Medstat region level. The MOR compares the adjusted odds of being adherent to the recommendation in two patients with identical characteristics, but living in two randomly selected Medstat regions. It is defined as the median of all possible, resulting ORs. The MOR is never below one as the comparison is always between the higher-propensity region and the lower-propensity region, for the outcome of interest.[24–26] A higher MOR indicates a higher level of unexplained variation in utilization after multivariable adjustment, and it can be compared directly with the ORs of the fixed effects.[24–26]

We then checked for the presence of spatial autocorrelation in the model residuals at the Medstat region level, for each measure.[22]

Finally, in cases with significant spatial autocorrelation present in the multilevel model residuals, we further developed Bayesian hierarchical logistic regression models capturing spatial variation at the Medstat region level through the Integrated Nested Laplace Approximations (INLA) approach.[27–30] This was performed with the R-INLA package.[31] The covariates included in the spatial multilevel models were the same as in the multilevel multivariable models above. The marginal effects of age divided into 50 groups were inspected graphically, which was more intuitive than reporting regression coefficients. The finally remaining geographic variation across Medstat regions was mapped out for each measure.

Statistical analyses were performed using R V.3.4.4,[32] STATA V.13, and MLwiN V.3.04[33] integrated in STATA using the runmlwin package. Mapping was conducted with QGIS V.1.14.16,[34] and spatial clustering analysis was done with GeoDa V.1.10.[35]

RESULTS

A total of 49 198 patients with diabetes were analyzed in this study. The mean age was 66.6 years, and women accounted for 45.0% of the whole study sample. Overall, 34 254 (69.6%) patients had at least two HbA1c tests in their assessment period, 21 808 (44.3%) patients had at least one kidney function examination, and 21 804 (44.3%) patients had at least one eye examination. Among the 49 198 patients with diabetes, 33 957 were below 75 years and were analyzed for LDL testing. In this subpopulation, 18 851 (55.5%) patients had at least one LDL test in the assessment period. The mean age was 60.1 years, and 41.2% were women. Table 1 shows the sociodemographics, health insurance preferences and clinical characteristics of the total population and of those below 75 years, respectively.

The ORs and 95% confidence/credible intervals (95% CIs) of all explanatory variables (except age, shown in figure 1) in both the multilevel multivariable models and the spatial multilevel models are shown in figure 2 (full numerical details are available from online supplementary table S1 and S2). For each pair of models representing one outcome, covariate effects were similar, except for language region. Regarding sociodemographics, women were more likely to follow the recommendations of eye examination and kidney function examination, while the opposite was true for LDL testing. Purchasing power index was positively associated with eye examination and kidney function examination, while it was negatively associated with HbA1c testing. Living in an urban area had a positive association with kidney function examination and LDL testing. Compared with the German-speaking area, living in the French or Italian speaking area of Switzerland demonstrated a negative association with HbA1c testing and eye examination, as well as positive

Table 1 Characteristics of n=49 198 patients with diabetes

Characteristics	Total	With biannual HbA1c testing	With annual eye examination	With annual kidney function examination	Age below 75 years	With annual LDL testing
n	49 198	34 254 (69.6%)	21 804 (44.3%)	21 808 (44.3%)	33 975	18 851 (55.5%)
Female gender	22 138 (45.0%)	15 136 (68.4%)	10 314 (46.6%)	9982 (45.1%)	13 977 (41.2%)	7572 (54.2%)
Age (mean, SD)	66.6 (13.7)	66.6 (13.0)	69.1 (12.2)	66.4 (13.0)	60.1 (11.2)	60.7 (10.5)
Purchasing power index (mean, SD)	99.8 (20.6)	99.6 (20.4)	100.45 (21.3)	100.0 (20.8)	99.5 (20.0)	99.7 (20.4)
Urban residence	38 478 (78.2%)	26 596 (69.1%)	17 039 (44.3%)	17 437 (45.3%)	26 562 (78.2%)	14 914 (56.1%)
Language						
German	35 882 (72.9%)	26 587 (74.1%)	16 493 (46.0%)	15 369 (42.8%)	24 911 (73.4%)	12 833 (51.5%)
French	9226 (18.8%)	5333 (57.8%)	3636 (39.4%)	4259 (46.2%)	6472 (19.1%)	4442 (68.6%)
Italian	4090 (8.3%)	2334 (57.1%)	1675 (41.0%)	2180 (53.3%)	2572 (7.6%)	1576 (61.2%)
Insurance coverage						
Only mandatory	13 120 (26.7%)	8673 (66.1%)	4787 (36.5%)	5669 (43.2%)	10 380 (30.6%)	5662 (54.5%)
Mandatory and supplementary	36 078 (73.3%)	25 581 (70.9%)	17 017 (47.2%)	16 139 (44.7%)	23 577 (69.4%)	13 189 (55.9%)
High deductible (SFr >500)	2770 (5.6%)	1692 (61.1%)	888 (32.1%)	978 (44.9%)	2262 (6.7%)	1058 (46.8%)
Mandatory insurance models						
Standard	29 097 (59.1%)	19 973 (68.6%)	12 870 (44.2%)	12 900 (44.3%)	19 207 (56.6%)	10 639 (55.4%)
Managed care	20 101 (40.9%)	14 281 (71.0%)	8934 (44.4%)	8908 (44.3%)	14 750 (43.4%)	8212 (55.7%)
Supplementary hospital care insurance	8582 (17.4%)	6085 (70.9%)	4544 (52.9%)	3965 (46.2%)	5336 (15.7%)	3038 (56.9%)
Multimorbidity (mean, SD)	2.6 (1.7)	2.6 (1.7)	2.8 (1.7)	2.7 (1.7)	2.4 (1.7)	2.5 (1.7)
Diabetes category						
Incident	6198 (12.6%)	4003 (64.6%)	2109 (34.0%)	2646 (42.7%)	4971 (14.6%)	2661 (53.5%)
Oral drug only	30 329 (61.6%)	20 294 (66.9%)	12 976 (42.8%)	13 318 (43.9%)	20 084 (59.1%)	11 331 (56.4%)
Insulin	12 671 (25.8%)	9957 (78.6%)	6719 (53.0%)	5844 (46.1%)	8902 (26.2%)	4859 (54.6%)
Ophthalmologist density/10 000 inhabitants	0.09 (0.17)	–	0.09 (0.18)	–	–	–

Multimorbidity: pharmaceutical cost groups were used to deduce chronic morbidity based on drug use.
HbA1c, glycated hemoglobin; LDL, low-density lipoprotein.

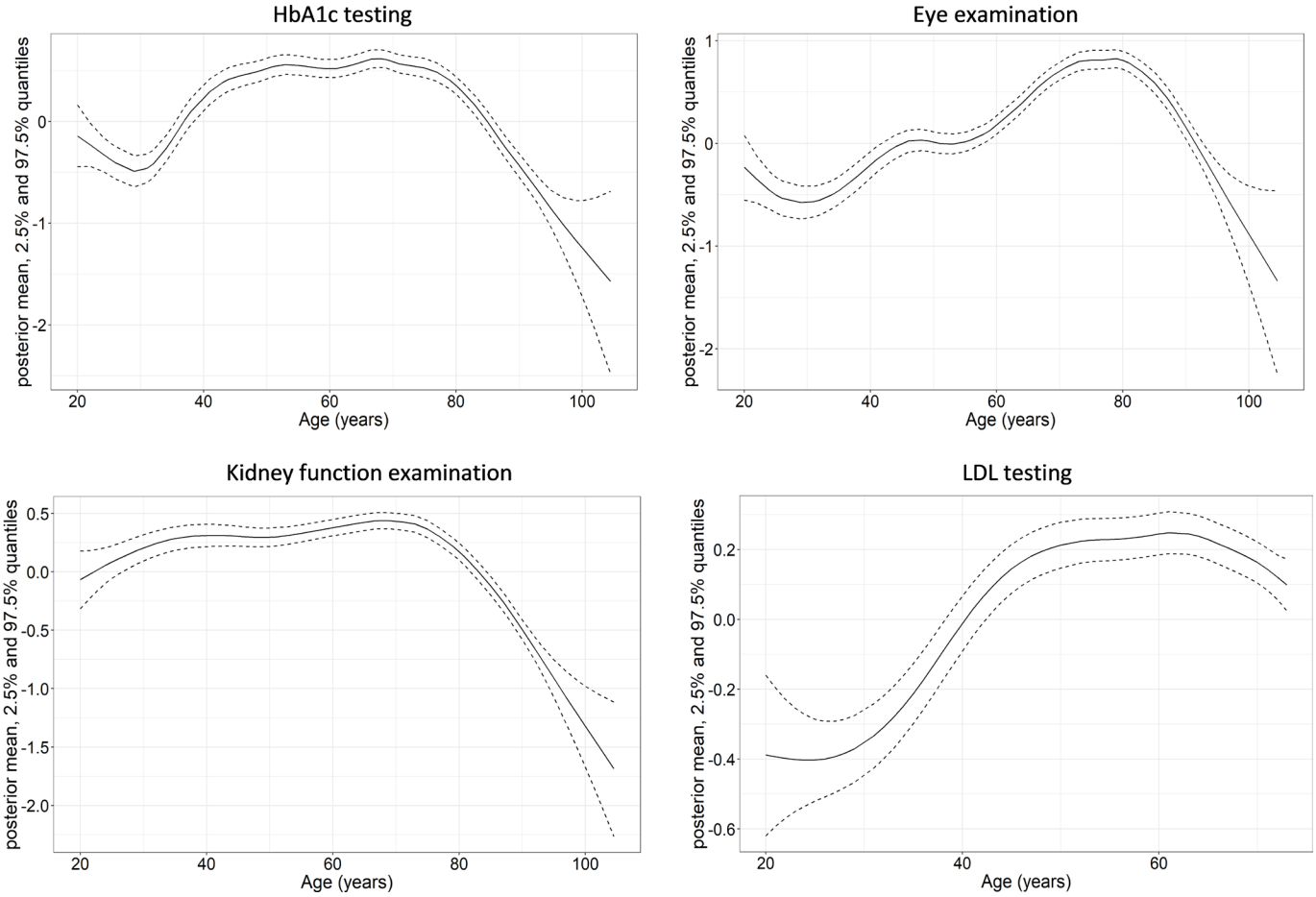

Figure 1 Age effect in spatial multilevel models. HbA1c, glycated hemoglobin; LDL, low-density lipoprotein.

associations with LDL testing and kidney function examination. As expected, these associations were strongly attenuated in the spatial multilevel models. The effects of health insurance preferences and clinical characteristics were mostly consistent across the four measures. Having any supplementary insurance (ORs across measures were between 1.08 and 1.28), having supplementary hospital care insurance (1.08–1.30), having chosen a managed care insurance model (1.04–1.17), and having more comorbidities (eg, having more than two morbidities compared with none: 1.25–1.57), were all positively associated with being adherent to the recommendations. Having chosen a higher deductible level had a negative association with being adherent to the recommendations (eg, SFr2500 compared with SFr300: 0.57–0.69). Prevalent cases receiving insulin compared with incident cases had a positive association with HbA1c testing, eye examination and kidney function examination, while having a negative association with LDL testing. A positive association between ophthalmologist density and eye examination was found in both models of eye examinations, with an OR of 1.13 in the spatial multilevel model.

The geographic distribution of the utilization of the four measures across Medstat regions is shown in figure 3. By visually inspecting the maps, we noted considerable geographic variation for each measure, with quite different spatial patterns. For HbA1c testing, utilization rates were generally higher in the German-speaking north and middle part of Switzerland, while there was no such pattern visible for the other three measures. Positive and statistically significant ($p<0.05$) Moran's I values of the raw rates indicating the presence of spatial autocorrelation were 0.46 for HbA1c testing, 0.27 for eye examination, 0.21 for kidney function examination, and 0.35 for LDL testing. After multilevel multivariable model adjustment, Moran's I values of the residuals at the Medstat region level decreased to 0.12 ($p<0.0001$) for HbA1c testing, 0.13 ($p=0.0001$) for kidney function examination, and 0.07 ($p=0.004$) for LDL testing. Only for eye examination, we found a slight increase of spatial autocorrelation to 0.30 ($p<0.001$) after model adjustments. In consequence, we regarded the spatial multilevel models as most appropriate because they accounted for the spatial structure in the data. The MORs in the multilevel multivariable models, describing variation between Medstat regions, were 1.28 for HbA1c testing, 1.31 for eye examination, 1.27 for kidney function examination, and 1.33 for LDL testing.

The unexplained spatial variation remaining after multivariable adjustment through spatial multilevel models for each measure is shown in figure 4. The OR values in figure 4 represent the odds of being adherent

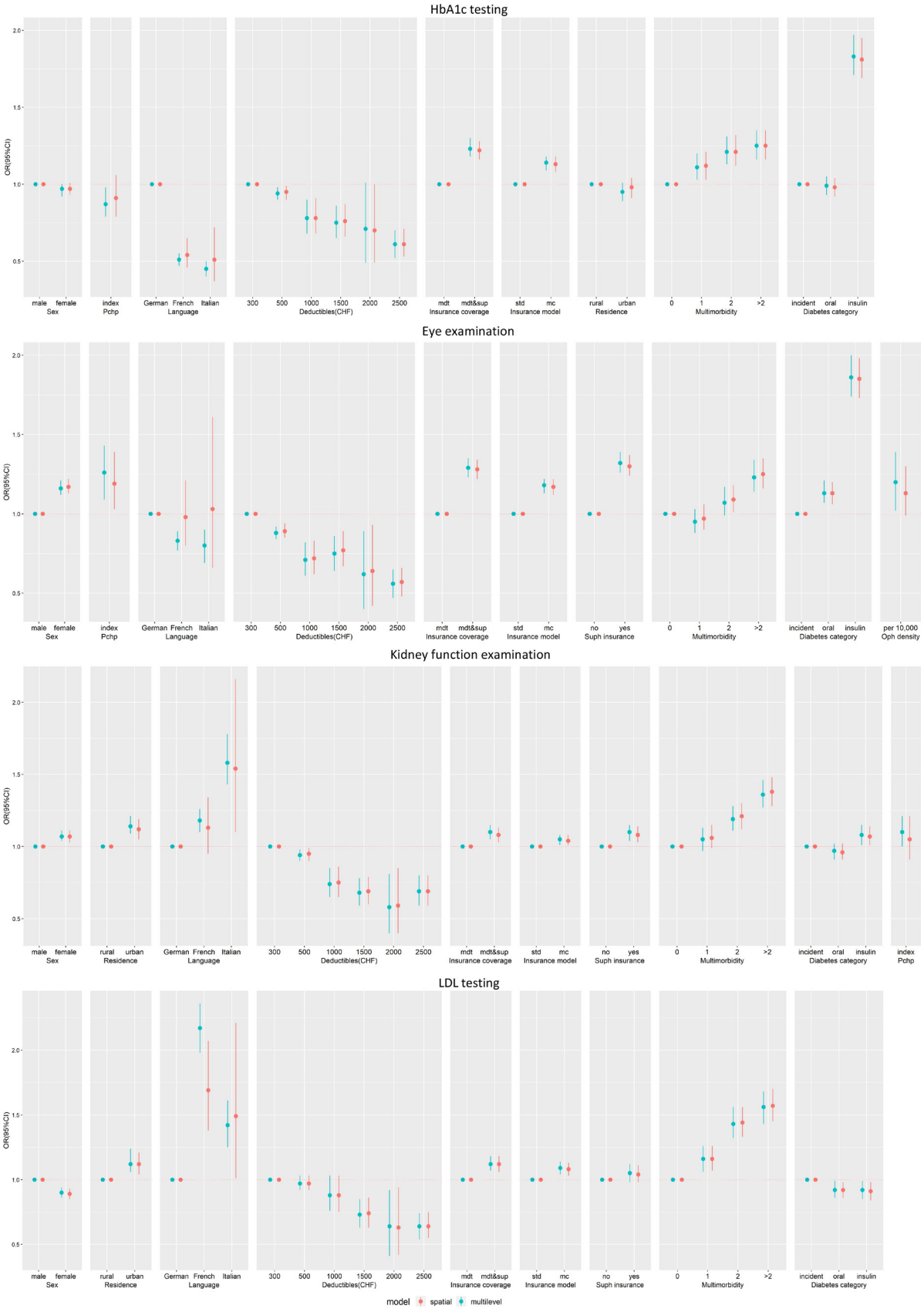

Figure 2 ORs and 95% CIs of fixed effects in multilevel multivariable models and spatial multilevel models. CHF, Swiss franc; HbA1c, glycated hemoglobin; LDL, low-density lipoprotein; mc, managed care; mdt, mandatory insurance; Oph: ophthalmologist; Pchp, purchasing power; std, standard; sup, supplementary insurance; Suph insurance, supplementary hospital care insurance. Multimorbidity: pharmaceutical cost groups were used to deduce chronic morbidity based on drug use.

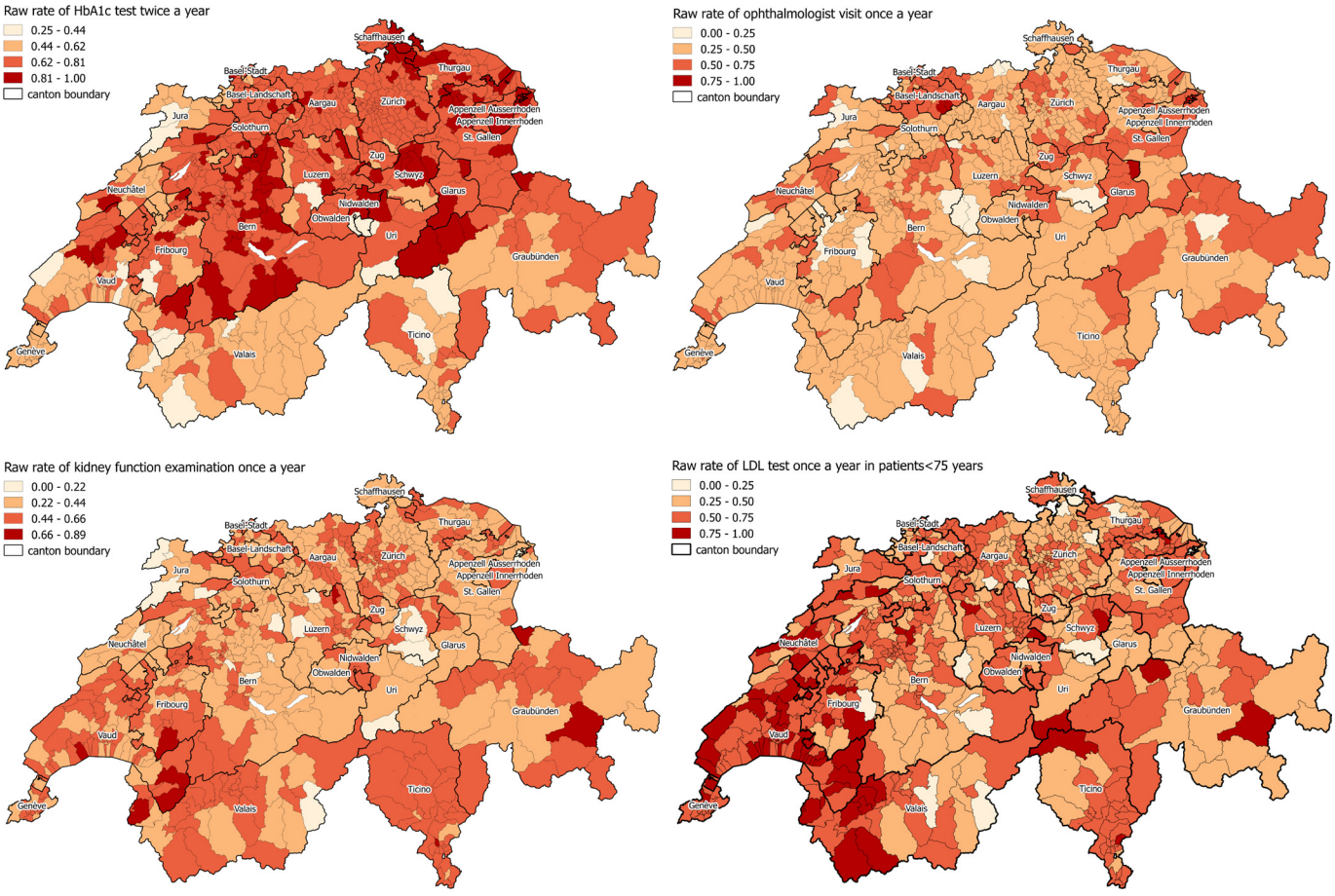

Figure 3 Raw utilization rates of four diabetes management measures across 705 Medstat regions. HbA1c, glycated hemoglobin; LDL, low-density lipoprotein.

to the recommendation in one specific Medstat region compared with the average odds in the whole of Switzerland. We observed spatial clusters of better adherence in the northeast and middle parts of the country for HbA1c testing, in the north and east parts for eye examination, in the southwest and southeast parts for kidney function examination, and in the southwest part for LDL testing.

DISCUSSION

Observed utilization rates in 2014 in Switzerland of four strongly recommended measures in diabetes management were 69.6% for biannual HbA1c testing, 44.3% for annual eye examination, 44.3% for annual kidney function examination, and 55.5% for annual LDL testing (in patients below 75 years). Associations between health insurance preferences and utilization were consistent across the four measures. Having supplementary insurance, choosing a lower deductible level, and choosing a managed care insurance model were positively associated with being adherent to the recommendations. After adjusting for all available influencing factors and spatial autocorrelation, the unexplained regional variation was only moderate. There was no common pattern of spatial clustering visible across the four studied measures.

The observed utilization rates suggest that the underlying recommendations were not being followed perfectly. In a previous study using year 2011 to 2013 data from the same data source, similar utilization rates were reported: 70.0% of patients had biannual HbA1c testing, 44.2% an annual eye examination, 12% both serum creatinine and albuminuria testing annually, and 59.0% an annual lipid profile (total cholesterol, HDL and LDL, and triglycerides).[13] The much higher rate of annual kidney function examination found in our study was mainly due to the use of a different definition of kidney function examination—a serum creatinine and/or albuminuria test.

Overall, few studies assessing the utilization of management measures recommended for diabetes patients exist, and some with discrepant findings. Some studies from the USA, Japan and Italy are directly comparable with ours as they reported on the utilization of at least one of our four measures of interest. For HbA1c testing, one study conducted in Texas, USA, reported a 54.8% biannual utilization rate,[36] while the utilization rate in an Italian study was relatively low (33.9%).[37] By contrast, a study from Japan using claims data found an annual utilization rate of 95.8%.[38] For eye examination, studies in the USA reported utilization rates of 15.3% (using claims

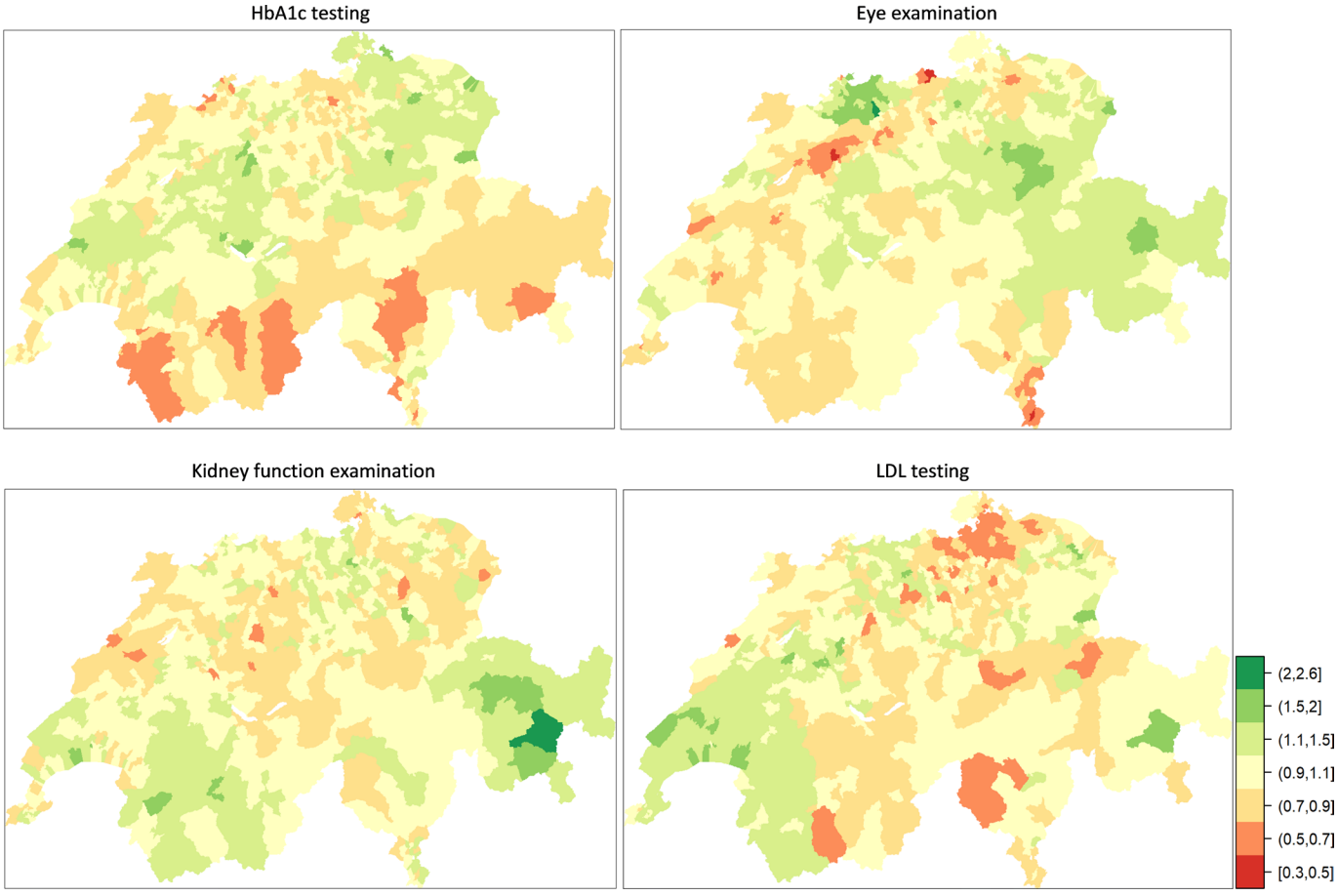

Figure 4 Unexplained variation in the utilization of four diabetes management measures in spatial multilevel models (OR values represent the odds of being adherent to the recommendation in one specific region compared with the average odds in the whole of Switzerland). HbA1c, glycated hemoglobin; LDL, low-density lipoprotein.

data),[39] 70% (using telephone survey data),[40] and 75% (data from rural Latinos).[41] A Japanese study reported a utilization rate of 35.6%,[38] and the rate in the Italian study was even lower (15.6%).[37] The Italian study also reported a utilization rate of LDL testing of 52.1%, which was similar to the finding in our study.[37] However, these different reports may not be entirely comparable with our study since the data sources and definitions of adherence to recommendations were different.

Patients' sociodemographics were associated with healthcare utilization. The probability of undergoing the four recommended measures was generally high between age 50 and 80 years, and decreased strongly thereafter. This was expected because the elderly may have more barriers to accessing healthcare services due to poor health status. Moreover, the measures may become less important in the elderly as comorbidities and life expectancy affect priority setting and the benefit of preventing long-term complications. Women were more likely to undergo eye examination and kidney function examination in our study, which was consistent with previous findings.[38 42 43] However, women were less likely to undergo annual LDL testing, which might be due to more attention to the risk of cardiovascular disease in men. Myocardial infarction and related conditions have traditionally been perceived as predominantly male diseases. Living in an urban area was positively associated with more utilization of annual kidney function examination and LDL testing, which may be partly explained by easier access to healthcare facilities than in rural areas. The language region effects on the utilization of the four measures found in the present study indicated that the language region plays an important role in influencing healthcare utilization, which might be due to different culture and norms in each language region.[44 45]

One of the key findings in the present study was the association between health insurance preferences and utilization of diabetes management measures, in a setting with mandatory insurance and universal access to care. Very few studies have explored the effect of health insurance–related factors on services utilization in patients with diabetes. Most of the available studies only concluded that uninsured patients were less likely to use healthcare services than insured patients or patients with private insurance.[36 40] While non-insurance does practically not occur in Switzerland, foregoing healthcare due to out-of-pocket payments is a well-documented phenomenon.[46] This is one of the first studies to look into potential influences of health insurance characteristics on utilization of measures on diabetes management in detail. Overall, we

found consistent effects of health insurance characteristics on utilization across the four measures of interest, and they persisted after controlling for other important influences such as age, health status, and to some extent income (defined by regional purchasing power index). Patients with higher deductibles tend to be healthier and willing to take more risks, and some invoices may be missed in these patients, which may partially explain our observation of lower utilization of the measures of interest. However, higher out-of-pocket costs may also make patients more reluctant to use these measures, which would make high deductibles a financial barrier to recommended healthcare.[47] Similarly, patients having supplementary insurance may be wealthier, and on average more health conscious. Thus, they may tend to seek care more frequently and regularly, as observed in our study. Patients choosing a managed care model had more utilization of the measures studied than patients choosing an insurance model offering completely free physician choice. This finding is of great interest because it may indicate that strengthening a coordinative role of primary care physicians in managed care and providing financial incentives to the insured for choosing such models may also positively impact certain healthcare utilization indicators or outcomes. More health insurance incentives for participation in managed care models could be considered to achieve optimized healthcare utilization.

Presence of comorbidities was associated with more utilization, which may be due to more health awareness and regular contact with healthcare providers. The finding of the lower uptake of LDL testing among prevalent cases was unexpected, as we would have expected prevalent patients to be more adherent to disease management and treatment compared with new patients.[48] The ophthalmologist density covariate reflected the access to eye examination services, and thus partly explained the higher utilization of eye examinations in patients living in regions with more ophthalmologists.

The unexplained geographic variation of utilization across small regions after adjusting for all available factors was only moderate for all four measures. One possible reason could be that we were unable to control for locally specific factors in our models. For example, physician-level factors such as age, years in practice, and the awareness of and attitude toward clinical guidelines and recommendations vary across physicians and could affect the communication with patients and finally the patients' behaviors.[49] In addition, some patient-level characteristics were not captured in our data source, for example, educational level or marital status, as well as patients' preferences, which were demonstrated to be potentially related to the utilization of healthcare services.[40] By mapping out the unexplained spatial variation, we noted that the spatial patterns of regional variation were inconsistent across the four measures studied. These patterns indicated that the utilization of the four measures strongly recommended to patients with diabetes differ substantially within Switzerland. The spatial variation of utilization might be even less prominent after controlling for more potentially influential factors unmeasured in the present study, such as physician characteristics which could not be captured from the claims data. Combination of different data sources may serve as a promising approach in future studies.

In addition to the limitations mentioned above, further potential weaknesses should be noted about this study. First, the health insurance claims data have limited clinical information; for example, outpatient diagnoses are lacking. The study population was selected according to the prescription of any diabetes medication, which may have led to some misclassification of prevalent and incident cases; this might partially account for the unexpected finding of more utilization of LDL testing in incident patients. It was impossible to distinguish between type 1 and type 2 diabetes. Patients with type 1 diabetes are a small fraction (approximately 8% in Switzerland in 2014[50]); they normally get the illness when they are young, tend to be well treated by specialists, and are generally better at self-management. Due to the high costs of insulin injections and the associated medical supplies and devices, choosing a low deductible level is expected in patients with type 1 diabetes. Such different behaviors may have had an impact on utilization of the four measures and influenced our results to a certain degree. Besides, the laboratory test results were not available from claims data and it was impossible to estimate the proportion of targets achieved for the diabetes management measures. Second, we used claims data from a single health insurer. Enrollees of other health insurers might theoretically have different characteristics and show different healthcare use patterns. However, the results presented were based on a population of 1.2 million covering all regions in Switzerland. The benefit package of the mandatory health insurance is defined at the federal level and is the same for all health insurers. Thus, we expect little deviation of enrollees' features compared with the total Swiss population, and the results should be generalizable to the whole of Switzerland.

In conclusion, we observed that the utilization of four diabetes management measures was not optimal in Switzerland although these measures have been recommended broadly and are based on strong evidence. Sociodemographics, health insurance preferences, and clinical characteristics were associated with their utilization. The presence of supplementary insurance, a lower deductible level, and participation in a managed care plan were associated with higher utilization, consistently across the four measures. After controlling for available factors and spatial autocorrelation, maps of remaining variation indicated inconsistent patterns of utilization in the four measures. Our findings indicate that the uptake of strongly recommended measures for diabetes management could possibly be optimized by providing further incentives to insured and care providers through insurance scheme design. By contrast, due to the absence of

marked regional variation patterns, we conclude that there may be only limited potential for improvement by targeted regional intervention (eg, awareness and promotion campaigns). Moreover, our novel approach aids in the identification of geographic variation and influencing factors of healthcare services use in Switzerland and comparable settings worldwide.

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Contributors MS, VvW, and HD developed the underlying study program and generated the idea of the present study. BB, EB, CB, and AU did data preparation and data management. WW, OG, and JB performed statistical analysis and wrote the main manuscript text. All authors together defined the analysis methodology, interpreted the statistical results, and critically reviewed the manuscript.

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