Temporal trends in quality of primary care for patients with type 2 diabetes mellitus: a population-based retrospective cohort study after implementation of a quality improvement initiative

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Abstract

Background: This study examined whether temporal trends exist in treatment of patients with type 2 diabetes (T2D) and quality of diabetes care after implementation of quality improvement initiative in primary care setting.

Methods: We conducted a population-based retrospective cohort study of 202,284 patients with T2D who were routinely managed in primary care clinics. We examined the change over time and the variability between clinics in quality-of-care from Hospital Authority administrative data over a five-year period (2009-2013), and used multilevel logistic regression to adjust for patient and clinic characteristics. Observational period was partitioned in five calendar years. Ten quality-of-care criteria were selected: adherence to seven process of care criteria (HbA1c test, renal function test, full lipid profile, urine protein analysis, retinal screening, lipid-lowering agent prescriptions among patients with hypercholesterolaemia, and ACEI/ARB prescriptions among patients with microalbuminuria) and three outcome of care criteria (HbA1c$\leq$7%, BP$\leq$130/80mmHg, LDL-C$\leq$2.6mmol/L). Variability of standards between clinics was assessed using intra-cluster correlation coefficients.

Results: Characteristics of Patients with T2D managed in primary care changed substantially during the observational period, with increasing age and usage of insulin, longer duration of diabetes but improved metabolic profiles (all P-trend<0.001). Performance rates of the seven process and three clinical outcome of care criteria increased remarkably over time (all P-trend<0.001). Variations in retinal screening delivery between clinics was considerable, albeit decreasing over time.

Conclusions: Coinciding with implementation of quality improvement initiative, quality of diabetes care improved significantly in the past 5 years, in part attributable to benefits of integrated multidisciplinary diabetes management.

Trial registration: Not applicable

List of abbreviations

T2D = Type 2 Diabetes

DM = Diabetes mellitus

RAMP-DM = Multidisciplinary Risk Assessment and Management Program for Patients with Diabetes Mellitus

PEP = Patient Empowerment Programme

ICPC-2 = International Classification of Primary Care, Second Edition

LDL-C = low-density lipoprotein–cholesterol

ACEI = angiotensin converting enzyme inhibitors (ACEI)

ARB = angiotensin receptor blockers

BP = blood pressure

OR = odds ratios

ICC = intra-class correlation

Manuscript

Introduction

Over the past decades, an integrated service model involving risk stratification[1], personalized treatment[2, 3] and multidisciplinary management[4, 5] have played an increasingly important role in the care/management of patients managed in the primary care setting. Such service model for patients with diabetes mellitus (DM) enhanced quality of care, leveraged better metabolic control as intermediate clinical outcomes, and early detection and prevention in diabetic complications. Furthermore, the launch of such service model within healthcare system can be regarded as the implementation of a quality improvement initiative that leads to measureable improvement in quality of care through continuous actions and efforts[6].

Many developed countries have implemented quality improvement initiatives to successfully improve the quality of diabetes care[7-14]. However, in Hong Kong, there was no prior development of diabetes care guidelines and implementation of quality improvement initiatives. In response to this evidence at policy level, the Hong Kong Hospital Authority reformulated their delivery and coverage of diabetes management in primary care. From 2009 onwards, the Hospital Authority has launched a quality improvement initiative, composing a series of primary care interventions, aiming at improving well-being of and quality of care for patients with chronic diseases, diabetes in particular. Coproduction of the two interventions (Multidisciplinary Risk Assessment and Management Program for Patients with Diabetes Mellitus; RAMP-DM) [15-19] and Patient Empowerment Programme; PEP) [20-26]) designated to innovate a more proactive and holistic approach in providing risk assessment for diabetic complications multi-faceted management, structured education and patient

empowerment for self-management. Enrollment to RAMP-DM, PEP or other interventions are offered to patients with newly diagnosed DM, where the overlapping interventions exists. In the period of 2009-2013, sequential implementation of RAMP-DM and PEP has aggregated substantial clinical benefits to participants and modest reductions in utilization of secondary care[24]. The PEP led to the benefits of substantial reductions in the frequency of emergency department visits and hospitalization episodes, and their associated direct medical costs[24]. Despite the considerable manpower and resources allocated to enhance the efficiency of diabetes management, comprehensive picture of temporal trends in process and clinical outcome of patients associated with the quality improvement initiative are lacking.

This study examined the inter-clinic variability and temporal trends in the treatment of patients with type 2 diabetes (T2D) and quality of diabetes care after implementation of quality improvement initiative in the primary care. We hypothesized that the decrease in variability between clinics, improved quality of diabetes care, and changes in treatment of patients with T2D were observed after implementation.

Method

Study design and cohort

A longitudinal, retrospective population-based study was conducted in 72 primary care clinics using the clinical management system administrative database of the Hong Kong Hospital Authority. All patients with T2D who had attended at least one general out-patient clinic or family medicine specialist clinic on any date between 1 January 2009 and 31 December 2013, and were identified with the *International Classification of Primary Care, Second Edition* (ICPC-2) diagnosis codes of 'T90' (Non-insulin dependent diabetes), were included to

measure the observed standard of care in the process and clinical outcomes of care criteria.

Patients with diabetes who were managed by endocrinologists in specialist outpatient clinics

were excluded. Out of 74 clinics, two clinics (2.7%) were not operated concurrently in all

five years between 2009 and 2013 due to reconstruction or suspension so 72 (97.3%) clinics

were included for analysis. General outpatient clinics in the Hospital Authority provided

primary care services for >170,000 adults with diabetes annually, of whom 202,284 patients

with T2D were included for analysis due to multiple visits of the same patients in each of the

year from 2009 to 2013. Data from clinical management system administrative database were

retrieved from Hong Kong Hospital Authority Statistics and Workforce Planning Department

at April 2014.

Intervention

Quality improvement initiative for diabetes care in primary care setting composes of two

major interventions: RAMP-DM and PEP. In brief, T2D patients participating in RAMP-DM

were offered a comprehensive risk factor screening for diabetic complications. A nurse

assessed the screening results and stratified patients into 'low', 'medium', 'high' or 'very

high' risk group. Based on individual risk stratification, patients were assigned to receive

interventions provided by a multidisciplinary team (physicians, nurses, optometrist, dietitian,

podiatrist, physiotherapist, and other allied health professionals). Comprehensive screening

and assessments were periodically repeated every one to two years according to patients'

stratified risk levels. The PEP is a structured diabetes education program aiming at providing

knowledge and skills, increasing self-awareness with regards to their own disease condition,

and facilitating autonomous self-regulation. The education curriculum of PEP included both

diabetes-specific and generic sessions. Diabetes-specific sessions covered comprehensive

information about diabetes, responsibility of self-care management, medications in diabetes

control, and contingency management on hypo- and hyperglycemia. Generic sessions covered the importance of self-management and behavior modification, healthy diet and regular exercise habit, goal setting, problem solving skills, stress coping management, psychosocial support and networking, and communications with healthcare professionals. Full details of RAMP-DM [15-19] and PEP[20-26] have been described elsewhere.

Quality of Care Measures

The evaluation of quality of diabetes care was primarily based on the classical taxonomy described by Donabedian et al[27, 28]. The approaches of Plan-Do-Study-Act model, Action Learning and Audit Spiral Methodologies were adopted in quality of care evaluation. The applicability and logistics of the implementation of the primary care interventions were discussed with key service providers in planning and feedback meetings. Feedback on the evaluation results with benchmark comparison were given to the Hospital Authority intervention teams to identify deficiencies, difficulties, recommendations to address issues encountered or anticipated, and further areas for quality of care enhancement. Multiple site visits were made regularly to understand gaps between the actual practice and intended intervention operation.

Development of evaluation framework and quality of diabetes care criteria have been described previously[29]. A evidence-based evaluation framework for process or outcome of care criteria was identified by literature review, international guideline [8, 30-32] and local reference framework[33], and further established by an iterative consultation process between Hospital Authority primary care working group and the University of Hong Kong research team.

Quality of care was measured by ten diabetes care quality criteria in evaluation framework, with breakdown of seven process criteria and three outcome criteria. In this study, process of care criteria were receipt of HbA1c measurement within the past one year, renal function test within the past one year, full lipid profile within the past one year, urine protein analysis (i.e. available for one of the following measurements: albumin creatinine ratio, protein creatinine ratio, albumin concentration, albumin excretion rate, 24-hour urine albumin, 24-hour urine protein, or urine for protein/albumin stick) within the past one year, retinal screening with retinal photo examination within the past one year, lipid-lowering agent prescriptions among patients with hypercholesterolaemia (defined as low-density lipoprotein–cholesterol (LDL-C) > 2.6 mmol/L), and angiotensin converting enzyme inhibitors (ACEI) or angiotensin receptor blockers (ARB) prescriptions among patients with microalbuminuria (defined as urine albumin/creatinine ratio 2.5-<25 mg/mmol in men and 3.5-<25 mg/mmol in women in both the first and repeated records). Clinical outcomes of care criteria were the proportion of patients with HbA1c level of 7% or less, proportion of patients with blood pressure (BP) reading of 130/80 mmHg or less, and proportion of patients with LDL-C level of 2.6 mmol/L or less.

Each quality of care criteria was evaluated in annual basis over five-year observation period, in exception with receipt of diabetic retinopathy (DMR) screening. The procedure code of retinal screening undertaken at primary care clinic was introduced in early 2009 when the first record of that procedure code was earlier than the implementation of quality improvement initiative. To avoid miscoding and misclassification bias, criteria of retinal screening was evaluated over period studied from 2010 to 2013.

Statistical Analysis

Characteristics of patients and clinics were summarized as mean and standard deviation for continuous variables and proportion for categorical variables by calendar years.

Crude performance rate to process and outcome of care criteria at patient level was calculated by years. For each quality criterion, crude performance rate was calculated by the number of eligible T2D patients adhered to the criteria by the end of the year divided by the total number of eligible T2D patients ever attending primary care outpatient clinics at the year. In particular, patients with hypercholesterolaemia and patients with microalbuminuria were eligible for quality criterion of prescription of lipid-lowering agent and prescription of ACEI/ARB, respectively. Trends in unadjusted process and outcome of care criteria over the five-year period of analysis were examined by the Cochran-Armitage χ^2 test.

To examine secular trends in the quality of care between 2009 and 2013, a multivariable multi-level logistic regression analysis was performed when correcting for clustering on the clinic levels, adjusting for confounding patient and clinic characteristics. Odds ratios (OR) and 95% confidence intervals were reported for outcomes in three dummy variables representing the time period of 2010-2013 with 2009 as the reference year. Reference category was year 2010 for DMR screening as outcome since DMR data in 2009 were not excluded from analysis.

To analyze the variability of quality of care for clinic level, we calculated the intra-cluster correlation (ICC) coefficients, as a ratio of the between-clinic variance and the variance of between-and within-clinic variances, for each quality criteria. The ICC means the extent of variability in quality criteria explained by the differences between clinics. A higher ICC at the clinic level reflects a smaller variance for quality criteria within the clinics and a larger variance between clinics.

All statistical analyses were performed using STATA Version 13.0 (StataCorp LP. College Station, Texas, U.S.), specifying commands of *xtmelogit* procedure for multi-level mixed-effects logistic regression[34]. All significance tests were two-tailed and those with a P-value less than 0.05 were considered statistically significant.

Results

A total of 170,000-190,000 eligible subjects with T2D among 72 clinics in Hong Kong were identified and included in the analysis each year. Table 1 shows their socio-demographics and clinical characteristics across the observational period. Larger proportions of smoker, current drinker and subjects with higher educational level were observed every year. Moreover, there was a significant trend of increasing age, decreasing lipid profile, longer duration of DM, higher proportion of subjects with hypertension and increasing usage of insulin.

Enrollment to RAMP-DM and PEP were referred through physicians and nurses at general outpatient clinics. Across a five-year time frame, there was a substantial increase in the coverage rate of RAMP-DM (from 2.7% in 2009 to 81.9% in 2013)[35] and PEP (from 2.1% in 2010 to 13.4% in 2013) interventions, most of T2D patient (82.4%) enrolling one of the interventions under quality improvement initiative at the end.

Table 2 depicts the performance rates of seven process and three clinical outcomes of care criteria over time. All process of care criteria except DMR screening showed trends of improvements. For instance, the annual HbA1c test increased from 70.84% in 2009 to 90.67% in 2013; the renal function test increased from 56.59% in 2009 to 91.69% in 2013; the prescriptions of lipid-lowering agent for patients with hypercholesterolaemia and

ACEI/ARB for patients with microalbuminuria increased by 54.03% and 12.86%, respectively in five years' time. For clinical outcomes of care criteria, there were also monotonic increments observed for the proportions of patients with BP ≤ 130/80mmHg (from 31.51 % in 2009 to 48.21% in 2013) and LDL-C ≤ 2.6mmol/L (from 28.29% in 2009 to 65.44% in 2013) across the observational period.

The unadjusted multi-level mixed effects logistic regressions were performed for each of the process and clinical outcomes of care criteria and the results are presented in Table 3. Taking 2009 as the reference year, subjects in the subsequent years had increasing odds of meeting the process and clinical outcomes of care criteria, as reflected by all the odds ratios exceeding 1. For example, subjects in 2013 had more than nine-fold odds of having annual test for renal function and full lipid profile, comparing with those in 2009. However, the effect on clinical outcomes of care criteria was not as strong as that on process of care criteria. Subjects in 2013 only had odds ranging from 2 to 4, though significant, of meeting the targets for HbA1c, BP and LDL-C, comparing with those in 2009. These results are in line with that presented in Table 2. Same regression models were fitted with the adjustment of patient's baseline and clinic characteristics, and clinic treated as the random effect. The effects on most of the process and outcome of care criteria were diluted, as reflected by the decrement in the (adjusted) odd ratios in Table 4. However, the effects were still highly significant when comparing with the data in 2009.

Discussions

This retrospective cohort study revealed an absolute increment in the performance of diabetes measurements in Hong Kong primary care setting between 2009 and 2013. The principal findings reflected a key achievement of quality improvement initiative, supporting our priori

hypothesis that such initiative improved quality of diabetes care, especially process of care, and decreased the variability of quality of care. After implementation of quality improvement initiative, trends in quality of diabetes care over time were moving upward visibly from uncorrected crude performance rates, demonstrating that proportions of adherence to six out of seven process criteria exceeded 70%, and proportions of adherence to two out of three outcome criteria exceeded 60%. After multi-level analysis with correlation for clustering effects within clusters, the odds of adherence to process or outcome of care were statistically higher for T2D patients managed in primary care clinics in 2013 than in earlier years when quality of care was comparatively low at baseline. Despite remarkable improvement in overall quality of care in the past 5 years, our results underlined that there is room for improvement in three clinical outcomes and process of retinal screening. Thus, improvement in process of care accelerated in the first three years (2009-2011) of the quality improvement initiative but velocity for the improvement attenuated in the fourth and fifth year (2012-2013) (Figure 1). Our findings were in parallel with trends in quality of diabetes care after a complex intervention in many developed countries. For instance, longitudinal analyses of patient individual data in the UK[7-9] disclosed such similar trends for the improved quality of diabetes care over time, accelerating in early year period after introduction of Quality and Outcomes Framework[8, 9] and financial incentive scheme[7] but attenuating velocity for the improvement afterwards. Furthermore, analyses of serial cross-sectional surveys in the US[10, 11] and Norway[12] reported substantial improvements in quality of care over time.

Striking improved trends identified in this five-year data could be attributable to a potential paradigm shift in the Hong Kong primary care interventions for diabetes, including implementation of quality improvement initiative, increasing physician referral to individual primary care interventions, or increasing patient participation in interventions. Indeed, the RAMP-DM intervention has provided periodic screening and assessments for diabetic

complication, fueling temporal growth in performance rates of process criteria. Furthermore, individual primary care interventions have undergone multiple feedback meetings under quality of care evaluation with adoption of Action Learning approach. Feedback to designed cluster coordinators has affected how frontline health professionals evolved major changes in routine practice to primary care clinics. On a hand, following feedback provided by coordinators, revision of quality criteria or benchmarked standard of criteria has contributed to quality of care improvement.

Patient characteristics with respect to demographics and clinical risk profiles change rapidly in T2D patients routinely managed in Hong Kong public primary care setting, including an aging population, a greater proportion with long duration of diabetes diagnosis (5 years or above), a greater proportion with history of hypertension, and more initiation of insulin. Changes in patient characteristics in this cohort were somewhat different to those in the UK primary care system[7], of which the characteristics slightly varied over the years. Yet, given progressively worsened clinical risk profile of this cohort, improvement in quality of care persisted with the concerted and continued effort in quality improvement initiative.

Our results added to current literature that implementation of quality improvement imitative reduced the disparities between clinics over time. The quality improvement initiative demonstrated considerably reduced variability in process of care criteria between clinics, as reflected by renal function test, full lipid profile test, urine protein analysis, lipid-lowering agent prescription and retinal screening. Similar observations that velocity for the improvements in healthcare quality may diminish over time were documented in the literature[36]. Publication of performance measure[37], audit feedback evaluation cycles[37], and sustainability efforts to expand the use of electronic medical records[38] are associated with sustained improvement in quality of diabetes care. Furthermore, inter-clinic variability

or heterogeneity seen in retinal screening delivered in primary care clinics decreased from 2009 to 2013, mainly attributable to the commencement of systematic retinal screening[39] as part of the RAMP-DM. However, despite an increased number of onsite fundus photography available during a 5-year period, only 30 out of 74 clinics (40.54%) installed with onsite digital fundus photography. Access to advocate timely systematic screening to patients who needed was limited, leading to low proportion of patients receiving retinal screening. Such structured barriers limited the performance rates of retinal screening and ever screening coverage. According to English NHS diabetic eye screening programme data[40], longer duration between DM diagnosis and first screening of diabetic retinopathy was associated with increased detection of severe stages of retinopathy such as referable diabetic retinopathy.

Existing pool of individual criteria is insufficiently evaluating the overall performance and quality of care of a primary care clinic. Complementary use of both composite measure and individual criteria had strategic implications for quality improvement plan at the clinic level. Clinics aiming for excellent overall performance might prioritize their efforts on individual criteria in low tier level of standard, whereas clinics striving for a specific care improvement might target only improvement in individual criteria to top tier level of standard.

Limitations

Performance rates of process criteria have only accounted for procedural coding of testing utilized in general outpatient clinics under primary care setting; we did not include procedural coding of testing occurring during the hospitalization and specialist outpatient clinics. Moreover, the procedural code of retinal screening was incomplete in 2009 data with a limited four-year assessment, in opposite to five-year assessment for other quality criteria. Secondly, administrative data before implementation of quality improvement initiative were

not available to assess quality of diabetes care at 2008 or earlier years. Our team got access to

data over the period between 1 January 2009 and 31 December 2013. Therefore, our results

were implausible to identify the extent of quality improvement at base year when compared

to previous years. Thirdly, the reduction of diabetic complication due to the quality

improvement initiative was not evaluated, although the decreases in incidence of diabetic

complication and death are regarded as net clinical benefit of intervention. However, the

design of this study evaluated the performance rate of quality criteria by years. Due to the

low annual incidence of diabetic complication in primary care setting, the incidence of

diabetic complication was not one of the outcome criteria in evaluation framework.

Moreover, the calculation of performance rate of quality of care criteria in this study only

involved patients who visited the clinics during the observation period, whereas patients with

undiagnosed diabetes were not captured in database. Those patients may have better clinical

measures and thus overestimate performance rates. In cases when clinics had under-detection

of hypercholesterolaemia or microalbuminuria, criteria of lipid-lowering agent prescription or

ACEI/ARB prescription might perform better. Finally, the improved performance of diabetes

measurements may be partly attributable to implementation of other factors or government-

driven policy such as the release of Reference Framework for Diabetes Care for adults[33] in

2010 which was found to be highly adopted among primary care physicians[41].

Conclusions

Performance of quality measurements of DM care at the primary care setting improved

significantly in the past 5 years after implementation of quality improvement initiative.

Improvement in performance of diabetes measurements was in part attributable to benefits of

integrated service model involving personalized medicine and multidisciplinary diabetes

management. However, due to the structural barriers to undertake retinal screening,

performance rates of retinal screening increased with the growing ratio of onsite fundus photography in primary care clinics during the evaluation period but such screening coverage remained for further improvement.

Competing interest

The authors declare that they have no competing interests.

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Author Contributions

C.K.H.W. wrote the manuscript, researched data. C.L.K.L. contributed to study design, and reviewed/edited the manuscript. Y.F.W. and A.K.C.C reviewed/edited the manuscript, contributed to statistical analysis and interpretation of results. C.S.C.F and E.Y.T.Y reviewed/edited the manuscript.

Ethics approval

Ethics approval of this study was granted by the Institutional Review Board of the University of Hong Kong/Hospital Authority: Hong Kong West Cluster (UW 10-369), New Territories East Cluster (CRE-2010.543), New Territories West Cluster (NTWC/CREC/1091/12), Kowloon East and Kowloon Central Cluster (KC/KE-10-0210/ER-3), Kowloon West Cluster

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Availability of data and materials

The lists of STATA statistical code used are available from the corresponding author at carlosho@hku.hk. However, the Hong Kong Hospital Authority administrative database cannot be shared due to licensing restrictions.

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Figure Legends

Figure 1. Yearly temporal trends of process of care criteria performance rate and coverage
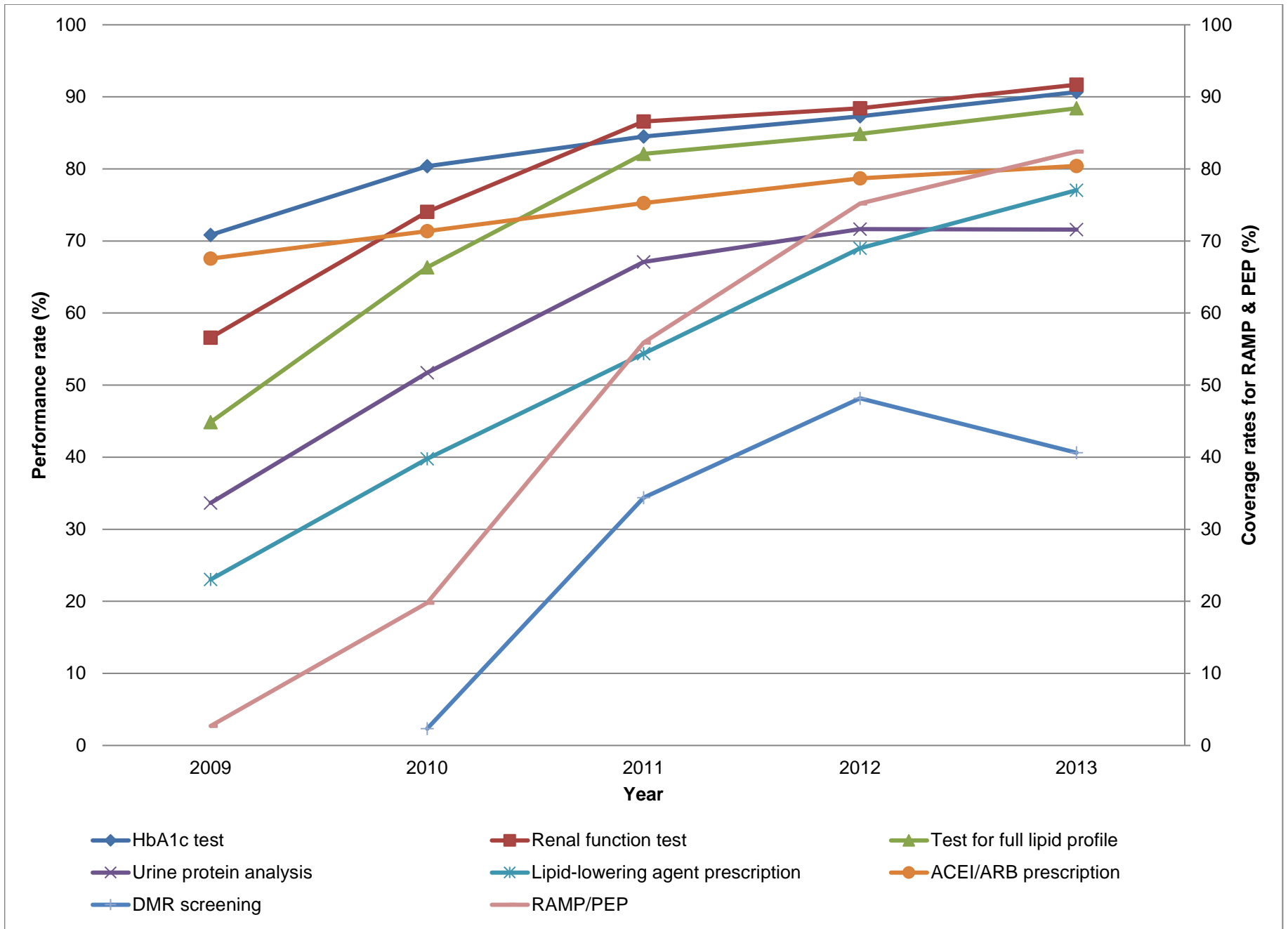
rate of quality improvement initiative

Figure 2. Yearly temporal trends of outcome of care criteria performance rate and coverage

rate of quality improvement initiative

Appendix

Appendix 1. Intra-cluster correlations of process of care criteria from 2009 to 2013

Appendix 2. Intra-cluster correlations of outcome of care criteria from 2009 to 2013
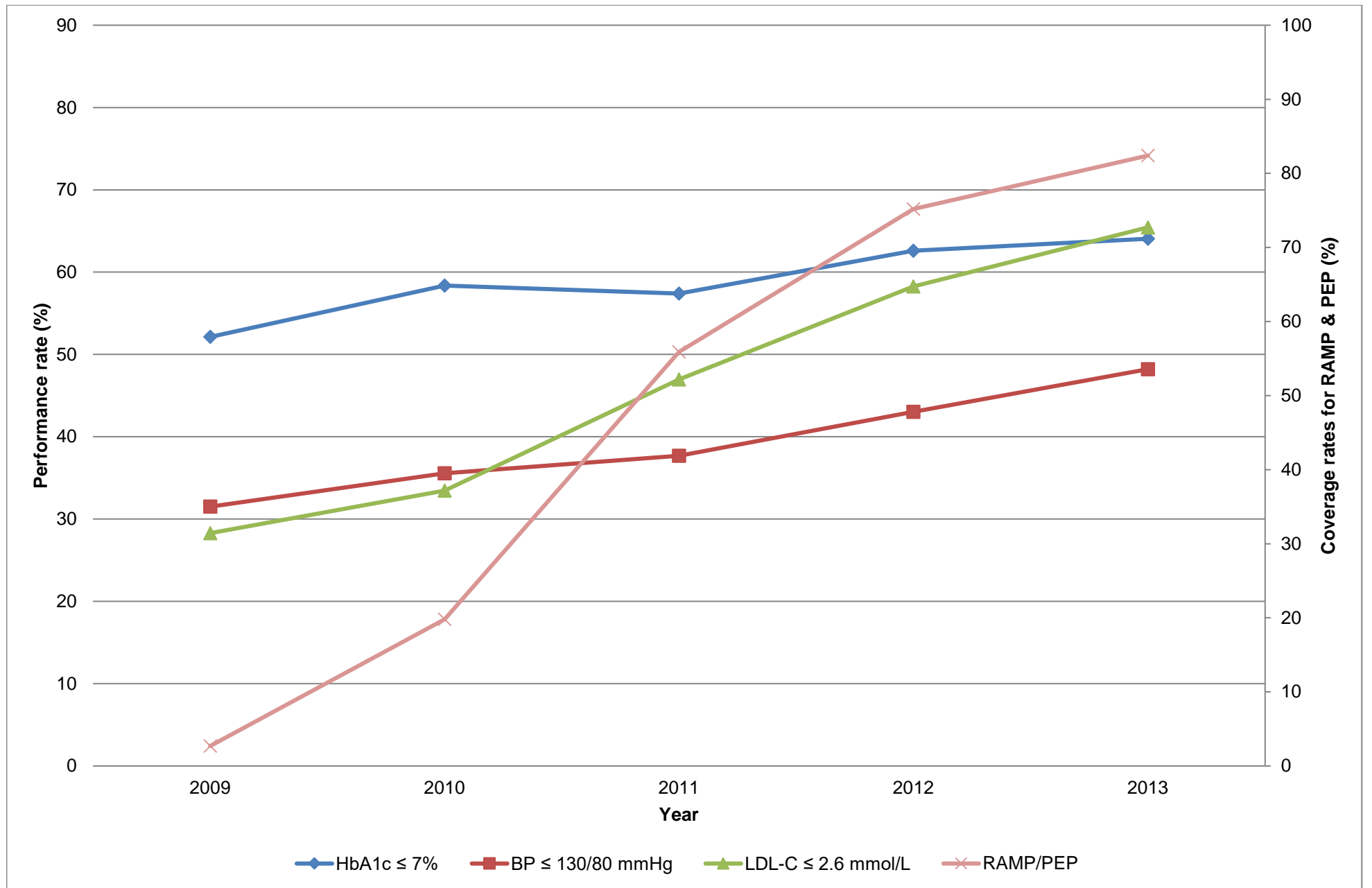
Table 1. Characteristics of Diabetic Patients Managed and Routinely Visited in Primary Care Outpatient Clinics Over Time

Variable	Year					P-value for trend
	2009	2010	2011	2012	2013	
Number of diabetic patients	172,551	178,993	184,690	180,108	172,543	
Socio-Demographic						
Age (mean±SD, n), year	66.09±12.08 (172,551)	66.46±12.03 (178,993)	66.86±12.01 (184,690)	67.62±11.87 (180,108)	68.38±11.71 (172,543)	< 0.001*
Gender (%, n)						1.000
Female	55.42 % (95,634)	54.95 % (98,360)	54.41 % (100,484)	54.41 % (97,988)	54.60 % (94,211)	
Male	44.58 % (76,917)	45.05 % (80,633)	45.59 % (84,206)	45.59 % (82,120)	45.40 % (78,332)	
Smoking status (%, n)						< 0.001*
Non-smoker	94.74 % (71,814)	93.19 % (87,455)	93.09 % (101,494)	91.51 % (88,929)	91.46 % (73,097)	
Smoker	5.26 % (3,991)	6.81 % (6,389)	6.91 % (7,535)	8.49 % (8,252)	8.54 % (6,823)	
Alcohol status (%, n)						< 0.001*
Non-drinker	84.38 % (39,210)	83.02 % (59,273)	82.46 % (68,818)	82.63 % (65,207)	82.05 % (53,060)	
Drinker	15.62 % (7,258)	16.98 % (12,122)	17.54 % (14,636)	17.37 % (13,712)	17.95 % (11,605)	
Educational level (%, n)						< 0.001*
No formal education/ Primary	60.12 % (28,955)	58.28 % (43,677)	58.05 % (51,393)	57.01 % (52,759)	57.25 % (44,703)	
Secondary/ Tertiary	39.88 % (19,211)	41.72 % (31,272)	41.95 % (37,132)	42.99 % (39,791)	42.75 % (33,381)	
Laboratory Results at Baseline (mean±SD, n)						
BMI, kg/m^2	25.62±3.92 (73,382)	25.48±3.94 (103,317)	25.43±3.93 (133,442)	25.40±3.96 (135,223)	25.48±3.96 (128,827)	< 0.001*
HbA1c, %	7.25±1.28 (122,238)	7.09±1.16 (143,885)	7.11±1.11 (156,043)	6.99±1.02 (157,216)	6.97±1.05 (156,441)	< 0.001*
Systolic blood pressure, mmHg	137.21±17.24 (165,921)	135.37±16.54 (174,233)	134.34±16.31 (181,851)	132.47±15.59 (178,029)	131.12±14.94 (170,211)	< 0.001*
Diastolic blood pressure, mmHg	75.33±10.46 (165,921)	74.67±10.18 (174,233)	74.18±10.16 (181,851)	73.56±10.17 (178,029)	72.76±10.02 (170,211)	< 0.001*
Triglyceride, mmol/L	1.71±1.10 (78,573)	1.56±1.02 (119,250)	1.52±0.97 (151,917)	1.44±0.90 (152,946)	1.42±0.87 (152,612)	< 0.001*
TC/HDL-C ratio	4.45±1.31 (78,143)	4.20±1.24 (119,660)	3.87±1.15 (151,660)	3.64±1.09 (152,864)	3.52±1.03 (152,547)	< 0.001*
LDL-C, mmol/L	3.12±0.85 (76,754)	3.00±0.82 (118,398)	2.74±0.78 (150,318)	2.55±0.73 (151,924)	2.44±0.70 (151,682)	< 0.001*
eGFR, ml/min/1.73m^2	80.21±56.56 (97,600)	81.88±32.83 (132,561)	83.14±30.57 (159,879)	82.12±29.66 (159,274)	81.49±25.10 (158,210)	< 0.001*
Clinical Characteristics						
Duration of diabetes, year (mean±SD, n)	6.90±6.33 (130,949)	7.13±6.42 (146,588)	7.39±6.53 (160,968)	8.15±6.54 (161,496)	9.07±6.50 (156,112)	< 0.001*
Duration of diabetes, year (%, n)						< 0.001*
≤ 5 years	51.52 % (67,465)	49.55 % (72,628)	47.84 % (77,003)	42.82 % (69,148)	36.09 % (56,340)	
5-10 years	25.87 % (33,871)	26.93 % (39,479)	25.75 % (41,450)	28.08 % (45,344)	30.63 % (47,811)	
> 10 years	22.61 % (29,613)	23.52 % (34,481)	26.41 % (42,515)	29.11 % (47,004)	33.28 % (51,961)	
History of hypertension (%, n)	71.52 % (123,405)	73.15 % (130,927)	74.36 % (137,344)	76.66 % (138,062)	78.51 % (135,470)	< 0.001*
Family history of diabetes mellitus (%, n)	13.26 % (22,875)	19.82 % (35,468)	21.85 % (40,359)	24.34 % (43,840)	21.89 % (37,762)	< 0.001*
Insulin used (%, n)	1.62 % (2,800)	1.95 % (3,498)	2.55 % (4,715)	3.63 % (6,532)	4.24 % (7,313)	< 0.001*

BMI = Body Mass Index; HbA1c = Haemoglobin A1c; TC = Total Cholesterol; HDL-C = High-Density Lipoprotein-Cholesterol ; LDL-C = Low-Density Lipoprotein-Cholesterol;

eGFR = Estimated Glomerular Filtration Rate

Notes:

* Significant differences (P < 0.05) by Cochran-Armitage test

Table 2. Temporal Trends in Quality of Diabetes Care of Primary Care Outpatient Clinics

Quality of care measure	Year					P-value for trend
	2009	2010	2011	2012	2013	
Process of Care Criteria (%, n)						
HbA1c test	70.84 % (122,238)	80.39 % (143,885)	84.49 % (156,043)	87.29 % (157,216)	90.67 % (156,441)	<0.001*
Renal function test	56.59 % (97,638)	74.06 % (132,563)	86.57 % (159,880)	88.43 % (159,274)	91.69 % (158,210)	<0.001*
Test for full lipid profile	44.86 % (77,408)	66.34 % (118,738)	82.10 % (151,622)	84.87 % (152,854)	88.41 % (152,539)	<0.001*
Urine protein analysis	33.65 % (58,061)	51.73 % (92,600)	67.08 % (123,882)	71.65 % (129,055)	71.58 % (123,513)	<0.001*
Prescription of lipid-lowering agent for patients with hypercholesterolaemia	23.02 % (14,754)	39.77 % (39,667)	54.37 % (64,749)	68.99 % (84,751)	77.05 % (96,027)	<0.001*
Prescription of ACEI/ARB for patients with microalbuminuria	67.56 % (4,776)	71.38 % (11,374)	75.25 % (21,732)	78.70 % (24,246)	80.42 % (24,873)	<0.001*
DMR screening	NA	2.32 % (4,146)	34.37 % (63,483)	48.17 % (86,755)	40.63 % (70,107)	<0.001*
Outcome of Care Criteria (%, n)						
HbA1c ≤ 7%	52.13 % (63,728)	58.37 % (83,986)	57.40 % (89,565)	62.61 % (98,433)	64.06 % (100,220)	<0.001*
BP ≤ 130/80 mmHg	31.51 % (52,280)	35.56 % (61,958)	37.69 % (68,544)	43.02 % (76,584)	48.21 % (82,061)	<0.001*
LDL-C ≤ 2.6 mmol/L	28.29 % (21,711)	33.46 % (39,617)	46.97 % (70,605)	58.25 % (88,491)	65.44 % (99,256)	<0.001*

HbA1c = Haemoglobin A1c; BP = Blood Pressure; LDL-C = Low-Density Lipoprotein-Cholesterol; ACEI = Angiotensin-Converting-Enzyme Inhibitor;

ARB = Angiotensin Receptor Blocker; DMR = Diabetes Mellitus Retinopathy; NA = Not Applicable

Notes:

* Significant differences (P < 0.05) by Cochran-Armitage test

Table 3. Unadjusted multi-level mixed effects logistic regressions

Quality of care measure	2010 vs 2009			2011 vs 2009†			2012 vs 2009†			2013 vs 2009†		
	OR	95% CI	P-value	OR	95% CI	P-value	OR	95% CI	P-value	OR	95% CI	P-value
Process of Care Criteria												
HbA1c test (n = 888,885)	1.691	(1.665,1.718)	<0.001*	2.253	(2.216,2.291)	<0.001*	2.839	(2.790,2.889)	<0.001*	4.033	(3.956,4.112)	<0.001*
Renal function test (n = 888,885)	2.258	(2.225,2.291)	<0.001*	5.254	(5.166,5.344)	<0.001*	6.229	(6.120,6.341)	<0.001*	9.115	(8.935,9.299)	<0.001*
Test for full lipid profile (n = 888,885)	2.536	(2.500,2.572)	<0.001*	6.147	(6.051,6.244)	<0.001*	7.520	(7.397,7.645)	<0.001*	10.388	(10.202,10.577)	<0.001*
Urine protein analysis (n = 888,885)	2.158	(2.129,2.189)	<0.001*	4.197	(4.138,4.257)	<0.001*	5.210	(5.135,5.287)	<0.001*	5.203	(5.126,5.280)	<0.001*
Prescription of lipid-lowering agent for patients with hypercholesterolaemia (n = 530,384)	2.240	(2.189,2.292)	<0.001*	4.107	(4.016,4.199)	<0.001*	7.960	(7.782,8.143)	<0.001*	12.205	(11.923,12.493)	<0.001*
Prescription of ACEI/ARB for patients with microalbuminuria (n = 113,618)	1.320	(1.241,1.404)	<0.001*	1.615	(1.524,1.712)	<0.001*	1.988	(1.875,2.109)	<0.001*	2.209	(2.082,2.344)	<0.001*
DMR screening (n = 716,334)	Reference due to no data in 2009			23.626	(22.871,24.405)	<0.001*	43.145	(41.769,44.566)	<0.001*	31.300	(30.299,32.334)	<0.001*
Outcome of Care Criteria												
HbA1c ≤ 7% (n = 735,823)	1.298	(1.278,1.318)	<0.001*	1.246	(1.227,1.265)	<0.001*	1.552	(1.529,1.576)	<0.001*	1.655	(1.630,1.681)	<0.001*
BP ≤ 130/80 mmHg (n = 870,245)	1.204	(1.187,1.222)	<0.001*	1.321	(1.303,1.340)	<0.001*	1.652	(1.629,1.675)	<0.001*	2.042	(2.013,2.071)	<0.001*
LDL-C ≤ 2.6 mmol/L (n = 649,076)	1.284	(1.259,1.310)	<0.001*	2.251	(2.208,2.294)	<0.001*	3.582	(3.515,3.651)	<0.001*	4.904	(4.811,5.000)	<0.001*

ACEI = Angiotensin-Converting-Enzyme Inhibitor; ARB = Angiotensin Receptor Blocker; DMR = Diabetes Mellitus Retinopathy; HbA1c = Haemoglobin A1c; BP = Blood Pressure; LDL-C = Low-Density Lipoprotein-Cholesterol; OR = Odds Ratio; CI = Confidence Interval

Note:

* Significant with p-value < 0.05

† Reference category was year 2010 for DMR screening, and year 2009 for other process and outcome of care criteria

Table 4. Adjusted multi-level mixed effects logistic regressions

Quality of care measure	2010 vs 2009			2011 vs 2009†			2012 vs 2009†			2013 vs 2009†		
	OR	95% CI	P-value	OR	95% CI	P-value	OR	95% CI	P-value	OR	95% CI	P-value
Process of Care Criteria												
HbA1c test (n = 394,740)	1.308	(1.163,1.471)	<0.001*	1.423	(1.261,1.606)	<0.001*	2.956	(2.535,3.447)	<0.001*	3.949	(3.286,4.745)	<0.001*
Renal function test (n = 394,895)	1.439	(1.291,1.605)	<0.001*	2.555	(2.257,2.893)	<0.001*	2.963	(2.582,3.399)	<0.001*	5.774	(4.814,6.925)	<0.001*
Test for full lipid profile (n = 403,146)	2.702	(2.543,2.870)	<0.001*	7.782	(7.199,8.412)	<0.001*	16.553	(14.912,18.375)	<0.001*	24.082	(21.108,27.476)	<0.001*
Urine protein analysis (n = 392,483)	1.644	(1.579,1.712)	<0.001*	3.053	(2.916,3.197)	<0.001*	5.200	(4.931,5.483)	<0.001*	2.645	(2.522,2.773)	<0.001*
Prescription of lipid-lowering agent for patients with hypercholesterolaemia (n = 296,475)	3.413	(3.286,3.545)	<0.001*	5.498	(5.290,5.714)	<0.001*	8.862	(8.526,9.212)	<0.001*	11.892	(11.430,12.373)	<0.001*
Prescription of ACEI/ARB for patients with microalbuminuria (n = 71,854)	1.421	(1.313,1.538)	<0.001*	1.646	(1.526,1.776)	<0.001*	1.953	(1.809,2.110)	<0.001*	2.050	(1.894,2.220)	<0.001*
DMR screening (n = 341,850)	Reference due to no data in 2009			59.861	(57.421,62.404)	<0.001*	222.189	(212.781,232.012)	<0.001*	137.369	(131.630,143.358)	<0.001*
Outcome of Care Criteria												
HbA1c ≤ 7% (n = 392,773)	1.281	(1.251,1.312)	<0.001*	1.165	(1.138,1.194)	<0.001*	1.448	(1.413,1.484)	<0.001*	1.584	(1.544,1.624)	<0.001*
BP ≤ 130/80 mmHg (n = 392,483)	1.242	(1.212,1.273)	<0.001*	1.307	(1.275,1.340)	<0.001*	1.609	(1.569,1.649)	<0.001*	1.883	(1.836,1.931)	<0.001*
LDL-C ≤ 2.6 mmol/L (n = 392,863)	1.269	(1.238,1.302)	<0.001*	2.259	(2.203,2.316)	<0.001*	3.488	(3.401,3.576)	<0.001*	4.564	(4.449,4.682)	<0.001*

ACEI = Angiotensin-Converting-Enzyme Inhibitor; ARB = Angiotensin Receptor Blocker; DMR = Diabetes Mellitus Retinopathy; HbA1c = Haemoglobin A1c; BP = Blood Pressure; LDL-C = Low-Density Lipoprotein-Cholesterol; OR = Odds Ratio; CI = Confidence Interval

Note:

* Significant with p-value < 0.05

† Reference category was year 2010 for DMR screening, and year 2009 for other process and outcome of care criteria

All models are adjusted by baseline characteristics