Primary Care Physician Volume and Quality of Diabetes Care

A Population-Based Cohort Study

Andrew Cheung, MD; Thérèse A. Stukel, PhD; David A. Alter, MD, PhD; Richard H. Glazier, MD, MPH; Vicki Ling, MSc; Xuesong Wang, MSc; and Baiju R. Shah, MD, PhD

Background: A relationship between higher patient volume and both better quality of care and better outcomes has been shown for many acute care conditions. Whether a volume–quality relationship exists for the outpatient management of chronic diseases is uncertain.

Objective: To explore the association between primary care physician volume and quality of diabetes care.

Design: Cohort study.

Setting: The study was conducted using linked population-based health care administrative data in Ontario, Canada.

Patients: 1 018 647 adults with diabetes in 2011 who received care from 9014 primary care physicians. Two measures of volume were ascertained for each physician: overall ambulatory volume (representing time available to devote to chronic disease management during patient encounters) and diabetes-specific volume (representing disease-specific expertise).

Measurements: Quality of care was measured over a 2-year period using 6 indicators: disease monitoring (eye examination, hemoglobin A_{1c} testing, and low-density lipoprotein cholesterol testing), prescription of appropriate medications (angiotensin-converting enzyme inhibitors or angiotensin-receptor blockers and statins), and adverse clinical outcomes (emergency department visits for hypoglycemia or hyperglycemia).

Results: Higher overall ambulatory volume was associated with lower rates of appropriate disease monitoring and medication prescription. In contrast, higher diabetes-specific volume was associated with better quality of care across all 6 indicators.

Limitation: Only a select set of quality indicators and potential confounders could be ascertained from available data.

Conclusion: Primary care physicians with busier ambulatory patient practices delivered lower-quality diabetes care, but those with greater diabetes-specific experience delivered higher-quality care. These findings show that relationships between physician volume and quality can be extended from acute care to outpatient chronic disease care. Health policies or programs to support physicians with low volume of patients with diabetes may improve care.

Primary Funding Source: Canadian Institutes of Health Research.

Ann Intern Med. doi:10.7326/M16-1056 **www.annals.org**
For author affiliations, see end of text.
This article was published at www.annals.org on 13 December 2016.

The volume of patients cared for by a physician affects the quality of the care delivered. Physicians are more skilled when treating larger numbers of patients, and better outcomes may in turn attract more referrals and lead to higher patient volumes (1). However, much of the literature exploring the association between volume and outcomes has focused on acute episodic care, largely delivered by surgeons or hospitals. A large U.S. study showed a strong link between surgeon volume and operative mortality for 8 procedures, with lower operative mortality among high-volume surgeons than their low-volume counterparts (2, 3). Improved performance in process measures and lower acute care mortality are associated with higher hospital volumes for heart failure and coronary artery disease (1, 4). Critically ill patients achieve better outcomes in higher-volume centers (5). In contrast to this extensive body of research, much less is known about whether physician volume influences outcomes in the outpatient management of chronic diseases.

Diabetes mellitus is an archetypal complex chronic disease. It has high prevalence, is associated with multiple other chronic diseases, and is managed overwhelmingly in primary care. Optimal care requires regular clinical and biochemical monitoring, prescription of appropriate medications, and time investment in patient education. Previous studies examining the relationship between physician volume and diabetes care have demonstrated conflicting results, with some studies showing that physicians with more patients with diabetes had better performance for process indicators of quality of care (6), whereas others showed that patients of such physicians were less likely to receive hemoglobin A_{1c} testing (7). A recent Canadian study found that primary care physicians' overall panel size did not influence quality of diabetes care (8). Physician volume might affect chronic disease care in 2 ways. First, physicians with large overall ambulatory volumes may face greater time constraints during office visits. These physicians may have fewer opportunities to focus on chronic disease management, particularly for patients with multiple complex and competing chronic diseases. In contrast, physicians caring for large numbers of patients with diabetes may develop greater expertise with the disease, leading to more efficient and higher-quality care. In this study, we examined both of these constructs for physician volume. Our objective was to explore the associations of both overall ambulatory volume and diabetes-specific volume with quality of diabetes care among primary care physicians in Ontario, Canada.

See also:

Editorial comment

METHODS

Study Design and Data Sources

We conducted a population-based cohort study using data from provincial health care administrative databases. These include the Ontario Health Insurance Plan database, which records all billing claims submitted by Ontario physicians for services; the Discharge Abstract Database, which records detailed information on all admissions to Ontario hospitals; the National Ambulatory Care Reporting System, which records detailed information on all emergency department visits; the Registered Persons Database, which records demographic information and deaths for all residents; the Ontario Drug Benefit program database, which records all prescriptions filled under the provincial formulary for patients aged 65 years or older; and the Ontario Diabetes Database, a registry of all patients with nongestational diabetes. The registry has been validated against primary care chart review and was found to have a sensitivity of 86% and a positive predictive value of 80% (9). Individuals are linked between the databases using unique encoded identifiers. Ontario has a single-payer universal health care system, and these databases therefore detail virtually all care received by all residents of the province.

Study Population

We identified all adult residents of Ontario aged 20 to 104 years who were recorded in the Ontario Diabetes Database as having been diagnosed with diabetes as of the index date (31 March 2011). Patients were excluded if they died or moved out of the province before 31 March 2013, if they were missing information on socioeconomic status, or if they were registered to receive health care in Ontario for less than 5 years before the index date (to ensure adequate look-back for baseline characteristics). Each patient was assigned to their usual primary care provider (10); in Canada, primary care is delivered predominantly by family physicians. All patients whose usual provider was not a comprehensive primary care physician (such as a family physician specializing in sports medicine or palliative care) were excluded (11).

Exposures and Outcomes

Two constructs for volume were defined for each primary care physician, based on their clinical activity in the 3 years preceding the index date: overall ambulatory volume and diabetes-specific volume. Overall ambulatory volume was calculated as the number of outpatient visits of any type the physician had during this period divided by the number of days the physician worked during this period (any days with ≤4 visits were excluded because they did not represent typical ambulatory practice days). Thus, physicians working part-time or for only part of the period were not penalized. Diabetes-specific volume was defined as the number of patients with diabetes for whom the physician was the usual primary care provider. To aid in interpreting the results, we created 5 groups for each volume measure defined at clinically meaningful cut points that were determined independent of the outcome results. The cut points were 20, 25, 30, and 40 patients per day for overall ambulatory volume and 100, 150, 200, and 300 patients for diabetes-specific volume.

We examined several patient-level indicators for the quality of diabetes care. Indicators were broadly categorized into 3 domains: 1) appropriate disease monitoring and testing within 2 years after the index date (≥1 eye examination, ≥3 hemoglobin A_{1c} tests, and ≥1 low-density lipoprotein [LDL] cholesterol test); 2) prescription of appropriate medications within 1 year after the index date (angiotensin-converting enzyme inhibitors [ACEIs] or angiotensin-receptor blockers [ARBs] and statins); and 3) adverse clinical outcomes within 2 years after the index date (emergency department visits with hypoglycemia, hyperglycemia, or their clinical consequences recorded as the patient's main problem; see **Appendix Table 1**, available at www.annals.org). For emergency department visits, lower frequency was considered higher-quality care; for the other indicators, higher frequency was considered higher-quality care. Prescriptions were assessed only for patients aged 65 years or older because they were eligible for the Ontario Drug Benefit program.

To better ensure that the observed associations with volume were specific to quality of diabetes care, we also examined 2 tracer indicators for which no relationship with either overall or diabetes-specific patient volume was expected: hospitalization for hip fracture and for cholecystectomy.

Statistical Analysis

Logistic regression modeling using generalized estimating equations was used to determine the association between volume and each quality-of-care indicator, with clustering of patients within physicians. We assumed an equicorrelation structure because patients of the same physician likely had similar outcomes. This model produces marginal or population-averaged odds ratios. Overall ambulatory volume and diabetes-specific volume were simultaneously modeled as physician-level exposures in each model. They were modeled first as log-transformed continuous variables to establish the existence of a trend for each quality indicator. We then modeled the outcomes as a function of the volume categories. From this model, predictive margins and their SEs were computed. Predictive margins are a type of direct standardization that average predicted values from regression models across the covariate distribution in the population. In contrast to odds ratios, they provide a measure of absolute rather than relative difference in quality indicators.

All models were adjusted for the following patient-level baseline confounders: age (20 to 54, 55 to 64, 65 to 74, and ≥75 years), sex, and their interactions; diabetes duration; socioeconomic status (measured ecologically as neighborhood-level household income); physician access (measured as the number of ambulatory visits to any physician in the preceding year); specialist involvement (defined as ambulatory care from an internist or endocrinologist in the preceding year; in

Canada, these physicians do not provide primary care); and acute myocardial infarction or congestive heart failure hospitalization in the previous 5 years. Models were also adjusted for the following physician-level confounders: sex, age, years since medical school graduation, medical school location, and the location of the physician's practice (measured as the median Rurality Index of Ontario score [12] for the patients assigned to their practice and categorized into urban, nonurban and rural; this score is an integrated measure of rurality based on population, population density, and travel time to basic and advanced medical services). The 2 tracer indicators were examined similarly, with the same covariate adjustment.

We conducted a sensitivity analysis that included patients with incomplete follow-up who had been excluded from the primary analysis because they had died or left Ontario. To ensure that the observed volume–outcome relationship was not a proxy for area variation in volumes and outcomes, we conducted another sensitivity analysis where we controlled for the 78 Ontario physician networks in the regression models (10). These are virtual networks of primary care physicians who care for common patients and share resources, such as acute care beds, specialists, and medical technologies. To assess the potential effect of unmeasured confounding, we conducted another sensitivity analysis using the methods of Lin and colleagues (13) to estimate the difference in prevalence between the highest- and lowest-volume groups of an unmeasured confounder that increased the odds of the outcome by 50% that would cause the observed CI to cross unity. Finally, we repeated the primary analyses with stratification on specialist care, physician full-time or part-time practice, and the primary care payment model under which the physician practiced (14). Over the past 15 years, about three quarters of Ontario primary care physicians joined patient enrollment models, all of which involve formal enrollment of patients; requirements to provide after-hours care; and incentives, including an annual fee for diabetes care using a flow sheet that captures recommended elements of care. These models have blended payment and vary in whether they are mostly fee-for-service (called enhanced fee-for-service) or mostly capitation. About half of capitation-based practices also joined a Family Health Team (team-based capitation), and the remainder did not (non–team-based capitation). There are several other smaller models of care, and the remainder of primary care physicians practice outside a model of care and remain in straight fee-for-service reimbursement.

Models were run using the GENMOD procedure in SAS Enterprise Guide, version 6.1 (SAS Institute). Marginal probabilities were computed using the XTGEE command in STATA/MP, version 13.1 (StataCorp).

Ethics Approval

The study was approved by the research ethics board of Sunnybrook Health Sciences Centre, Toronto, Ontario.

Role of the Funding Source

Funding for the study was provided by the Canadian Institutes of Health Research, which had no involvement in the design of the study, analysis or interpretation of the data, or the decision to publish the results.

RESULTS

There were 1 203 721 patients with diabetes as of 31 March 2011. We excluded 10 100 patients who were not aged 20 to 104 years, 15 898 who were not Ontario residents, 33 177 without 5 years of look-back for baseline characteristics, 62 852 who could not be assigned to a comprehensive primary care physician, 58 432 who died or moved before 31 March 2013, and 4615 with missing data on socioeconomic status. Our final cohort included 1 018 647 patients with diabetes assigned to 9014 primary care physicians. Baseline characteristics for physicians and patients are presented in Tables 1 and 2. Nearly all physicians with high overall ambulatory volume had urban practices and were receiving fee-for-service remuneration. Patients of physicians with low diabetes-specific volume were younger and were more likely to receive specialist care.

Overall ambulatory volume was inversely related to most quality indicators for diabetes care (Table 3). Compared with patients of physicians with the lowest overall volume, patients of those with higher volumes had lower marginal rates of appropriate eye examination, hemoglobin A_{1c} testing, and LDL cholesterol testing. Similarly, these patients were less likely to fill prescriptions for ACEIs or ARBs and for statins. Marginal rates of emergency department visits for hypoglycemia and hyperglycemia were lower with increasing overall ambulatory volume, but the trend did not reach statistical significance.

In contrast, diabetes-specific volume was directly related to quality of diabetes care (Table 3). Patients of physicians with higher diabetes-specific volume had higher marginal rates of appropriate eye examinations, hemoglobin A_{1c} testing, and LDL cholesterol testing and higher rates of prescriptions for ACEIs or ARBs and statins. They also had lower rates of emergency department visits for hypoglycemia or hyperglycemia.

The relationships between both overall and diabetes-specific volumes and the tracer indicators are shown in Appendix Table 2 (available at www.annals.org). There were no differences across overall ambulatory patient volume or diabetes-specific volume groups for both tracer indicators.

A sensitivity analysis that included patients with incomplete follow-up found slightly lower predictive margins for all indicators (data not shown). However, the overall trends and the consistency in the relationship between volume and quality of care were unchanged. Similarly, a sensitivity analysis adding Ontario physician networks in the regression models led to virtually identical results for all indicators (data not shown), suggesting no confounding by location.

Table 1. Baseline Patient and Physician Characteristics: Overall Ambulatory Volume*

Characteristic	Overall Ambulatory Volume				
	≤20 Patients/Day	>20–≤25 Patients/Day	>25–≤30 Patients/Day	>30–≤40 Patients/Day	>40 Patients/Day
Patients					
Total	191 431	184 851	175 808	239 595	226 962
Age					
20–54 y	53 029 (27.7)	50 058 (27.1)	48 905 (27.8)	68 714 (28.7)	73 519 (32.4)
55–64 y	51 035 (26.7)	48 428 (26.2)	46 674 (26.5)	64 018 (26.7)	60 891 (26.8)
65–74 y	46 711 (24.4)	45 085 (24.4)	42 694 (24.3)	57 423 (24.0)	51 181 (22.6)
≥75 y	40 656 (21.2)	41 280 (22.3)	37 535 (21.3)	49 440 (20.6)	41 371 (18.2)
Sex					
Female	98 838 (51.6)	91 899 (49.7)	83 932 (47.7)	112 088 (46.8)	105 326 (46.4)
Male	92 593 (48.4)	92 952 (50.3)	91 876 (52.3)	127 507 (53.2)	121 636 (53.6)
Diabetes duration					
<2 y	29 927 (15.6)	28 107 (15.2)	26 613 (15.1)	35 702 (14.9)	33 865 (14.9)
2–<5 y	41 733 (21.8)	40 359 (21.8)	38 560 (21.9)	52 906 (22.1)	51 954 (22.9)
5–<10 y	55 092 (28.8)	53 063 (28.7)	51 160 (29.1)	69 393 (29.0)	67 834 (29.9)
≥10 y	64 679 (33.8)	63 322 (34.3)	59 475 (33.8)	81 594 (34.1)	73 309 (32.3)
Socioeconomic status					
Lowest	40 013 (20.9)	37 558 (20.3)	35 782 (20.4)	50 935 (21.3)	53 958 (23.8)
Second-lowest	38 930 (20.3)	38 531 (20.8)	36 790 (20.9)	52 113 (21.8)	52 905 (23.3)
Middle	36 696 (19.2)	37 079 (20.1)	35 749 (20.3)	49 644 (20.7)	48 348 (21.3)
Second-highest	38 211 (20.0)	37 659 (20.4)	35 988 (20.5)	48 251 (20.1)	40 832 (18.0)
Highest	37 581 (19.6)	34 024 (18.4)	31 499 (17.9)	38 652 (16.1)	30 919 (13.6)
Specialist involvement in care	36 528 (19.1)	34 623 (18.7)	33 117 (18.8)	44 931 (18.8)	42 339 (18.7)
Prior hospitalization for acute myocardial infarction or congestive heart failure	8134 (4.2)	7617 (4.1)	7214 (4.1)	9630 (4.0)	8536 (3.8)
Prior all-cause hospitalization	20 767 (10.8)	19 079 (10.3)	17 325 (9.9)	23 091 (9.6)	20 517 (9.0)
Physicians					
Total	3165	1821	1339	1546	1143
Sex					
Female	1806 (57.1)	791 (43.4)	429 (32.0)	378 (24.5)	214 (18.7)
Male	1359 (42.9)	1030 (56.6)	910 (68.0)	1168 (75.5)	929 (81.3)
Age					
≤40 y	806 (25.5)	314 (17.2)	165 (12.3)	189 (12.2)	99 (8.7)
41–50 y	892 (28.2)	472 (25.9)	334 (24.9)	397 (25.7)	366 (32.0)
51–60 y	806 (25.5)	591 (32.5)	421 (31.4)	479 (31.0)	377 (33.0)
≥61 y	661 (20.9)	444 (24.4)	419 (31.3)	481 (31.1)	301 (26.3)
Years since graduation					
≤15	1003 (31.7)	403 (22.1)	202 (15.1)	248 (16.0)	136 (11.9)
16–25	856 (27.0)	475 (26.1)	368 (27.5)	388 (25.1)	386 (33.8)
26–35	730 (23.1)	561 (30.8)	404 (30.2)	473 (30.6)	357 (31.2)
≥36	576 (18.2)	382 (21.0)	365 (27.3)	437 (28.3)	264 (23.1)
Medical school location					
Canada	2635 (83.3)	1409 (77.4)	977 (73.0)	958 (62.0)	656 (57.4)
Foreign	530 (16.7)	412 (22.6)	362 (27.0)	588 (38.0)	487 (42.6)
Practice location					
Urban	2233 (70.6)	1301 (71.4)	1056 (78.9)	1264 (81.8)	985 (86.2)
Nonurban	496 (15.7)	364 (20.0)	229 (17.1)	232 (15.0)	137 (12.0)
Rural	436 (13.8)	156 (8.6)	54 (4.0)	50 (3.2)	21 (1.8)
Payment model					
Team-based capitation	859 (27.1)	386 (21.2)	161 (12.0)	99 (6.4)	23 (2.0)
Non–team-based capitation	524 (16.6)	377 (20.7)	299 (22.3)	229 (14.8)	72 (6.3)
Enhanced fee-for-service	777 (24.5)	667 (36.6)	633 (47.3)	871 (56.3)	725 (63.4)
Traditional fee-for-service	879 (27.8)	364 (20.0)	237 (17.7)	333 (21.5)	319 (27.9)
Other	126 (4.0)	27 (1.5)	9 (0.7)	14 (0.9)	4 (0.3)
Part-time vs. full-time practice					
Part-time	2452 (77.5)	931 (51.1)	500 (37.3)	419 (27.1)	182 (15.9)
Full-time	713 (22.5)	890 (48.9)	839 (62.7)	1127 (72.9)	961 (84.1)
Diabetes-specific volume					
≤100 patients	2583 (81.6)	930 (51.1)	443 (33.1)	463 (29.9)	322 (28.2)
101–150 patients	422 (13.3)	504 (27.7)	359 (26.8)	268 (17.3)	125 (10.9)
151–200 patients	127 (4.0)	266 (14.6)	314 (23.5)	352 (22.8)	166 (14.5)
201–300 patients	29 (0.9)	110 (6.0)	189 (14.1)	344 (22.3)	279 (24.4)
≥301 patients	4 (0.1)	11 (0.6)	34 (2.5)	119 (7.7)	251 (22.0)

* Values are numbers (percentages) unless otherwise indicated. Percentages may not sum to 100 due to rounding.

Table 2. Baseline Patient and Physician Characteristics: Diabetes-Specific Volume*

Characteristic	Diabetes-Specific Volume				
	≤100 Patients	101–150 Patients	151–200 Patients	201–300 Patients	≥301 Patients
Patients					
Total	207 168	209 551	212 027	226 969	162 932
Age					
20–54 y	68 104 (32.9)	58 190 (27.8)	56 761 (26.8)	62 876 (27.7)	48 294 (29.6)
55–64 y	54 505 (26.3)	55 295 (26.4)	56 949 (26.9)	60 570 (26.7)	43 727 (26.8)
65–74 y	45 707 (22.1)	50 894 (24.3)	52 561 (24.8)	55 079 (24.3)	38 853 (23.8)
≥75 y	38 852 (18.8)	45 172 (21.6)	45 756 (21.6)	48 444 (21.3)	32 058 (19.7)
Sex					
Female	112 059 (54.1)	101 041 (48.2)	98 202 (46.3)	104 789 (46.2)	75 992 (46.6)
Male	95 109 (45.9)	108 510 (51.8)	113 825 (53.7)	122 180 (53.8)	86 940 (53.4)
Diabetes duration					
<2 y	33 894 (16.4)	31 836 (15.2)	31 898 (15.0)	33 478 (14.8)	23 108 (14.2)
2–<5 y	45 511 (22.0)	45 638 (21.8)	46 176 (21.8)	50 831 (22.4)	37 356 (22.9)
5–<10 y	59 723 (28.8)	60 585 (28.9)	61 061 (28.8)	66 111 (29.1)	49 062 (30.1)
≥10 y	68 040 (32.8)	71 492 (34.1)	72 892 (34.4)	76 549 (33.7)	53 406 (32.8)
Socioeconomic status					
Lowest	41 642 (20.1)	41 190 (19.7)	44 848 (21.2)	50 363 (22.2)	40 203 (24.7)
Second-lowest	40 301 (19.5)	42 311 (20.2)	45 451 (21.4)	51 230 (22.6)	39 976 (24.5)
Middle	39 898 (19.3)	42 020 (20.1)	43 160 (20.4)	48 134 (21.2)	34 304 (21.1)
Second-highest	42 533 (20.5)	43 977 (21.0)	42 275 (19.9)	43 597 (19.2)	28 559 (17.5)
Highest	42 794 (20.7)	40 053 (19.1)	36 293 (17.1)	33 645 (14.8)	19 890 (12.2)
Specialist involvement in care	44 174 (21.3)	39 825 (19.0)	38 437 (18.1)	40 468 (17.8)	28 634 (17.6)
Prior hospitalization for acute myocardial infarction or congestive heart failure	8075 (3.9)	8808 (4.2)	9125 (4.3)	9180 (4.0)	5943 (3.6)
Prior all-cause hospitalization	21 244 (10.3)	21 493 (10.3)	21 690 (10.2)	21 970 (9.7)	14 382 (8.8)
Physicians					
Total	4741	1678	1225	951	419
Sex					
Female	2692 (56.8)	533 (31.8)	218 (17.8)	126 (13.2)	49 (11.7)
Male	2049 (43.2)	1145 (68.2)	1007 (82.2)	825 (86.8)	370 (88.3)
Age					
≤40 y	1318 (27.8)	162 (9.7)	61 (5.0)	25 (2.6)	7 (1.7)
41–50 y	1416 (29.9)	451 (26.9)	285 (23.3)	216 (22.7)	93 (22.2)
51–60 y	1144 (24.1)	584 (34.8)	430 (35.1)	355 (37.3)	161 (38.4)
≥61 y	863 (18.2)	481 (28.7)	449 (36.7)	355 (37.3)	158 (37.7)
Years since graduation					
≤15	1608 (33.9)	241 (14.4)	88 (7.2)	42 (4.4)	13 (3.1)
16–25	1348 (28.4)	469 (27.9)	322 (26.3)	230 (24.2)	104 (24.8)
26–35	1022 (21.6)	553 (33.0)	413 (33.7)	373 (39.2)	164 (39.1)
≥36	763 (16.1)	415 (24.7)	402 (32.8)	306 (32.2)	138 (32.9)
Medical school location					
Canada	3606 (76.1)	1282 (76.4)	861 (70.3)	646 (67.9)	240 (57.3)
Foreign	1135 (23.9)	396 (23.6)	364 (29.7)	305 (32.1)	179 (42.7)
Practice location					
Urban	3675 (77.5)	1174 (70.0)	877 (71.6)	756 (79.5)	357 (85.2)
Nonurban	640 (13.5)	335 (20.0)	265 (21.6)	164 (17.2)	54 (12.9)
Rural	426 (9.0)	169 (10.1)	83 (6.8)	31 (3.3)	8 (1.9)
Payment model					
Team-based capitation	758 (16.0)	374 (22.3)	236 (19.3)	132 (13.9)	28 (6.7)
Non–team-based capitation	615 (13.0)	346 (20.6)	280 (22.9)	193 (20.3)	67 (16.0)
Enhanced fee-for-service	1438 (30.3)	770 (45.9)	611 (49.9)	557 (58.6)	297 (70.9)
Traditional fee-for-service	1801 (38.0)	159 (9.5)	81 (6.6)	64 (6.7)	27 (6.4)
Other	129 (2.7)	29 (1.7)	17 (1.4)	5 (0.5)	0 (0)
Part-time vs. full-time practice					
Part-time	3664 (77.3)	540 (32.2)	196 (16.0)	66 (6.9)	18 (4.3)
Full-time	1077 (22.7)	1138 (67.8)	1029 (84.0)	885 (93.1)	401 (95.7)
Overall ambulatory volume					
≤20 patients/day	2583 (54.5)	422 (25.1)	127 (10.4)	29 (3.0)	4 (1.0)
>20–≤25 patients/day	930 (19.6)	504 (30.0)	266 (21.7)	110 (11.6)	11 (2.6)
>25–≤30 patients/day	443 (9.3)	359 (21.4)	314 (25.6)	189 (19.9)	34 (8.1)
>30–≤40 patients/day	463 (9.8)	268 (16.0)	352 (28.7)	344 (36.2)	119 (28.4)
>40 patients/day	322 (6.8)	125 (7.4)	166 (13.6)	279 (29.3)	251 (59.9)

* Values are numbers (percentages) unless otherwise indicated. Percentages may not sum to 100 due to rounding.

Table 3. Predictive Margins for Each Quality Indicator, by Overall Ambulatory Volume and Diabetes-Specific Volume*

Variable	Quality Indicator					
	Eye Examination	LDL Cholesterol Testing	Hemoglobin A_{1c} Testing	Prescriptions for ACEIs/ARBs	Prescriptions for Statins	Emergency Department Visits for Hypoglycemia or Hyperglycemia
Overall ambulatory volume						
≤20 patients/day	72.0 (71.7–72.4)	85.5 (85.0–85.9)	55.0 (54.1–55.8)	74.7 (74.2–75.2)	74.9 (74.3–75.5)	1.20 (1.14–1.25)
>20–≤25 patients/day	70.8 (70.5–71.2)	85.5 (85.1–85.9)	55.2 (54.4–56.1)	74.2 (73.7–74.7)	73.9 (73.3–74.4)	1.11 (1.06–1.16)
>25–≤30 patients/day	69.5 (69.1–69.9)	85.3 (84.9–85.7)	53.9 (53.0–54.7)	73.1 (72.6–73.7)	73.2 (72.5–73.8)	1.14 (1.09–1.19)
>30–≤40 patients/day	68.2 (67.9–68.6)	84.4 (84.0–84.8)	51.5 (50.7–52.3)	72.3 (71.8–72.8)	72.0 (71.4–72.6)	1.16 (1.11–1.20)
>40 patients/day	67.1 (66.6–67.5)	84.4 (83.9–84.9)	50.1 (49.1–51.1)	70.8 (70.2–71.4)	70.3 (69.6–71.1)	1.14 (1.09–1.20)
P value for trend	<0.001	<0.001	<0.001	<0.001	<0.001	0.150
Diabetes-specific volume						
≤100 patients	67.0 (66.7–67.4)	82.2 (81.7–82.6)	50.0 (49.3–50.8)	70.6 (70.0–71.1)	68.4 (67.8–69.0)	1.26 (1.20–1.32)
101–150 patients	69.3 (68.9–69.7)	84.2 (83.8–84.6)	52.5 (51.8–53.3)	72.2 (71.7–72.7)	71.6 (71.0–72.2)	1.19 (1.14–1.24)
151–200 patients	70.4 (70.0–70.8)	84.6 (84.1–85.0)	53.4 (52.5–54.2)	73.0 (72.5–73.5)	73.1 (72.5–73.7)	1.21 (1.16–1.25)
201–300 patients	70.3 (69.9–70.7)	86.0 (85.6–86.5)	54.7 (53.8–55.7)	74.3 (73.7–74.8)	74.7 (74.0–75.3)	1.09 (1.04–1.14)
≥301 patients	69.8 (69.2–70.4)	87.5 (86.9–88.1)	53.0 (51.6–54.4)	74.7 (73.9–75.6)	76.1 (75.2–77.1)	0.96 (0.90–1.02)
P value for trend	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

ACEI = angiotensin-converting enzyme inhibitor; ARB = angiotensin-receptor blocker; LDL = low-density lipoprotein.
* Values are percentages (95% CIs).

An additional sensitivity analysis was conducted to estimate the potential effect of unmeasured confounding. Across the appropriate disease monitoring and appropriate prescriptions indicators, an unmeasured confounder that increased the odds of the outcome by 50% would have needed a difference in prevalence between the highest- and lowest-volume groups of approximately 30% or more to cause the observed CIs to cross unity.

We explored various factors that might influence the relationship between volume and quality of diabetes care by using a series of stratified analyses. When stratifying on the physician-level factors of payment model, we found no meaningful differences in volume–quality relationships across strata (Appendix Table 3, available at www.annals.org). We also explored whether volume–quality relationships differed among patients who were also being treated by specialists. In general, patients receiving specialist care had better performance on the process measures of quality, but they also had higher rates of emergency department visits. In addition, the gradients in quality of care across both primary care volume measures were modestly lower in magnitude among patients who were receiving specialist care than those who were not (Appendix Table 4, available at www.annals.org). Likewise, the gradients in quality of care across both volume measures did not differ between physicians in full-time practice and those in part-time practice (Appendix Table 5, available at www.annals.org).

DISCUSSION

Our study showed a clear and consistent association between primary care physician volume and quality of diabetes management in an outpatient setting. Patients of physicians with higher overall ambulatory volumes had consistently lower marginal rates of appropriate disease monitoring and appropriate prescriptions, demonstrating worse performance among these physicians. In contrast, higher diabetes-specific volume was associated with higher marginal rates of appropriate disease monitoring and appropriate prescriptions and lower marginal rates of emergency department visits, demonstrating better performance across all 6 indicators. There were clear gradients in marginal rates across overall ambulatory volume groups and diabetes-specific volume groups for nearly all quality indicators, and these gradients were consistent in direction. The magnitude of these gradients is clinically important: If all primary care physicians had achieved the same rate of eye examinations as those with the lowest overall ambulatory volume, more than 25 000 additional patients would have had an examination. These relationships were independent of each other and also of cardiovascular comorbidity and socioeconomic status. We found no differences in the relationships between volume and quality when stratifying by physician payment model, including for team-based care models having greater paramedical resourcing. Likewise, the relationships were similar regardless of whether patients received specialist care.

Although a relationship between volume and quality has previously been demonstrated with procedural and hospital-based volumes, there has been less research demonstrating associations between outpatient volumes and quality of care in chronic disease management. Our study provides evidence of such a relationship in the outpatient context. Furthermore, as expected, there was no relationship between either overall or diabetes-specific volume and the 2 tracer indicators (hip fracture and cholecystectomy), which confirms the specificity of the study findings.

Physicians with busy practices and large numbers of visits per day may have been too rushed during individual patient appointments to ensure that appropriate chronic disease management was addressed, which may explain why lower rates of disease monitoring and fewer prescriptions for appropriate medications were associated with increasing overall patient volume. In contrast, greater diabetes-specific experience was associated with better care. Primary care physicians with high diabetes-specific volume may develop specialized expertise with the disease, which may explain why their patients achieve better performance on quality indicators despite fewer of them actually receiving care from diabetes specialists. The stratified analysis confirmed that patients treated by diabetes specialists had better performance for process quality indicators (15), and it also showed that the effects of volume on quality (both the negative effect of increasing overall ambulatory volume and the positive effect of increasing diabetes-specific volume) were attenuated for these patients.

Most previous research examining volume–outcome relationships in health care has focused on acute episodic care (either surgical care or inpatient acute care). A recent study showed that increasing primary care physician volume for acute respiratory infection was associated with greater antibiotic prescribing rates, greater use of broad-spectrum antibiotics, and lower guideline-concordant care (16). Most other studies examining volume–outcome relationships in the outpatient management of chronic disease have focused on diabetes, and some found results similar to ours. Wang and colleagues reported from a single Taiwanese center and found that for patients treated by nonspecialists, higher overall volume was associated with reduced likelihood of both hemoglobin A_{1c} testing and a hemoglobin A_{1c} level less than 7% (17). Holmboe and associates studied 26 260 Connecticut Medicare beneficiaries and showed that eye examination, hemoglobin A_{1c} testing, and lipid testing increased with larger diabetes-specific volumes (6). However, our findings differ from those of several other published studies. Turchin and coworkers studied patients of 368 primary care physicians at 2 academic centers in Boston, Massachusetts, and found that diabetes-specific volume was negatively associated with hemoglobin A_{1c} testing but was not associated with LDL cholesterol testing (7). A small Danish study found no association between overall volume and hemoglobin A_{1c} levels (18), and a study of about 11 000 patients in the U.S. Department of Veterans Affairs system found no association between overall volume and hemoglobin A_{1c} levels or eye examinations (19). Finally, a recent Canadian study found no relationship between overall volume and hemoglobin A_{1c} testing, lipid testing, or eye examination (8). However, that study examined panel size as the measure of physician volume, whereas our study examined the number of visits per day because this is more closely related to how the time constraints of a physician's practice might affect the quality of care delivered.

Our study differs from and builds on this previously published literature by examining a very large cohort of patients that is population-based rather than being limited to a single center or to academic practices. In addition, the previous studies did not account for the potential effect of concurrent specialist care on quality. Our study was unique in that it found consistent gradients across volume groups and across a range of quality indicators. It examined both overall and diabetes-specific volumes simultaneously and so was able to determine the independent effects of each on quality. Finally, our study examined 2 tracer indicators for which we hypothesized a priori that no relationship with volume would be found, confirming the specificity of our findings.

Our study has several strengths, including its population-based design and inclusion of a broad sample of patients and physicians from a wide variety of settings; the use of routinely collected health care administrative data covering an entire population, ensuring complete ascertainment of outcomes with virtually no missing data or loss to follow-up; and the analysis of quality indicators at the patient level rather than ecologically at the physician level. However, our study also has limitations. First, the Ontario Drug Benefit database captures only prescriptions filled by patients aged 65 years or older, so we could not ascertain drug indicators in younger patients. However, virtually all patients in the age group we studied would have indications for both medication categories studied according to clinical practice guidelines, which strengthens the suitability of these indicators as quality measures. Second, the use of administrative databases precluded the ascertainment of other process quality indicators, such as foot examination or behavioral goal setting, and intermediate quality indicators, such as hemoglobin A_{1c} levels or blood pressure control. Finally, we were unable to adjust our analyses for patient-level clinical factors, such as body mass index, that were unavailable in our data. However, whether these factors require adjustment is uncertain because they are unlikely to differ by physician volume, and the quality indicators we studied apply to all patients regardless of these baseline characteristics.

The identification of an association between physician volume and quality of diabetes management has important implications for both future research and health system planning. Given that we focused predominantly on process measures of quality, future research could explore whether volume and quality are linked in the same way when assessing clinical measures of quality, such as risk factor control or complication rates. In addition, the association between volume and quality or outcomes in the ambulatory management of other chronic diseases (such as coronary artery disease, chronic obstructive pulmonary disease, and cancer screening) could be studied to determine whether these associations are generalizable beyond diabetes. Our findings can also inform future policymaking because they show a positive association between diabetes-specific volume and quality in outpatient diabetes management. Future policies to improve quality of diabetes care may offer peer support and mentoring, point-of-care support, or enhanced specialty–

primary care interactions to primary care physicians with low diabetes-specific volume.

In conclusion, we found a consistent, graded, and independent relationship between primary care physician volumes and a range of diabetes quality-of-care indicators. Physicians with higher overall ambulatory volume had poorer quality of care, whereas those with higher diabetes-specific volume delivered better care. These findings show that relationships between physician volume and quality can be extended from acute care to outpatient chronic disease care.

From University of Toronto, Institute for Clinical Evaluative Sciences, Toronto Rehabilitation Institute, St. Michael's Hospital, and Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada.

Disclaimer: The opinions, results, and conclusions reported in this article are those of the authors. No endorsement by the Canadian Institutes of Health Research, the Institute for Clinical Evaluative Sciences, the Ontario Ministry of Health and Long-Term Care, or the Canadian Institute for Health Information is intended or should be inferred.

Acknowledgment: The authors thank Brogan, Ottawa, Ontario, for use of its Drug Product and Therapeutic Class Database. The study relied on data and information compiled and provided by the Canadian Institute for Health Information.

Grant Support: Funding for the study was provided by a Foundation Grant (FDN143303) and an Emerging Team Grant in Applied Health Services and Policy Research (ETG92248) from the Canadian Institutes of Health Research. Dr. Alter is a Career Investigator with the Heart and Stroke Foundation of Ontario and holds a Research Chair in Cardiovascular Metabolic Rehabilitation at the University Health Network-Toronto Rehabilitation Institute. Dr. Glazier is supported as a clinician-scientist in the Department of Family and Community Medicine at the University of Toronto and at St. Michael's Hospital. The Institute for Clinical Evaluative Sciences is a nonprofit research institute funded by the Ontario Ministry of Health and Long-Term Care.

Disclosures: Authors have disclosed no conflicts of interest. Forms can be viewed at www.acponline.org/authors/icmje/ConflictOfInterestForms.do?msNum=M16-1056.

Reproducible Research Statement: *Study protocol and data set:* Not available. *Statistical code:* Available from Dr. Shah (e-mail, baiju.shah@ices.on.ca).

Requests for Single Reprints: Baiju R. Shah, MD, PhD, Institute for Clinical Evaluative Sciences, G106 – 2075 Bayview Avenue, Toronto, Ontario M4N 3M5, Canada.

Current author addresses and author contributions are available at www.annals.org.

References

1. Halm EA, Lee C, Chassin MR. Is volume related to outcome in health care? A systematic review and methodologic critique of the literature. Ann Intern Med. 2002;137:511-20. [PMID: 12230353] doi:10.7326/0003-4819-137-6-200209170-00012
2. Birkmeyer JD, Siewers AE, Finlayson EV, Stukel TA, Lucas FL, Batista I, et al. Hospital volume and surgical mortality in the United States. N Engl J Med. 2002;346:1128-37. [PMID: 11948273]
3. Birkmeyer JD, Stukel TA, Siewers AE, Goodney PP, Wennberg DE, Lucas FL. Surgeon volume and operative mortality in the United States. N Engl J Med. 2003;349:2117-27. [PMID: 14645640]
4. Joynt KE, Orav EJ, Jha AK. The association between hospital volume and processes, outcomes, and costs of care for congestive heart failure. Ann Intern Med. 2011;154:94-102. [PMID: 21242366] doi:10.7326/0003-4819-154-2-201101180-00008
5. Nguyen YL, Wallace DJ, Yordanov Y, Trinquart L, Blomkvist J, Angus DC, et al. The volume-outcome relationship in critical care: a systematic review and meta-analysis. Chest. 2015;148:79-92. [PMID: 25927593] doi:10.1378/chest.14-2195
6. Holmboe ES, Wang Y, Tate JP, Meehan TP. The effects of patient volume on the quality of diabetic care for Medicare beneficiaries. Med Care. 2006;44:1073-7. [PMID: 17122710]
7. Turchin A, Shubina M, Pendergrass ML. Relationship of physician volume with process measures and outcomes in diabetes. Diabetes Care. 2007;30:1442-7. [PMID: 17337489]
8. Dahrouge S, Hogg W, Younger J, Muggah E, Russell G, Glazier RH. Primary care physician panel size and quality of care: a population-based study in Ontario, Canada. Ann Fam Med. 2016;14:26-33. [PMID: 26755780] doi:10.1370/afm.1864
9. Hux JE, Ivis F, Flintoft V, Bica A. Diabetes in Ontario: determination of prevalence and incidence using a validated administrative data algorithm. Diabetes Care. 2002;25:512-6. [PMID: 11874939]
10. Stukel TA, Glazier RH, Schultz SE, Guan J, Zagorski BM, Gozdyra P, et al. Multispecialty physician networks in Ontario. Open Med. 2013;7:e40-55. [PMID: 24348884]
11. Kiran T, Glazier RH, Campitelli MA, Calzavara A, Stukel TA. Relation between primary care physician supply and diabetes care and outcomes: a cross-sectional study. CMAJ Open. 2016;4:E80-7. [PMID: 27280118] doi:10.9778/cmajo.20150065
12. Kralj B. Measuring "rurality" for purposes of health-care planning: an empirical measure for Ontario. Ont Med Rev. 2000;67:33-52.
13. Lin DY, Psaty BM, Kronmal RA. Assessing the sensitivity of regression results to unmeasured confounders in observational studies. Biometrics. 1998;54:948-63. [PMID: 9750244]
14. Hutchison B, Glazier R. Ontario's primary care reforms have transformed the local care landscape, but a plan is needed for ongoing improvement. Health Aff (Millwood). 2013;32:695-703. [PMID: 23569049] doi:10.1377/hlthaff.2012.1087
15. Shah BR, Hux JE, Laupacis A, Zinman B, Zwarenstein M. Deficiencies in the quality of diabetes care: comparing specialist with generalist care misses the point. J Gen Intern Med. 2007;22:275-9. [PMID: 17357000]
16. Gidengil C, Linder JA, Hunter G, Setodji C, Mehrotra A. The volume-quality relationship in antibiotic prescribing: when more isn't better. Inquiry. 2015;52. [PMID: 25672338] doi:10.1177/0046958015571130
17. Wang JS, Lin SY, Sheu WH, Lee IT, Tseng LN, Song YM. Effects of patient volume on quality of outpatient diabetes care. Diabetes Res Clin Pract. 2009;84:e27-9. [PMID: 19269708] doi:10.1016/j.diabres.2009.02.010
18. Hansen LJ, Olivarius Nde F, Siersma V, Andersen JS. Doctors' characteristics do not predict long-term glycaemic control in type 2 diabetic patients. Br J Gen Pract. 2003;53:47-9. [PMID: 12564278]
19. Stefos T, Burgess JF Jr, Mayo-Smith MF, Frisbee KL, Harvey HB, Lehner L, et al. The effect of physician panel size on health care outcomes. Health Serv Manage Res. 2011;24:96-105. [PMID: 21471580] doi:10.1258/hsmr.2011.011001

Current Author Addresses: Dr. Cheung: Department of Medicine, McMaster University, Health Sciences Centre, 3W10, 1200 Main Street West, Hamilton, Ontario L8N 3Z5, Canada.
Drs. Stukel, Alter, Glazier, and Shah; Ms. Ling; and Ms. Wang: Institute for Clinical Evaluative Sciences, G106 – 2075 Bayview Avenue, Toronto, Ontario M4N 3M5, Canada.

Author Contributions: Conception and design: A. Cheung, T.A. Stukel, D.A. Alter, R.H. Glazier, B.R. Shah.
Analysis and interpretation of the data: A. Cheung, T.A. Stukel, D.A. Alter, R.H. Glazier, V. Ling, X. Wang, B.R. Shah.
Drafting of the article: A. Cheung.
Critical revision of the article for important intellectual content: T.A. Stukel, D.A. Alter, R.H. Glazier, B.R. Shah.
Final approval of the article: A. Cheung, T.A. Stukel, D.A. Alter, R.H. Glazier, V. Ling, X. Wang, B.R. Shah.
Statistical expertise: T.A. Stukel.
Obtaining of funding: T.A. Stukel.

Appendix Table 1. ICD-10-CA Codes Used to Identify Emergency Department Visits for Hypoglycemia and Hyperglycemia

Code	Description
E10.0*	Type 1 diabetes mellitus with coma
E10.1*	Type 1 diabetes mellitus with ketoacidosis
E10.63	Type 1 diabetes mellitus with hypoglycemia
E11.0*	Type 2 diabetes mellitus with coma or hyperosmolarity
E11.1*	Type 2 diabetes mellitus with ketoacidosis
E11.63	Type 2 diabetes mellitus with hypoglycemia
E13.0*	Other specified diabetes mellitus with coma or hyperosmolarity
E13.1*	Other specified diabetes mellitus with ketoacidosis
E13.63	Other specified diabetes mellitus with hypoglycemia
E14.0*	Unspecified diabetes mellitus with coma or hyperosmolarity
E14.1*	Unspecified diabetes mellitus with ketoacidosis
E14.63	Unspecified diabetes mellitus with hypoglycemia
E15	Hypoglycemic coma
E16.0	Drug-induced hypoglycemia
E16.1	Other hypoglycemia
E16.2	Hypoglycemia, unspecified
R73.*	Abnormal glucose test
T38.3	Poisoning by insulin and oral hypoglycemic drugs

ICD-10-CA = International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Canada.

Appendix Table 2. Predictive Margins for Each Tracer Indicator, by Overall Ambulatory Volume and Diabetes-Specific Volume*

Variable	Tracer Indicator	
	Hip Fracture	Cholecystectomy
Overall ambulatory volume		
≤20 patients/day	0.41 (0.38–0.45)	0.22 (0.19–0.24)
>20–≤25 patients/day	0.40 (0.38–0.43)	0.22 (0.20–0.24)
>25–≤30 patients/day	0.43 (0.40–0.46)	0.20 (0.18–0.22)
>30–≤40 patients/day	0.41 (0.38–0.44)	0.21 (0.19–0.23)
>40 patients/day	0.42 (0.39–0.45)	0.22 (0.19–0.24)
P value for trend	0.66	0.141
Diabetes-specific volume		
≤100 patients	0.43 (0.39–0.46)	0.23 (0.20–0.26)
101–150 patients	0.44 (0.41–0.47)	0.22 (0.20–0.24)
151–200 patients	0.42 (0.39–0.45)	0.22 (0.20–0.24)
201–300 patients	0.39 (0.37–0.42)	0.20 (0.18–0.22)
≥301 patients	0.38 (0.35–0.42)	0.20 (0.17–0.22)
P value for trend	0.152	0.42

* Values are percentages (95% CIs).

Appendix Table 3. Predictive Margins for Each Quality Indicator According to Overall Ambulatory Volume and Diabetes-Specific Volume: Stratified by Primary Care Payment Model*

Payment Model, by Quality Indicator	Overall Ambulatory Volume					*P* Value for Trend
	≤20 Patients/Day	>20–≤25 Patients/Day	>25–≤30 Patients/Day	>30–≤40 Patients/Day	>40 Patients/Day	
Eye examination						
Team-based capitation	74.2 (73.7–74.8)	74.3 (73.7–75.0)	73.7 (72.8–74.7)	73.3 (72.2–74.5)	72.6 (70.2–74.9)	0.038
Non–team-based capitation	72.6 (71.8–73.4)	72.9 (72.2–73.7)	72.1 (71.3–72.8)	71.4 (70.6–72.2)	72.5 (71.1–73.9)	0.042
Enhanced fee-for-service	68.6 (67.8–69.3)	68.3 (67.6–68.9)	67.8 (67.2–68.4)	67.2 (66.7–67.7)	66.5 (66.0–67.0)	<0.001
Traditional fee-for-service	69.9 (68.9–70.9)	66.9 (65.7–68.1)	66.3 (65.0–67.6)	64.0 (62.9–65.1)	62.5 (61.5–63.5)	<0.001
Other	78.2 (77.1–79.3)	79.2 (77.2–81.2)	76.7 (73.0–80.3)	75.4 (72.2–78.7)	76.3 (70.7–81.9)	0.010
LDL cholesterol testing						
Team-based capitation	85.0 (84.2–85.8)	84.4 (83.6–85.2)	84.5 (83.2–85.7)	83.4 (81.9–85.0)	81.0 (77.5–84.6)	0.008
Non–team-based capitation	84.6 (83.6–85.6)	85.1 (84.2–85.9)	84.2 (83.3–85.1)	83.3 (82.2–84.4)	81.6 (79.6–83.6)	0.001
Enhanced fee-for-service	86.3 (85.6–87.0)	86.4 (85.8–87.0)	86.3 (85.7–86.9)	85.2 (84.7–85.7)	84.8 (84.3–85.3)	<0.001
Traditional fee-for-service	85.2 (84.0–86.3)	85.8 (84.5–87.1)	84.6 (83.1–86.1)	83.1 (81.8–84.4)	81.9 (80.4–83.4)	<0.001
Other	83.9 (82.0–85.7)	86.9 (84.2–89.6)	86.3 (81.3–91.3)	82.2 (77.8–86.7)	88.3 (82.4–94.3)	0.118
Hemoglobin A_{1c} testing						
Team-based capitation	58.9 (57.4–60.3)	58.4 (56.9–59.9)	58.4 (56.2–60.7)	55.8 (53.0–58.7)	51.6 (45.4–57.8)	0.025
Non–team-based capitation	55.5 (53.6–57.4)	57.6 (55.8–59.3)	55.7 (53.9–57.5)	53.0 (50.9–55.1)	52.7 (49.0–56.4)	0.055
Enhanced fee-for-service	50.3 (48.8–51.8)	52.4 (51.0–53.7)	52.5 (51.3–53.7)	50.9 (49.9–51.9)	50.5 (49.4–51.6)	0.017
Traditional fee-for-service	53.5 (51.0–55.9)	53.2 (50.4–56.1)	49.6 (46.5–52.8)	48.4 (45.8–51.0)	44.8 (42.1–47.5)	<0.001
Other	64.4 (61.7–67.1)	65.9 (61.6–70.2)	64.2 (56.2–72.1)	69.0 (63.0–74.9)	68.8 (59.3–78.3)	0.097
Prescriptions for ACEIs/ARBs						
Team-based capitation	75.9 (75.1–76.7)	74.7 (73.9–75.5)	74.2 (73.0–75.5)	72.6 (71.0–74.3)	71.7 (68.4–75.0)	<0.001
Non–team-based capitation	74.0 (72.9–75.1)	74.7 (73.7–75.7)	73.0 (71.9–74.0)	72.7 (71.5–73.8)	72.8 (70.8–74.8)	0.133
Enhanced fee-for-service	73.2 (72.2–74.2)	73.3 (72.4–74.2)	73.2 (72.4–74.1)	72.8 (72.2–73.5)	71.6 (70.8–72.3)	<0.001
Traditional fee-for-service	72.4 (71.0–73.9)	72.3 (70.6–74.0)	70.2 (68.4–72.1)	68.5 (67.0–70.1)	67.8 (66.2–69.4)	<0.001
Other	75.5 (73.4–77.5)	75.8 (72.4–79.2)	78.1 (72.5–83.8)	76.5 (71.4–81.7)	72.5 (62.1–82.9)	0.92
Prescriptions for statins						
Team-based capitation	74.4 (73.4–75.4)	73.2 (72.2–74.3)	72.2 (70.6–73.8)	72.4 (70.3–74.5)	69.2 (64.9–73.6)	0.015
Non–team-based capitation	74.0 (72.8–75.3)	74.4 (73.3–75.5)	73.4 (72.2–74.5)	72.1 (70.8–73.4)	70.3 (67.9–72.7)	0.008
Enhanced fee-for-service	75.5 (74.4–76.6)	74.2 (73.2–75.2)	74.1 (73.2–75.1)	73.1 (72.3–73.8)	71.9 (71.1–72.8)	<0.001
Traditional fee-for-service	71.3 (69.6–73.0)	69.6 (67.5–71.6)	69.4 (67.1–71.6)	67.8 (65.9–69.7)	65.8 (63.9–67.8)	<0.001
Other	73.0 (70.7–75.3)	73.0 (69.0–77.0)	73.3 (66.2–80.4)	69.7 (63.3–76.0)	74.7 (63.6–85.7)	0.42
Emergency department visits for hypoglycemia or hyperglycemia						
Team-based capitation	1.40 (1.30–1.50)	1.35 (1.24–1.45)	1.48 (1.32–1.65)	1.32 (1.13–1.51)	1.58 (1.18–1.97)	0.79
Non–team-based capitation	1.30 (1.17–1.43)	1.13 (1.03–1.23)	1.27 (1.16–1.37)	1.29 (1.18–1.40)	1.37 (1.17–1.56)	0.79
Enhanced fee-for-service	1.02 (0.93–1.12)	0.95 (0.87–1.03)	0.95 (0.88–1.02)	1.07 (1.01–1.12)	1.07 (1.00–1.13)	0.016
Traditional fee-for-service	1.05 (0.90–1.20)	1.16 (0.98–1.35)	1.15 (0.95–1.34)	1.06 (0.90–1.21)	1.22 (1.06–1.38)	0.77
Other	1.49 (1.22–1.76)	1.63 (1.08–2.17)	1.75 (0.74–2.76)	1.50 (0.68–2.33)	1.08 (–.00–2.17)	0.146
	Diabetes-Specific Volume					
	≤100 Patients	101–150 Patients	151–200 Patients	201–300 Patients	≥301 Patients	
Eye examination						
Team-based capitation	74.1 (73.4–74.8)	74.2 (73.6–74.8)	74.6 (73.9–75.3)	73.1 (72.1–74.0)	73.9 (71.9–75.9)	0.43
Non–team-based capitation	72.0 (71.1–72.8)	72.6 (71.9–73.3)	72.3 (71.6–73.1)	72.8 (71.9–73.6)	71.0 (69.5–72.4)	0.39
Enhanced fee-for-service	66.3 (65.7–66.9)	67.2 (66.7–67.8)	68.2 (67.7–68.8)	67.8 (67.3–68.4)	66.9 (66.1–67.6)	<0.001
Traditional fee-for-service	62.3 (61.5–63.0)	67.2 (66.1–68.3)	67.2 (65.7–68.6)	67.4 (65.8–69.0)	68.9 (66.7–71.2)	<0.001
Other	77.6 (76.0–79.1)	78.4 (76.7–80.2)	77.6 (75.0–80.2)	79.6 (75.8–83.5)	NA	0.055
LDL cholesterol testing						
Team-based capitation	83.0 (82.0–84.0)	84.2 (83.3–85.0)	84.4 (83.4–85.4)	85.6 (84.4–86.8)	86.3 (83.8–88.7)	<0.001
Non–team-based capitation	81.6 (80.4–82.8)	83.2 (82.3–84.1)	84.3 (83.4–85.2)	84.9 (83.8–85.9)	86.4 (84.7–88.0)	<0.001
Enhanced fee-for-service	82.2 (81.5–82.9)	84.3 (83.7–84.9)	84.6 (84.0–85.2)	86.5 (86.0–87.1)	87.9 (87.3–88.6)	<0.001
Traditional fee-for-service	80.5 (79.4–81.6)	84.2 (82.8–85.5)	85.0 (83.4–86.6)	85.7 (84.0–87.5)	87.5 (85.0–89.9)	<0.001
Other	84.5 (81.8–87.3)	86.0 (83.1–88.8)	83.2 (79.7–86.7)	87.0 (81.8–92.2)	NA	0.84
Hemoglobin A_{1c} testing						
Team-based capitation	57.3 (55.7–59.0)	57.6 (56.1–59.2)	58.1 (56.3–59.9)	59.1 (56.7–61.5)	58.5 (53.1–63.9)	0.039
Non–team-based capitation	53.0 (51.0–55.1)	54.9 (53.2–56.6)	55.3 (53.5–57.1)	56.7 (54.5–58.9)	55.7 (51.8–59.5)	0.017
Enhanced fee-for-service	49.2 (48.0–50.4)	51.4 (50.3–52.5)	51.2 (50.0–52.3)	52.7 (51.5–53.9)	50.3 (48.7–52.0)	<0.001
Traditional fee-for-service	46.8 (45.0–48.6)	48.4 (45.7–51.0)	51.1 (47.7–54.5)	51.8 (47.9–55.8)	51.2 (45.0–57.4)	<0.001
Other	63.8 (59.8–67.9)	67.1 (62.6–71.5)	64.4 (59.4–69.4)	68.2 (60.0–76.3)	NA	0.99

Continued on following page

Appendix Table 3—Continued

Payment Model, by Quality Indicator	Diabetes-Specific Volume					*P* Value for Trend
	≤100 Patients	101–150 Patients	151–200 Patients	201–300 Patients	≥301 Patients	
Prescriptions for ACEIs/ARBs						
Team-based capitation	73.2 (72.2–74.2)	74.3 (73.4–75.1)	75.0 (74.0–76.0)	76.5 (75.3–77.7)	76.5 (73.9–79.1)	<0.001
Non–team-based capitation	72.0 (70.7–73.2)	72.3 (71.3–73.3)	73.4 (72.4–74.4)	75.0 (73.9–76.2)	74.8 (72.9–76.8)	0.017
Enhanced fee-for-service	70.7 (69.8–71.7)	72.3 (71.6–73.1)	72.5 (71.7–73.2)	73.0 (72.3–73.8)	73.6 (72.6–74.6)	<0.001
Traditional fee-for-service	68.4 (67.3–69.6)	68.9 (67.3–70.4)	69.6 (67.6–71.6)	72.9 (70.8–74.9)	73.5 (70.5–76.6)	<0.001
Other	75.9 (73.1–78.8)	77.8 (74.9–80.8)	73.5 (69.3–77.8)	75.3 (68.4–82.1)	NA	0.54
Prescriptions for statins						
Team-based capitation	70.5 (69.3–71.8)	72.1 (71.0–73.2)	73.8 (72.6–75.1)	76.9 (75.3–78.4)	75.7 (72.2–79.1)	<0.001
Non–team-based capitation	70.7 (69.3–72.2)	71.8 (70.7–73.0)	73.3 (72.1–74.4)	74.4 (73.0–75.7)	76.3 (74.1–78.4)	<0.001
Enhanced fee-for-service	68.4 (67.4–69.5)	72.3 (71.4–73.2)	73.4 (72.5–74.3)	74.4 (73.6–75.3)	75.6 (74.5–76.8)	<0.001
Traditional fee-for-service	65.6 (64.3–66.9)	68.0 (66.1–69.9)	68.7 (66.1–71.2)	70.7 (68.0–73.5)	75.6 (71.7–79.4)	<0.001
Other	69.8 (66.4–73.3)	75.9 (72.5–79.2)	71.5 (66.6–76.5)	76.3 (68.7–83.9)	NA	0.199
Emergency department visits for hypoglycemia or hyperglycemia						
Team-based capitation	1.49 (1.35–1.63)	1.39 (1.28–1.51)	1.37 (1.25–1.50)	1.35 (1.20–1.51)	1.17 (0.90–1.44)	0.077
Non–team-based capitation	1.31 (1.16–1.46)	1.38 (1.26–1.50)	1.32 (1.21–1.42)	1.15 (1.04–1.25)	1.07 (0.92–1.22)	0.121
Enhanced fee-for-service	1.19 (1.10–1.29)	1.09 (1.02–1.16)	1.11 (1.04–1.18)	0.97 (0.91–1.02)	0.85 (0.79–0.91)	<0.001
Traditional fee-for-service	1.26 (1.13–1.39)	1.04 (0.89–1.20)	1.11 (0.92–1.31)	1.11 (0.92–1.31)	0.82 (0.60–1.04)	0.003
Other	1.78 (1.33–2.24)	1.53 (1.08–1.98)	1.14 (0.63–1.65)	1.11 (0.35–1.87)	NA	0.119

ACEI = angiotensin-converting enzyme inhibitor; ARB = angiotensin-receptor blocker; LDL = low-density lipoprotein; NA = not applicable.
* Values are percentages (95% CIs).

Appendix Table 4. Predictive Margins for Each Quality Indicator According to Overall Ambulatory Volume and Diabetes-Specific Volume: Stratified by Specialist Care*

Specialist Care, by Quality Indicator	Overall Ambulatory Volume					*P* Value for Trend
	≤20 Patients/Day	>20–≤25 Patients/Day	>25–≤30 Patients/Day	>30–≤40 Patients/Day	>40 Patients/Day	
Eye examination						
No	69.5 (69.1–70.0)	68.2 (67.7–68.6)	66.9 (66.4–67.4)	65.6 (65.2–66.0)	64.3 (63.8–64.8)	<0.001
Yes	81.5 (81.0–82.0)	81.0 (80.5–81.5)	79.9 (79.4–80.4)	79.2 (78.7–79.6)	78.5 (78.0–79.0)	<0.001
LDL cholesterol testing						
No	85.1 (84.6–85.5)	84.9 (84.5–85.4)	84.6 (84.1–85.0)	83.6 (83.2–84.1)	83.5 (83.0–84.0)	<0.001
Yes	87.1 (86.6–87.7)	88.1 (87.7–88.6)	88.2 (87.7–88.8)	87.5 (87.1–88.0)	88.4 (87.9–89.0)	0.034
Hemoglobin A_{1c} testing						
No	52.3 (51.4–53.3)	52.3 (51.4–53.2)	50.8 (49.8–51.8)	48.3 (47.4–49.2)	46.5 (45.4–47.5)	<0.001
Yes	65.5 (64.6–66.4)	67.2 (66.4–68.0)	66.9 (66.1–67.8)	65.7 (64.9–66.5)	65.7 (64.8–66.6)	0.52
Prescriptions for ACEIs/ARBs						
No	73.3 (72.7–73.9)	72.6 (72.1–73.2)	71.6 (71.0–72.2)	70.5 (69.9–71.0)	68.9 (68.2–69.6)	<0.001
Yes	80.6 (79.8–81.3)	81.0 (80.3–81.7)	80.0 (79.3–80.7)	80.1 (79.4–80.7)	79.6 (78.9–80.4)	0.011
Prescriptions for statins						
No	73.2 (72.5–73.9)	72.1 (71.4–72.7)	71.4 (70.7–72.1)	70.0 (69.4–70.7)	68.2 (67.4–69.0)	<0.001
Yes	82.0 (81.2–82.7)	81.2 (80.4–81.9)	81.0 (80.3–81.8)	80.9 (80.3–81.6)	79.9 (79.0–80.7)	<0.001
Emergency department visits hypoglycemia or hyperglycemia						
No	0.83 (0.78–0.88)	0.78 (0.74–0.83)	0.81 (0.76–0.86)	0.82 (0.78–0.86)	0.82 (0.77–0.87)	0.72
Yes	2.75 (2.56–2.94)	2.52 (2.34–2.69)	2.58 (2.40–2.76)	2.61 (2.45–2.77)	2.54 (2.35–2.72)	0.091
	Diabetes-Specific Volume					
	≤100 Patients	101–150 Patients	151–200 Patients	201–300 Patients	≥301 Patients	
Eye examination						
No	64.2 (63.8–64.7)	66.6 (66.2–67.0)	67.8 (67.4–68.2)	67.6 (67.1–68.1)	67.0 (66.3–67.7)	<0.001
Yes	79.0 (78.6–79.5)	80.2 (79.7–80.6)	80.6 (80.1–81.1)	80.1 (79.6–80.6)	79.7 (79.0–80.3)	<0.001
LDL cholesterol testing						
No	81.3 (80.8–81.8)	83.3 (82.8–83.7)	83.7 (83.3–84.2)	85.4 (84.9–85.9)	87.1 (86.5–87.7)	<0.001
Yes	85.8 (85.2–86.4)	87.6 (87.2–88.1)	87.8 (87.4–88.3)	88.8 (88.3–89.3)	89.6 (89.0–90.3)	<0.001
Hemoglobin A_{1c} testing						
No	46.7 (45.9–47.6)	49.1 (48.2–49.9)	50.2 (49.3–51.1)	51.7 (50.7–52.7)	50.1 (48.5–51.6)	<0.001
Yes	64.1 (63.3–64.9)	66.4 (65.6–67.1)	66.6 (65.8–67.4)	67.4 (66.5–68.3)	66.2 (64.9–67.5)	<0.001
Prescriptions for ACEIs/ARBs						
No	68.5 (67.9–69.1)	70.4 (69.8–70.9)	71.3 (70.7–71.8)	72.8 (72.2–73.4)	73.5 (72.6–74.4)	<0.001
Yes	79.4 (78.7–80.2)	79.9 (79.3–80.6)	80.4 (79.7–81.0)	80.6 (79.9–81.3)	81.0 (80.1–81.9)	<0.001
Prescriptions for statins						
No	66.0 (65.3–66.7)	69.6 (68.9–70.2)	71.3 (70.7–72.0)	73.0 (72.3–73.7)	74.6 (73.5–75.6)	<0.001
Yes	79.3 (78.4–80.1)	80.6 (79.9–81.3)	80.9 (80.2–81.6)	81.6 (80.9–82.3)	83.0 (82.0–83.9)	<0.001
Emergency department visits hypoglycemia or hyperglycemia						
No	0.92 (0.86–0.98)	0.86 (0.81–0.91)	0.84 (0.79–0.88)	0.78 (0.74–0.83)	0.64 (0.59–0.70)	<0.001
Yes	2.72 (2.54–2.91)	2.60 (2.44–2.77)	2.80 (2.63–2.97)	2.45 (2.28–2.61)	2.33 (2.12–2.55)	0.013

ACEI = angiotensin-converting enzyme inhibitor; ARB = angiotensin-receptor blocker; LDL = low-density lipoprotein.
* Values are percentages (95% CIs).

Appendix Table 5. Predictive Margins for Each Quality Indicator According to Overall Ambulatory Volume and Diabetes-Specific Volume: Stratified by Full- or Part-Time Practice*

Practice, by Quality Indicator	Overall Ambulatory Volume					*P* Value for Trend
	≤20 Patients/Day	>20–≤25 Patients/Day	>25–≤30 Patients/Day	>30–≤40 Patients/Day	>40 Patients/Day	
Eye examination						
Full-time	73.2 (72.6–73.9)	71.7 (71.2–72.2)	70.0 (69.6–70.5)	68.8 (68.4–69.2)	67.6 (67.1–68.0)	<0.001
Part-time	70.4 (70.0–70.8)	69.1 (68.5–69.6)	68.1 (67.3–68.8)	65.6 (64.7–66.5)	63.6 (62.1–65.1)	<0.001
LDL cholesterol testing						
Full-time	85.8 (85.2–86.5)	85.2 (84.6–85.7)	85.3 (84.8–85.8)	84.9 (84.5–85.4)	84.8 (84.3–85.3)	0.007
Part-time	84.7 (84.2–85.1)	85.4 (84.8–85.9)	85.2 (84.4–85.9)	82.4 (81.4–83.5)	82.7 (81.0–84.5)	0.001
Hemoglobin A_{1c} testing						
Full-time	56.8 (55.3–58.2)	56.2 (55.0–57.3)	54.5 (53.5–55.6)	51.8 (50.9–52.7)	50.6 (49.6–51.6)	<0.001
Part-time	53.2 (52.3–54.0)	53.2 (52.1–54.3)	51.8 (50.3–53.2)	50.2 (48.3–52.0)	46.9 (43.7–50.2)	<0.001
Prescriptions for ACEIs/ARBs						
Full-time	76.0 (75.2–76.8)	74.5 (73.8–75.1)	73.5 (72.9–74.2)	72.8 (72.2–73.3)	71.1 (70.5–71.8)	<0.001
Part-time	73.1 (72.6–73.7)	73.3 (72.5–74.0)	72.0 (71.0–73.0)	69.7 (68.4–71.0)	69.3 (67.0–71.7)	<0.001
Prescriptions for statins						
Full-time	76.2 (75.3–77.1)	74.4 (73.6–75.2)	73.8 (73.0–74.5)	72.7 (72.1–73.4)	71.0 (70.3–71.8)	<0.001
Part-time	72.8 (72.2–73.5)	72.1 (71.3–73.0)	71.4 (70.2–72.6)	69.0 (67.5–70.6)	67.3 (64.7–70.0)	<0.001
Emergency department visits for hypoglycemia or hyperglycemia						
Full-time	1.20 (1.11–1.29)	1.07 (1.01–1.14)	1.13 (1.08–1.19)	1.14 (1.09–1.18)	1.10 (1.05–1.16)	0.57
Part-time	1.25 (1.18–1.31)	1.23 (1.14–1.32)	1.14 (1.03–1.26)	1.19 (1.05–1.33)	1.51 (1.24–1.78)	0.038
	Diabetes-Specific Volume					
	≤100 Patients	101–150 Patients	151–200 Patients	201–300 Patients	≥301 Patients	
Eye examination						
Full-time	67.7 (67.1–68.3)	69.5 (69.0–69.9)	70.1 (69.7–70.5)	69.8 (69.4–70.3)	69.3 (68.7–69.9)	<0.001
Part-time	68.1 (67.7–68.4)	69.5 (69.0–70.1)	70.7 (69.8–71.6)	70.6 (69.1–72.1)	68.9 (66.1–71.6)	<0.001
LDL cholesterol testing						
Full-time	82.5 (81.7–83.2)	83.6 (83.1–84.2)	84.2 (83.8–84.7)	85.7 (85.3–86.2)	87.2 (86.6–87.8)	<0.001
Part-time	83.0 (82.6–83.4)	85.5 (84.9–86.1)	86.0 (85.1–86.9)	87.7 (86.3–89.0)	90.6 (88.5–92.8)	<0.001
Hemoglobin A_{1c} testing						
Full-time	50.6 (49.3–51.9)	52.3 (51.4–53.3)	53.2 (52.2–54.1)	54.3 (53.3–55.2)	52.7 (51.2–54.1)	<0.001
Part-time	51.4 (50.7–52.1)	53.2 (52.0–54.4)	53.3 (51.4–55.2)	55.7 (52.6–58.9)	51.1 (45.1–57.1)	<0.001
Prescriptions for ACEIs/ARBs						
Full-time	70.9 (70.0–71.7)	72.0 (71.4–72.6)	72.6 (72.0–73.2)	74.0 (73.4–74.5)	74.5 (73.7–75.3)	<0.001
Part-time	71.6 (71.0–72.1)	72.8 (72.0–73.5)	74.4 (73.2–75.6)	74.3 (72.4–76.2)	72.8 (69.3–76.4)	<0.001
Prescriptions for statins						
Full-time	68.6 (67.6–69.5)	71.2 (70.5–71.9)	72.8 (72.1–73.4)	74.3 (73.6–74.9)	75.6 (74.7–76.6)	<0.001
Part-time	69.9 (69.3–70.5)	72.9 (72.0–73.8)	74.2 (72.8–75.6)	75.0 (72.8–77.3)	78.1 (74.1–82.0)	<0.001
Emergency department visits for hypoglycemia or hyperglycemia						
Full-time	1.16 (1.07–1.25)	1.22 (1.16–1.28)	1.20 (1.14–1.25)	1.09 (1.04–1.13)	0.97 (0.91–1.03)	<0.001
Part-time	1.33 (1.26–1.39)	1.12 (1.04–1.20)	1.22 (1.09–1.35)	1.11 (0.92–1.29)	0.60 (0.38–0.82)	<0.001

ACEI = angiotensin-converting enzyme inhibitor; ARB = angiotensin-receptor blocker; LDL = low-density lipoprotein.
* Values are percentages (95% CIs).