CMAJ OPEN

Research

Relation between primary care physician supply and diabetes care and outcomes: a cross-sectional study

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Abstract

Background: Higher primary care physician supply is associated with lower mortality due to heart disease, cancer and stroke, but its relation to diabetes care and outcomes is unknown. We examined the association between primary care physician supply and evidence-based testing and hospital visits for people with diabetes in naturally occurring multispecialty physician networks in Ontario, Canada.

Methods: We conducted a cross-sectional analysis between Apr. 1, 2009, and Mar. 31, 2011, using linked administrative data. We included all Ontario residents over 40 years of age with a diagnosis of diabetes before Apr. 1, 2007, who were alive on Apr. 1, 2009 (N = 712 681). We tested the association between physician supply and outcomes at the network level using separate Poisson regression models for urban and nonurban physician networks. We accounted for clustering at the physician and network level and adjusted for patient characteristics.

Results: Patients in physician networks with a high supply of primary care physicians were more likely to receive the optimal number of evidence-based tests for diabetes than patients in networks with low primary care physician supply (urban relative risk [RR] 1.06, 95% confidence interval [CI] 1.04–1.07; nonurban RR 1.17, 95% CI 1.14–1.21) but were no different regarding emergency department visits (urban RR 1.05, 95% CI 0.94–1.17; nonurban RR 0.96, 95% CI 0.85–1.08) or hospital admissions for diabetes complications (urban RR 1.01, 95% CI 0.89–1.14; nonurban RR 0.91, 95% CI 0.77–1.07).

Interpretation: Having more primary care physicians per capita is associated with better diabetes care but not with reduced hospital visits in this setting. Further research to understand this relation and how it varies by setting is important for resource planning.

Diabetes mellitus affects a growing proportion of the population and is responsible for substantial morbidity and mortality worldwide.[1–3] The increase in diabetes prevalence is expected to contribute to rising health care costs driven partly by an increase in diabetes-related admissions to hospital.[4] Primary care physicians play an important role in diabetes management and are responsible for implementing evidence-based guidelines that can improve outcomes for people with diabetes. Appropriate management of cardiovascular risk factors such as blood pressure and cholesterol can reduce the risk of cardiovascular complications;[5,6] regular eye examinations can lead to early detection and treatment of diabetic retinopathy;[7] maintenance of reduced blood glucose levels can prevent skin and soft-tissue infections.[8]

There is increasing recognition of the important role primary care physicians play in reducing admissions to hospital for ambulatory-care sensitive conditions and related health care spending.[9] Research has demonstrated that jurisdictions with more primary care physicians per capita generally have better health outcomes, including lower all-cause mortality and lower mortality due to heart disease, cancer and stroke.[10] However, little is known about the relation between primary care physician supply and adherence to evidence-based testing for diabetes or hospital visits for diabetes-related complications.

Large multispecialty physician group practices, with a central role for primary care practitioners, have been shown to achieve high-quality, low-cost care for patients with chronic

Competing interests: None declared.

This article has been peer reviewed.

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***CMAJ Open* 2016. DOI:10.9778/cmajo.20150065**

disease.[11–14] These physician networks provide a coherent and novel way to obtain population-based provider performance measurement and may ultimately provide an approach to organizing care and advancing shared accountability for improving quality and lowering costs among a group of providers.[15,16] Networks are ideally suited to examine the relation between provider supply and population outcomes. They are small enough to detect meaningful variations in outcomes but large enough for outcome rates to be relatively stable over time. Most importantly, they include the primary care physicians who contribute most of the care for the assigned population, regardless of geographic borders, and are highly self-contained, a particularly important advantage in urban areas where patients often cross municipal boundaries to receive care.

Our study used naturally occurring multispecialty physician networks in Ontario, Canada,[17] to assess the relation between primary care physician supply and diabetes care and outcomes. We hypothesized that networks with higher primary care physician supply would have higher rates of recommended testing for diabetes and fewer diabetes-related hospital visits.

Methods

We used administrative data to conduct a cross-sectional analysis between Apr. 1, 2009, and Mar. 31, 2011, to assess the relation between supply of primary care physicians and evidence-based testing and hospital visits for people with diabetes in naturally occurring multispecialty physician networks in Ontario, Canada. Study data were held securely in a linked, deidentified form at the Institute for Clinical Evaluative Sciences and accessed through a comprehensive research agreement with the Ontario Ministry of Health and Long-Term Care. Ethics approval for this analysis was obtained from the Research Ethics Board of Sunnybrook Health Sciences Centre, Toronto.

Ontario is Canada's most populous province, with a population of 13.2 million people in 2010. Physician services, hospital care and laboratory testing are fully insured and free at the point-of-care for all permanent residents through the Ontario Health Insurance Plan (OHIP).

Study population

We identified Ontarians with diabetes who were aged 40–100 years using a validated algorithm with 86% sensitivity and 97% specificity.[18] Patients were included if they had diabetes before Apr. 1, 2007 (i.e., 2 years before the start of the study), and were alive on Apr. 1, 2009. We excluded patients with no contact with the health care system in the 2 years before Apr. 1, 2009, patients who were residents of a long-term care facility and patients who could not be assigned to a physician network. All other patients were included when assessing outcomes related to hospital visits. However, when assessing adherence to evidence-based testing, we further excluded patients who died before the end of the study period and patients who could not be assigned to a usual provider of primary care. In our study, we were not able to capture laboratory tests done in hospitals; when assessing evidence-based testing, we excluded patients assigned to physicians or physician networks where there was a high likelihood that laboratory testing was being done in hospital (Appendices 1 and 2, available at www.cmajopen.ca/content/4/1/E80/suppl/DC1).

Multispecialty physician networks

We assessed the relation between primary care supply and diabetes care and outcomes at the level of naturally occurring multispecialty physician networks. We previously identified 78 informal multispecialty physician networks in Ontario by using health administrative data to exploit natural linkages among patients, physicians and hospitals based on existing patient flow.[17] Briefly, we linked each Ontario resident to their usual provider of primary care. We linked each specialist to the hospital where they performed the most inpatient services, and each primary care physician to the hospital where most of their patient panel was admitted for nonmaternal medical care. Each resident was then linked to the same hospital as his or her usual provider of primary care. Smaller clusters were aggregated to create networks based on a minimum population size, distance and loyalty. Networks were highly self-contained. "Loyalty," the proportion of care to network residents provided by physicians and hospitals within their network, was 81%. Networks are not formally organized but rather represent groupings of patients, physicians and hospitals that are linked based on patient health care–seeking behaviour.

Primary care physician supply

The primary exposure for the study was the comprehensive primary care physician full time equivalents (FTEs) per capita for each network. We calculated FTEs by use of total physician payments from all sources and assigning an FTE of 1.00 to physicians who fell between the 40th and 60th percentiles of their specialty.[19,20] Comprehensive primary care physicians included all primary care physicians in patient enrolment models.[21] In addition, primary care physicians who worked more than 50 days per year and who had billing activity in a wide variety of primary care areas were considered comprehensive.

We stratified our analyses by network rurality because patient characteristics, access to care and the role of primary care physicians potentially differ in urban and nonurban areas. Other researchers have taken a similar approach.[22] We used the Rurality Index of Ontario,[23] which accounts for population size and travel time to categorize physician networks into urban (Rurality Index of Ontario score 0–9), nonurban (Rurality Index of Ontario score 10–39) and remote (Rurality Index of Ontario score ≥ 40). We excluded remote networks from the analysis because they were small in number and generally represented geographically distant communities with unique health care challenges.[24]

For our analysis, we computed comprehensive primary care physician FTEs per 100 000 network population and grouped networks into tertiles of low, medium and high primary care physician supply based on about equal numbers of cohort members per tertile. Tertiles were created after exclusion of remote networks but before networks were stratified into urban and nonurban.

Outcome measures

Optimal diabetes monitoring

We obtained information on evidence-based testing for diabetes from physician and laboratory billing claims to OHIP. We defined optimal diabetes monitoring based on the Canadian Diabetes Association 2003 and 2008 clinical practice guidelines as receiving 1 retinal eye examination, 4 glycated hemoglobin (HbA_{1C}) tests and 1 cholesterol test over the 2-year study period (binary variable).[25,26]

Hospital visits for diabetes complications

We obtained information on emergency department visits and hospital admissions for diabetes complications from databases maintained by the Canadian Institute for Health Information. We defined hospital visits for diabetes complications as any visit related to hyperglycemia or hypoglycemia, skin or soft-tissue infection, or cardiovascular events (binary variable) (see Appendix 3, available at www.cmajopen.ca/content/4/1/E80/suppl/DC1).

Patient and network characteristics

We obtained information on patient age, sex and residential postal code from the database of all people registered with OHIP. We linked information on neighbourhood income from the 2006 Canadian census to patients' residential postal codes and stratified income into quintiles.[27] Registration with OHIP within 10 years of the start of the study period was used as a proxy for recent immigration. We used a validated algorithm to detect outpatient visits for mental health diagnoses in the past 2 years.[28] The Johns Hopkins Adjusted Clinical Group Case-Mix System was used to measure comorbidity using adjusted diagnosis groups and to assign patients to a resource utilization band based on similar expected health care use (1 = low, 5 = high).[29] We calculated FTEs for specialty physicians using the same method we used to calculate primary care physician FTEs. For optometrists and ophthalmologists, we calculated network supply using head count because FTE data were not available.

Statistical analyses

We used Poisson regression with a robust variance estimator to examine the association between primary care physician supply and outcomes (optimal monitoring for diabetes, 1 or more emergency department visits for diabetes complications and 1 or more hospital admissions for diabetes complications) after adjusting for patient characteristics. A secondary analysis included network characteristics in the models. We used Poisson regression with a robust variance estimator to analyze binary outcomes to express the effects in terms of relative risks (RRs) rather than odds ratios. We used this approach because our outcomes of interest were common and an odds ratio would have conveyed an inflated effect size.[30] Patient-level variables included age group, sex, income quintile, recent OHIP registration (proxy for immigration), diabetes duration (years since diagnosis), mental health diagnosis (none, nonpyschotic, psychotic), number of adjusted diagnosis groups (comorbidity), and resource utilization band (morbidity). Network-level variables included optometrist, ophthalmologist and endocrinologist supply per capita for evidence-based testing models, and hospital bed, endocrinologist, general internist and cardiologist supply for emergency department and hospital admission models.

Generalized estimating equations models were used to account for the correlated nature of the data because patients assigned to the same usual provider of primary care or physician network would undergo similar treatment and have correlated outcomes. For evidence-based testing models, we clustered analyses at the level of the usual provider of primary care because primary care physicians are responsible for ordering tests. For hospital visits related to diabetes complications, we clustered analyses at the network level because patients within a network are more likely to have similar hospital admission rates based on care and hospital bed supply. All statistical analyses were done using SAS 9.3 (SAS Institute Inc., Cary, NC), and statistical models were done using PROC GENMOD. All tests were 2-tailed. We used p less than 0.05 as the level of statistical significance.

Results

We analyzed data for evidence-based testing and hospital visits for 610 441 and 712 681 Ontario residents with diabetes, respectively (Figure 1). The mean primary care physician FTE for networks in the high supply tertile were 74 per 100 000 and 77 per 100 000 for urban and nonurban networks, respectively. Patient characteristics were similar for both cohorts (Table 1 and Appendix 4, available at www.cmajopen.ca/content/4/1/E80/suppl/DC1).

Rates of optimal monitoring for diabetes were higher in networks with higher primary care physician supply per capita (urban: high-supply networks 37% v. low-supply networks 35%; nonurban: high-supply networks 43% v. low supply networks 37%) (Table 2). Rates of hospital admissions and emergency department visits for diabetes complications were relatively similar between networks with low, medium and high primary care physician supply.

After adjustment for patient characteristics, patients belonging to networks with medium and high primary care supply were more likely to receive optimal monitoring compared with patients belonging to networks with low primary care supply (Table 3). This association was true for both urban and nonurban networks but stronger for the latter (adjusted RR for high-supply networks: urban 1.06, 95% confidence interval [CI] 1.04–1.07; nonurban adjusted RR 1.17, 95% CI 1.14–1.21). There was no significant association between primary care physician supply and emergency department visits or hospital admissions for either urban or nonurban networks. Results were similar when network characteristics were added to the model (results not shown).

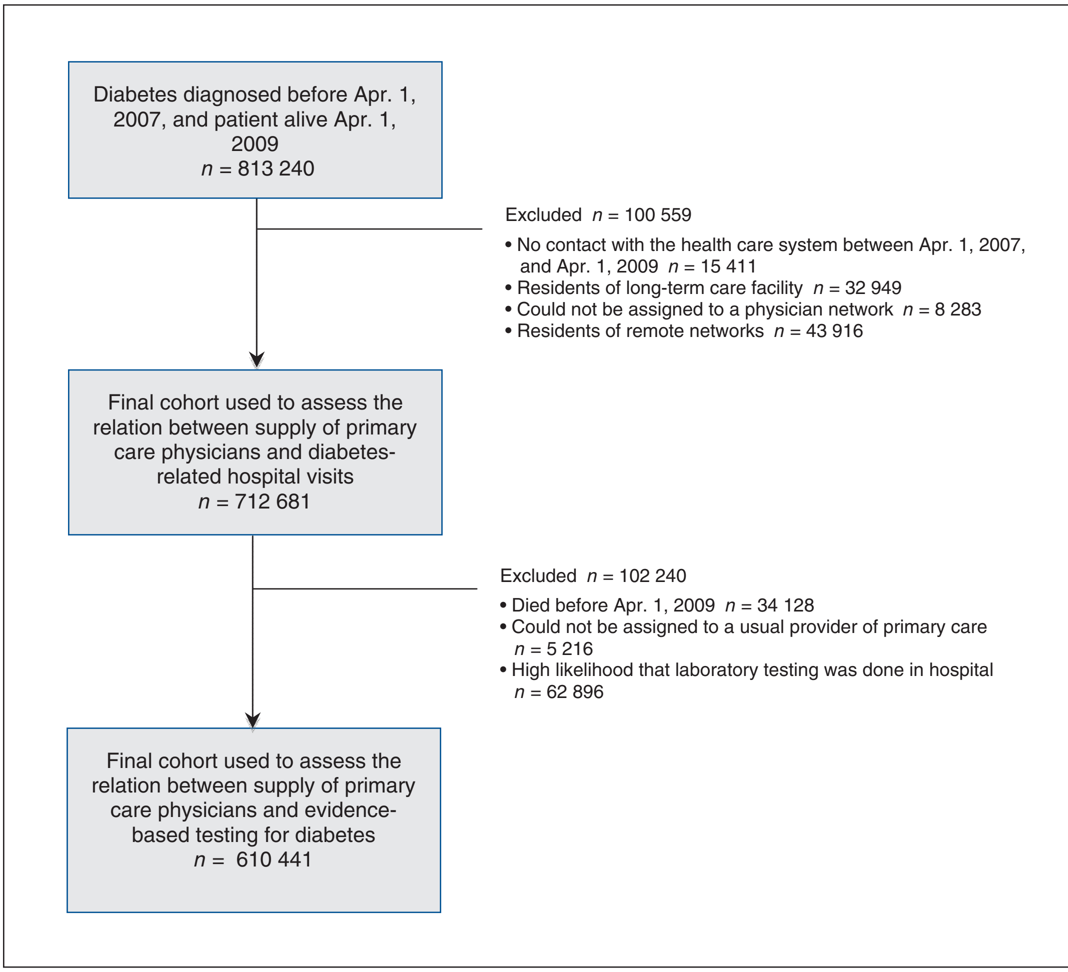

Figure 1: Cohort selection for patients with diabetes included in the analysis.

Interpretation

Our study used naturally occurring multispecialty physician networks to understand the relation between primary care physician supply and diabetes care and outcomes. We found that patients with diabetes were more likely to receive recommended testing in networks with a high supply of primary care physicians compared with networks with a low supply and that this relation was more marked in nonurban than in urban networks. We found no relation between primary care physician supply and hospital visits for diabetes complications.

Our findings are in keeping with research from the United States that has shown that states with more general practitioners have higher rates of effective care.[31] In our study, compared with urban networks, nonurban networks had fewer primary care physicians in areas of low supply and more primary care physicians in areas of high supply, which may explain the stronger association between primary care physician supply and diabetes care we found in nonurban networks. The stronger association in nonurban networks may also be explained by differences in the delivery of primary care or in the role of the primary care physician. The differing role of primary care physicians may also explain why we found that hospital visit rates were higher in non-urban networks compared with urban networks. For example, primary care physicians in non-urban settings are more likely to work in the emergency department and as hospitalists, which changes the dynamic of who visits and is admitted to hospital.

There is a large body of research exploring the relation between primary care supply and health outcomes generally, but findings vary by country. Studies from the US have found that higher primary care physician supply is associated with better patient outcomes, including lower mortality[10,32] and fewer admissions to hospital for ambulatory care–sensitive conditions,[32] even after controlling for patient characteristics and specialty workforce. In contrast, studies from the United Kingdom found that the inverse association between primary care physician supply and all-cause mortality,[33] coronary artery disease mortality[34] and hospital admissions[33] disappeared after controlling for patient and practice characteristics.

Our findings are in contrast to a recent analysis of 31 European countries that found that better access to primary care was associated with lower hospital admission rates for diabetes after controlling for disease prevalence and hospital

Table 1: Baseline patient and network characteristics as of Apr. 1, 2009, stratified by rurality and primary care physician supply for study population (*n* = 712 681)

	Urban primary care physician supply			Nonurban primary care physician supply		
Characteristics	Low (*n* = 199 534)	Medium (*n* = 217 955)	High (*n* = 169 853)	Low (*n* = 27 694)	Medium (*n* = 22 370)	High (*n* = 75 275)
Network characteristics						
Primary care physician FTE per 100 000						
Median (IQR)	63.00 (3.00)	66.79 (3.12)	72.05 (4.47)	61.04 (6.64)	69.03 (3.46)	74.89 (8.11)
Range	59.0–64.0	64.2–70.3	70.4–82.4	57.2–64.1	64.6–69.3	71.5–92.5
Primary care physician loyalty						
Median (IQR)	78.02 (3.59)	81.48 (13.96)	80.56 (12.30)	90.83 (8.40)	87.62 (2.91)	91.00 (6.71)
Range	71.8–95.9	71.5–95.6	61.9–90.7	83.4–95.2	79.6–89.0	81.3–94.7
Endocrinologist FTE per 100 000						
Median (IQR)	0.93 (0.76)	1.28 (0.90)	2.37 (3.32)	0.00 (0.99)	0.00 (0.00)	0.74 (1.29)
Range	0.0–2.9	0.0–5.2	0.0–31.9	0.0–4.2	0.0–0.0	0.0–1.6
General internal medicine FTE per 100 000						
Median (IQR)	4.56 (3.82)	6.76 (5.11)	7.29 (10.48)	8.32 (3.00)	7.56 (3.78)	5.72 (3.02)
Range	2.8–25.8	2.7–18.0	2.4–27.5	5.9–12.2	4.7–11.2	3.1–9.0
Cardiologist FTE per 100 000						
Median (IQR)	3.79 (3.29)	3.07 (1.47)	8.76 (11.09)	0.00 (2.74)	0.01 (2.03)	3.31 (5.12)
Range	1.3–8.6	1.3–8.0	2.1–20.9	0.0–2.8	0.0–4.8	0.0–8.1
No. of ophthalmologists per 100 000						
Median (IQR)	2.27 (2.39)	3.17 (4.41)	3.62 (4.13)	1.92 (1.20)	2.09 (1.82)	2.84 (1.23)
Range	0.5–4.0	0.0–9.6	1.1–25.0	1.4–3.8	0.0–3.0	0.0–8.7
No. of optometrists per 100 000						
Median (IQR)	12.40 (3.59)	15.50 (2.11)	14.55 (8.46)	15.95 (1.29)	17.15 (2.80)	16.89 (7.88)
Range	7.8–21.2	2.0–27.4	0.0–20.0	13.9–20.2	14.1–25.0	9.9–21.8
No. of hospital beds per 100 000						
Median (IQR)	0.89 (0.32)	1.10 (0.65)	1.84 (1.63)	1.58 (0.25)	1.44 (0.41)	1.70 (0.84)
Range	0.6–2.4	0.7–2.2	0.9–7.0	1.2–1.8	0.9–2.0	1.2–2.6
Physician characteristics						
Patient age, yr, no. (%)						
40–65	114 388 (57.3)	119 187 (54.7)	90 075 (53.0)	13 913 (50.2)	10 942 (48.9)	38 132 (50.7)
66–85	79 523 (39.9)	91 003 (41.8)	73 327 (43.2)	12 719 (45.9)	10 484 (46.9)	34 407 (45.7)
> 85	5 623 (2.8)	7 765 (3.6)	6 451 (3.8)	1 062 (3.8)	944 (4.2)	2 736 (3.6)
Male, %	105 537 (52.9)	114 602 (52.6)	88 836 (52.3)	14 886 (53.8)	12 081 (54.0)	40 432 (53.7)
Income quintile, no. (%)						
1 (lowest)	44 591 (22.3)	46 797 (21.5)	36 927 (21.7)	6 092 (22.0)	4 544 (20.3)	16 098 (21.4)
2	45 596 (22.9)	46 836 (21.5)	36 539 (21.5)	5 804 (21.0)	4 510 (20.2)	15 676 (20.8)
3	42 392 (21.2)	45 079 (20.7)	30 174 (17.8)	5 805 (21.0)	4 864 (21.7)	14 911 (19.8)
4	38 647 (19.4)	41 258 (18.9)	31 468 (18.5)	5 570 (20.1)	4 723 (21.1)	15 777 (21.0)
5 (highest)	27 795 (13.9)	36 738 (16.9)	33 800 (19.9)	4 096 (14.8)	3 689 (16.5)	12 438 (16.5)
Missing, no. (%)	513 (0.3)	1 247 (0.6)	945 (0.6)	327 (1.2)	40 (0.2)	375 (0.5)
Recent OHIP registrant, no. (%)	10 710 (5.4)	8 320 (3.8)	4 038 (2.4)	341 (1.2)	147 (0.7)	662 (0.9)
Diabetes duration, yr, no. (%)						
2–3	41 171 (20.6)	46 724 (21.4)	34 125 (20.1)	5 317 (19.2)	4 445 (19.9)	14 698 (19.5)
4–9	82 550 (41.4)	89 042 (40.9)	71 184 (41.9)	11 119 (40.1)	9 056 (40.5)	30 871 (41.0)
10–14	41 264 (20.7)	44 885 (20.6)	34 567 (20.4)	5 859 (21.2)	4 671 (20.9)	15 992 (21.2)
≥ 15	34 549 (17.3)	37 304 (17.1)	29 977 (17.6)	5 399 (19.5)	4 198 (18.8)	13 714 (18.2)
Mental health diagnosis, no. (%)						
None	146 558 (73.5)	156 771 (71.9)	121 071 (71.3)	21 090 (76.2)	17 446 (78.0)	57 765 (76.7)
Nonpsychotic	50 521 (25.3)	57 926 (26.6)	45 756 (26.9)	6 160 (22.2)	4 597 (20.5)	16 355 (21.7)
Psychotic	2 455 (1.2)	3 258 (1.5)	3 026 (1.8)	444 (1.6)	327 (1.5)	1 155 (1.5)
Number of ADGs*, no. (%)						
0	1 775 (0.9)	1 942 (0.9)	1 481 (0.9)	201 (0.7)	196 (0.9)	671 (0.9)
1	5 469 (2.7)	7 232 (3.3)	5 612 (3.3)	1 066 (3.8)	908 (4.1)	3 134 (4.2)
2–5	67 924 (34.0)	77 730 (35.7)	59 740 (35.2)	9,942 (35.9)	8 654 (38.7)	29 255 (38.9)
6–10	92 061 (46.1)	96 252 (44.2)	74 374 (43.8)	11 949 (43.1)	9 343 (41.8)	31 784 (42.2)
≥ 11	32 305 (16.2)	34 799 (16.0)	28 646 (16.9)	4,536 (16.4)	3 269 (14.6)	10 431 (13.9)
RUB†, no. (%)						
0	1 775 (0.9)	1 942 (0.9)	1 481 (0.9)	201 (0.7)	196 (0.9)	671 (0.9)
1	824 (0.4)	1 060 (0.5)	756 (0.4)	120 (0.4)	105 (0.5)	314 (0.4)
2	13 277 (6.7)	16 222 (7.4)	12 279 (7.2)	2 192 (7.9)	1 951 (8.7)	5 994 (8.0)
3	118 296 (59.3)	124 170 (57.0)	95 418 (56.2)	14 732 (53.2)	12 228 (54.7)	41 294 (54.9)
4	41 809 (21.0)	45 473 (20.9)	36 208 (21.3)	6 024 (21.8)	4 587 (20.5)	15 683 (20.8)
5	23 553 (11.8)	29 088 (13.3)	23 711 (14.0)	4 425 (16.0)	3 303 (14.8)	11 319 (15.0)

Note: ADG = adjusted diagnosis group, FTE = full time equivalent, IQR = inter-quartile range, OHIP = Ontario Health Insurance Plan, RUB = resources utilization band.
*General measure of comorbidity generated by the Johns Hopkins ACG Case-Mix System. A higher number of ADGs represents higher comorbidity.
†Measure of health care use generated by the Johns Hopkins Adjusted Clinical Group Case-Mix System. A higher number represents greater health care use.

bed supply.[35] This difference in findings may be explained by differences in measurement and by contextual factors. We used physician supply as our primary exposure, whereas Kringos and colleagues used a comprehensive measure of access that included physician supply as well as information on appointment systems and after-hours availability. In addition, Canada has a lower number of acute care hospital beds per capita compared with European countries,[36] and hospital admissions in this context may represent more serious disease that is less influenced by primary care. Furthermore, Canada has one of the lowest rates of same-day access in primary care,[37] which may negate the potential positive impact of higher primary care physician supply on emergency department visits. These differences in context suggest that how primary care services are organized and delivered modulates the impact of physician supply on care and outcomes.

Strengths and limitations

Our study was cross-sectional, so we cannot infer causation. In addition, the use of administrative data has inherent limitations. Our assessment of evidence-based testing included process measures with a modest association with outcomes.[38] We did not have access to laboratory tests done in hospital or eye examinations paid for privately, and so we likely underestimated overall testing rates. However, we limited the impact of missing data by excluding physicians and physician networks where there was a high likelihood that laboratory testing was done in hospital. We also did not have access to test result data, blood pressure measurement or complete prescribing data, which limited our insight into the quality of diabetes care.

We did not include death as an outcome because it was rare in this cohort, but this omission may have biased our findings related to hospital visits toward the null.

There was not a large difference in primary care physician supply between low- and high-supply networks, particularly in urban areas, which may have resulted in smaller observed correlations. In addition, 10%–20% of patients received some primary care outside their network, which may have slightly diluted the effect of network supply. Despite our large sample, our study was likely not powered to detect very small differences in outcomes. These small differences, however, would likely not have been as clinically meaningful.

Table 2: Outcomes between Apr. 1, 2009, to Mar. 31, 2011, stratified by rurality and primary care physician supply

	Patients, no. (%)					
	Urban			Nonurban		
Outcome	Low	Medium	High	Low	Medium	High
Evidence-based testing (*n* = 621 692)						
Retinal eye examination	130 627 (70.8)	139 644 (71.7)	106 120 (72.5)	9 172 (77.5)	11 194 (77.4)	44 963 (76.8)
Cholesterol test	164 171 (89.0)	170 794 (87.7)	127 818 (87.4)	9 947 (84.0)	12 785 (88.4)	50 931 (87.0)
HbA_{1c} test						
0	26 014 (14.1)	29 285 (15.0)	22 613 (15.5)	1 833 (15.5)	1 864 (12.9)	8,107 (13.8)
1–3	81 639 (44.2)	81 517 (41.8)	60 042 (41.0)	4 889 (41.3)	5 190 (35.9)	21 180 (36.2)
≥ 4	76 852 (41.7)	84 014 (43.1)	63 628 (43.5)	5 118 (43.2)	7 404 (51.2)	29 252 (50.0)
Optimal monitoring*	64 308 (34.9)	70 134 (36.0)	53 836 (36.8)	4 352 (36.8)	6 284 (43.5)	25 065 (42.8)
Hospital visits for diabetes complications† (*n* = 756 597)						
Hospital admissions						
0	189 465 (95.0)	206 006 (94.5)	160 396 (94.4)	25 559 (92.3)	20 689 (92.5)	69 976 (93.0)
1	7 166 (3.6)	8 507 (3.9)	6 706 (4.0)	1 525 (5.5)	1 186 (5.3)	3 829 (5.1)
2	1 809 (0.9)	2 142 (1.0)	1 661 (1.0)	362 (1.3)	304 (1.4)	905 (1.2)
≥ 3	1 094 (0.5)	1 300 (0.6)	1 090 (0.6)	248 (0.9)	191 (0.9)	565 (0.8)
≥ 1	10 069 (5.0)	11 949 (5.5)	9 457 (5.6)	2 135 (7.7)	1 681 (7.5)	5 299 (7.0)
Emergency department visits						
0	188 264 (94.4)	204 141 (93.7)	158 508 (93.3)	24 992 (90.2)	20 314 (90.8)	68 559 (91.1)
1	8 318 (4.2)	10 105 (4.6)	8 267 (4.9)	1 914 (6.9)	1 517 (6.8)	4 798 (6.4)
2	1 847 (0.9)	2 325 (1.1)	1 975 (1.2)	471 (1.7)	330 (1.5)	1 175 (1.6)
≥ 3	1 105 (0.6)	1 384 (0.6)	1 103 (0.6)	317 (1.1)	209 (0.9)	743 (1.0)
≥ 1	11 270 (5.6)	13 814 (6.3)	11 345 (6.7)	2 702 (9.8)	2 056 (9.2)	6 716 (8.9)

Note: HBA_{1c} = glycated hemoglobin.
*Optimal monitoring defined as 1 retinal eye exam, 1 cholesterol test, and 4 HBA_{1c} tests during the 2-year study period.
†Hospital visits for diabetes complications included visits for hyper/hypoglycemia, skin or soft-tissue infection, or cardiovascular events.

Table 3: Association between primary care physician supply and optimal monitoring* (*n* = 610 441) and hospital visits for diabetes complications† (*n* = 712 681), by urban and nonurban networks

	Urban		Nonurban	
Outcome/model	RR (95% CI)	*p* value	RR (95% CI)	*p* value
Optimal monitoring*				
Unadjusted				
High	1.06 (1.04–1.07)	< 0.001	1.16 (1.13–1.20)	< 0.001
Medium	1.03 (1.02–1.04)	< 0.001	1.18 (1.14–1.23)	< 0.001
Low (reference)	1.00		1.00	
Adjusted for patient characteristics‡				
High	1.06 (1.04–1.07)	< 0.001	1.17 (1.14–1.21)	< 0.001
Medium	1.04 (1.03–1.05)	< 0.001	1.19 (1.14–1.23)	< 0.001
Low (reference)	1.00		1.00	
≥ 1 emergency department visits				
Unadjusted				
High	1.11 (0.89–1.38)	0.4	0.96 (0.83–1.11)	0.6
Medium	1.10 (0.87–1.40)	0.4	0.94 (0.79–1.12)	0.5
Low (reference)	1.00		1.00	
Adjusted for patient characteristics‡				
High	1.05 (0.94–1.17)	0.4	0.96 (0.85–1.08)	0.5
Medium	0.99 (0.89–1.10)	0.9	0.95 (0.80–1.11)	0.5
Low (reference)	1.00		1.00	
One or more hospital admissions				
Unadjusted				
High	1.04 (0.84–1.29)	0.70	0.93 (0.79–1.10)	0.4
Medium	1.08 (0.85–1.36)	0.5	0.97 (0.83–1.13)	0.7
Low (reference)	1.00		1.00	
Adjusted for patient characteristics‡				
High	1.01 (0.89–1.14)	0.9	0.91 (0.77–1.07)	0.2
Medium	0.97 (0.86–1.10)	0.6	1.09 (0.94–1.27)	0.2
Low (reference)	1.00		1.00	

Note: CI = confidence Interval, RR = relative risk.
*Defined as 1 retinal eye exam, 1 cholesterol test and 4 glycated hemoglobin tests during the 2-year study period.
†Visits for hyperglycemia or hypoglycemia, skin or soft-tissue infection, or cardiovascular events.
‡Age, sex, income quintile, recent immigration, diabetes duration, mental health diagnosis, comorbidity and morbidity.

Finally, there are many contextual factors that likely influenced our findings and that may limit their generalizability. For example, in Canada, access to physician and hospital services is free at the point-of-care for all permanent residents, yet same-day access to primary care physicians is worse and emergency department usage is higher than in other high-income countries.[39]

Our study has some unique strengths. There are only a handful of studies that have assessed the relation between primary care physician supply and diabetes outcomes. We used naturally occurring multispecialty physician networks as our unit of analysis, which gave us both sufficient variability and stability in our exposure and outcome measures. Analysis at the network level also meant that we could account for care that occurred across municipal boundaries, as is often the case in urban areas.

Conclusion

In this cohort of Ontario residents with diabetes, more primary care physicians per capita was associated with better diabetes care but not reduced hospital visits for diabetes complications. We need further research to understand the relation between primary care supply and rates of diabetes complications and how this relation may vary in different settings. Identifying the ideal supply of primary care physicians in relation to health outcomes and cost has important implications for resource planning.

References

1. Cheng YJ, Imperatore G, Geiss LS, et al. Secular changes in the age-specific prevalence of diabetes among US adults: 1988–2010. *Diabetes Care* 2013;36:2690-6.
2. Lipscombe LL, Hux J. Trends in diabetes prevalence, incidence, and mortality in Ontario, Canada 1995–2005: a population-based study. *Lancet* 2007; 369:750-6.
3. Shaw J, Sicree R, Zimmet P. Global estimates of the prevalence of diabetes for 2010 and 2030. *Diabetes Res Clin Practice* 2010;87:4-14.
4. An economic tsunami: the cost of diabetes in Canada. Ottawa: Canadian Diabetes Association; 2009.
5. Collins R, Armitage J, Parish S, et al. MRC/BHF Heart Protection Study of cholesterol-lowering with simvastatin in 5963 people with diabetes: a randomised placebo-controlled trial. *Lancet* 2003;361:2005-16.
6. UK Prospective Diabetes Study Group. Tight blood pressure control and risk of macrovascular and microvascular complications in type 2 diabetes: UKPDS 38. *BMJ*. 1998;317:703-13.
7. Cheung N, Mitchell P, Wong TY. Diabetic retinopathy. *Lancet* 2010;376: 124-36.
8. Joshi N, Caputo GM, Weitekamp MR, et al. Infections in patients with diabetes mellitus. *N Engl J Med* 1999;341:1906-12.
9. Mostashari F, Sanghavi D, McClellan M. Health reform and physician-led accountable care: The paradox of primary care physician leadership. *JAMA* 2014;311:1855-6.
10. Starfield B, Shi L, Macinko J. Contribution of primary care to health systems and health. *Milbank Q* 2005;83:457-502.
11. Bodenheimer T, Wagner EH, Grumbach K. Improving primary care for patients with chronic illness: the chronic care model, Part 2. *JAMA* 2002; 288:1909-14.
12. Manns BJ, Tonelli M, Zhang J, et al. Enrolment in primary care networks: impact on outcomes and processes of care for patients with diabetes. *CMAJ* 2012;184:E144-52.
13. Schmittdiel JA, Shortell SM, Rundall TG, et al. Effect of primary health care orientation on chronic care management. *Ann Fam Med* 2006;4:117-23.
14. Wagner EH, Austin BT, Davis C, et al. Improving chronic illness care: translating evidence into action. *Health Aff (Millwood)* 2001;20:64-78.
15. Bynum JP, Bernal-Delgado E, Gottlieb D, et al. Assigning ambulatory patients and their physicians to hospitals: a method for obtaining population-based provider performance measurements. *Health Serv Res* 2007; 42(1 Pt 1):45-62.
16. Fisher ES, Staiger DO, Bynum JP, et al. Creating accountable care organizations: the extended hospital medical staff. *Health Aff (Millwood)* 2007;26: w44-57.
17. Stukel T, Glazier RH, Schultz SE, et al. Multispecialty physician networks in Ontario. *Open Med* 2013;7(2): e40-55.
18. Hux JE, Ivis F, Flintoft V, et al. Diabetes in Ontario: determination of prevalence and incidence using a validated administrative data algorithm. *Diabetes Care* 2002;25:512-6.
19. Full-time equivalent physicians report, Canada, 2002–2003 and 2003–2004. Ottawa: Canadian Institute for Health Information; 2006.
20. Henry DA, Schulz SE, Glazier RH, et al. Payments to Ontario physicians from Ministry of Health and Long-Term Care sources, 1992/93 to 2009/10. ICES Investigative Report. Toronto: Institute for Clinical Evaluative Sciences; 2012.
21. 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.
22. Shi L, Macinko J, Starfield B, et al. Primary care, social inequalities and all-cause, heart disease and cancer mortality in US counties: a comparison between urban and non-urban areas. *Public Health* 2005;119:699-710.
23. Kralj B. Measuring rurality — RIO2008_BASIC: methodology and results. Toronto: Ontario Medical Association; 2009.
24. Glazier RH, Gozdyra P, Yeritsyan N. Geographic access to primary care and hospital services for rural and northern communities: report to the Ontario Ministry of Health and Long-Term Care. Toronto: Institute for Clinical Evaluative Sciences; 2011.
25. Canadian Diabetes Association Clinical Practice Guidelines Expert Committee. Canadian Diabetes Association 2003 clinical practice guidelines for the prevention and management of diabetes in Canada. *Can J Diabetes* 2003; 27:(Suppl 2).
26. Canadian Diabetes Association Clinical Practice Guidelines Expert Committee. Canadian Diabetes Association 2008 clinical practice guidelines for the prevention and management of diabetes in Canada. *Can J Diabetes* 2008; 32:S1-201.
27. Finkelstein MM. Ecologic proxies for household income: How well do they work for the analysis of health and health care utilization? *Can J Public Health* 2004;95:90-4.
28. Steele LS, Glazier R, Lin E, et al. Using administrative data to measure ambulatory mental health service provision in primary care. *Med Care* 2004; 42:960-5.
29. The Johns Hopkins ACG System. Baltimore: Johns Hopkins. Available: www.acg.jhsph.org/ (accessed 2016 Feb. 1).
30. McNutt L-A, Wu C, Xue X, et al. Estimating the relative risk in cohort studies and clinical trials of common outcomes. *Am J Epidemiol* 2003;157:940-3.
31. Baicker K, Chandra A. Medicare spending, the physician workforce, and beneficiaries'quality of care. 2004. *Health Aff (Millwood)* 2004;Jan–Jun; Suppl Web Exclusives:W4,184-97.
32. Chang C-H, Stukel TA, Flood AB, et al. Primary care physician workforce and Medicare beneficiaries' health outcomes. *JAMA* 2011;305:2096-104.
33. Gulliford MC, Jack RH, Adams G, et al. Availability and structure of primary medical care services and population health and health care indicators in England. *BMC Health Serv Res* 2004;4:12.
34. Levene LS, Baker R, Bankart MJG, et al. Association of features of primary health care with coronary heart disease mortality. *JAMA* 2010;304:2028-34.
35. Kringos DS, Boerma W, van der Zee J, et al. Europe's strong primary care systems are linked to better population health but also to higher health spending. *Health Aff* 2013;32:686-94.
36. Squires D. The US health system in perspective: a comparison of twelve industrialized nations. Washington (DC): The Commonwealth Fund; 2011.
37. *Where you live matters: Canadian views on health care quality*. Results from the 2013 Commonwealth Fund International Health Policy Survey of the General Public. Canadian Health Care Matters, Bulletin 8. Toronto: Health Council of Canada; 2014.
38. Glazier RH, Harris SB, Tompkins JW, et al. Number of HbA1c tests unrelated to quality of diabetes control: an electronic medical record data linkage study. *Diabetes Res Clin Pract* 2011;93:e37-40.
39. *How do Canadians rate the health care system*? Results from the 2010 Commonwealth Fund International Health Policy Survey. Canadian Health Care Matters, Bulletin 4. Health Council of Canada; 2010.

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Funding: Funding was provided by an Emerging Team Grant (ETG92248) in Applied Health Services and Policy Research from the Canadian Institutes of Health Research. The funding agency had no role in the study design; in the collection, analysis, or interpretation of data; in the writing of the report; or in the decision to submit the report for publication.

Acknowledgements: The authors thank the following people from the Institute for Clinical Evaluative Sciences: Sue Schultz, Senior Epidemiologist, and Jun Guan, Lead Analyst, for their work in establishing the Ontario physician networks and calculating the supply characteristics for each of these physician networks; Drew Wilton, Senior Analyst, for his help in preparing the data; and Ashley Corallo, Research Coordinator, for her help in coordinating the project when it began.

Disclaimer: This study was supported by the Institute for Clinical Evaluative Sciences, which is funded by annual grants from the Ontario Ministry of Health and Long-Term Care. Dr. Kiran is supported as a Clinician Investigator and Dr. Glazier as a Clinician Scientist by the Department of Family and Community Medicine at the University of Toronto and at St. Michael's Hospital.

The opinions, results and conclusions reported in this article are those of the authors and are independent from the funding sources. No endorsement by the Institute for Clinical Evaluative Sciences or the Ontario Ministry of Health and Long-Term Care is intended or should be inferred. Parts of this material are based on data and information compiled and provided by the Canadian Institute for Health Information (CIHI). However, the analyses, conclusions, opinions and statements expressed herein are those of the author, and not necessarily those of CIHI.

Supplemental information: For reviewer comments and the original submission of this manuscript, please see www.cmajopen.ca/content/4/1/E80/suppl/DC1