Relationship of Physician Volume to Process Measures and Outcomes in Diabetes

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Running title: Physician Volume and Diabetes Care

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**Objective:** The volume of patients cared for by an individual physician (physician volume) has been linked to improved outcomes for a number of conditions. It is not known whether a similar association exists for treatment of diabetes. In this study we aimed to determine whether physician volume is associated with improved process measures and outcomes in diabetes care.

**Research Design and Methods:** This retrospective cohort study analyzed electronic medical records data for 7,120 patients with diabetes treated by 368 primary care physicians at practices affiliated with two large academic hospitals. The associations between physician volume of diabetic patients (diabetes volume) and annual A1C and LDL testing, and blood pressure, A1C and LDL levels were evaluated.

**Results:** In multivariable analysis absolute diabetes volume was linked to decreased odds of A1C testing (4% less for each additional patient seen; p = 0.05) and relative diabetes volume (fraction of the total patients seen who had diabetes) was associated with decreased odds of both A1C (25% less for every 10% increase in the number of diabetic patients seen annually; p = 0.03) and LDL testing (20% less for every 10% increase in the number of diabetic patients; p < 0.001). Physician volume was not significantly associated with the odds of blood pressure, A1C or LDL control at the end of the study.

**Conclusions:** Higher physician volume in care of diabetic patients is associated with decreased adherence to surveillance guidelines and no measurable difference in treatment outcomes.
Lowering blood pressure, blood glucose and cholesterol levels decreases the rate of diabetes complications(1-3). Nevertheless, the majority of patients with diabetes have blood pressure, A1C and LDL cholesterol above the levels suggested by the guidelines(4-7).

Diabetes care is complex and frequently involves coordinating multiple medication, diet and exercise regiments. Individual physicians’ experience dealing with these complicated issues could be an important factor contributing to the quality of care of diabetic patients. Multiple publications have shown that physicians with a higher number of patients with a particular condition or procedure have better patient outcomes than low-volume physicians(8-11). Most of these reports analyze outcomes of surgical or other procedures, and almost all focus on inpatient care(12). It is unknown whether these findings can be generalized to the relationship of outcomes with individual physicians’ experience in treatment of a complex medical illness, such as diabetes, in an outpatient setting.

The number of patients with diabetes in the U.S. is increasing exponentially(13), while the number of endocrinologists is not(14). Consequently the majority of diabetes management will continue to be delivered by primary care physicians. It has been suggested that patients may benefit from referral to high-volume centers and physicians for treatment of conditions where case volume is associated with improved outcomes(8; 15). If a causative association exists between physician volume and outcomes in outpatient treatment of a common disease with a high rate of complications, such as diabetes, it could have extensive implications for the healthcare system. In this paper we report the results of a study that assessed whether the number of diabetic patients cared for by an individual physician (diabetes volume) is an independent predictor of quality of diabetes care.

RESEARCH DESIGN AND METHODS

Study Patients and Settings
We conducted a retrospective cohort study of care of diabetic patients followed by primary care physicians at Massachusetts General Hospital and Brigham and Women’s Hospital between 01/01/2000 and 08/31/2005. Patients were included in our analysis if they were 18 years of age and older, had a documented diagnosis of diabetes mellitus, had at least two encounters at least one year apart with a physician in a primary care specialty during the study period, and had at least one blood pressure, A1C, and LDL measurement documented during the study period. Documented diagnosis of diabetes was ascertained using analysis of the text of physician notes in the electronic medical record as previously described(16). Patients treated by an endocrinologist were excluded. The institutional review board at Partners HealthCare System approved the study.

Measures of Physician Experience
The primary measure of physician experience was the number of diabetic patients treated annually by the physician (diabetes volume). Secondary measures of physician experience included the frequency of encounters with diabetic patients, the fraction of diabetic patients among all of the physician’s patients, and the fraction of encounters with diabetic patients among all of the physician’s encounters.

Diabetes volume was calculated as the average number of patients with diabetes the physician had seen every year over the course of the study. Frequency of encounters with diabetic patients was calculated as the average daily number of notes for patients with diabetes the physician authored over the
course of the study. Relative diabetes volume was calculated as the ratio of the average annual number of patients with diabetes to the average annual number of all patients seen by the physician. Fraction of encounters with diabetic patients was calculated as the ratio of the average daily number of notes for patients with diabetes to the average daily number of all notes authored by the physician.

**Outcome Measures**

For each patient in the study we computed several process and intermediate outcome measures. Process measures were based on the criteria used by the Health Employer Data and Information Set (17) and included the fraction of calendar years between the first and the last encounter with the patient’s primary care physician when the patient had at least one A1C or LDL measurement. The patient’s primary care physician was identified as the physician in a primary care specialty with whom the patient had the largest number of documented encounters over the study period.

Intermediate outcomes included A1C, LDL and systolic (SBP) and diastolic (DBP) blood pressure levels. For every physician in the study, we determined the change in the fraction of patients for whom the corresponding outcome was below the recommended treatment goal over the course of the study. The change was calculated as the difference between the fraction of patients whose last level of the corresponding outcome variable measured on or prior to their last encounter with the physician was below the recommended treatment goal, and the fraction of the same patients whose first level of the outcome variable measured on or after their first visit with the physician was below the recommended treatment goal. This study used 129 and 84 mm Hg, 7.0% and 99 mg/dL as the recommended treatment goals of SBP and DBP, A1C and LDL cholesterol levels respectively, in accordance with the guidelines published prior to the beginning of the study period(18; 19).

**Data Sources**

Demographic and health insurance information, laboratory data, billing codes and the text of physician notes were obtained from the electronic medical record system at Massachusetts General Hospital and Brigham and Women’s Hospital. Blood pressure values were extracted from the text of physician notes in the electronic medical record as previously described(20). Physician specialty and training status were obtained from the Massachusetts Board of Registration in Medicine.

**Statistical Analysis**

Summary statistics at both the patient and the physician level were constructed by using frequencies and proportions for categorical data and by using means, standard deviations, medians, and ranges for continuous variables. The univariate associations between physician diabetes volume and process measures and outcomes of diabetes care were assessed by comparing these measures between physician volume quartiles. Kruskal-Wallis test was used for continuous variables, and Chi-square test for binary variables.

In order to account for clustering between patients treated by the same physician and to adjust for other covariates, separate multiple logistic regression models were constructed for the probability of annual A1C and LDL measurements and the probability of last blood pressure, A1C, and LDL levels being below the treatment goal. We fit the models using generalized estimating equations to correct for correlated observations(21). In addition to the measures of physician experience, the covariates for the process measures models included patients’ age, ethnicity, gender, primary language, physician age and training level. Analysis was
also adjusted for the documented diagnosis of coronary artery disease (ascertained using ICD-9 diagnostic codes in the billing data(22)) as a common co-morbidity that significantly raises the risk of morbidity and mortality in diabetic patients. The models for the proportions of patients with blood pressure, A1C, and LDL levels below the treatment goal at the last measurement also included testing frequency (A1C and LDL only), length of follow-up and whether these outcomes were below goal at the first measurement. All analyses were performed with SAS statistical software, version 9.1.

RESULTS

We identified 21,912 patients aged ≥ 18 years with a documented diagnosis of diabetes who had at least one outpatient visit at either hospital during the study period and were not treated by an endocrinologist. Among these, 7,120 patients had at least one note by a physician in a primary care specialty in the electronic medical record, had least two documented encounters at least one year apart during the study period, and at least one documented blood pressure, A1C, and LDL measurement, and were included in the study.

The mean age of the study patients was 63.7 years, 55.8% were women, and 58.5% were white (Table 1). The majority (84.3%) of patients had either Medicare or a private health insurance. Median length of PCP follow-up during the study period was 3.0 years and 29% of patients had follow-up between one and two years.

Diabetes Care Process Measures and Outcomes

On average the study patients had A1C and LDL measured in 85% and 74% of the study years, respectively, while 63% of the patients had A1C and 38% had LDL measured every year. 31% of the study patients had both tests done at least once during every year of the study.

The mean SBP and DBP of the study patients were 130 and 75 mm Hg, respectively. SBP was below the treatment goal for 38% of patients at their first study visit and 51.5% at their last study visit – an increase of 13.5%. Similarly, the fraction of patients whose DBP was below the treatment goal increased from 76 to 87% between their first and last study visits.

The mean A1C of the study patients was 7.6%, and LDL 100 mg/dL. The fraction of patients whose A1C and LDL were below the treatment goals increased from 34% to 40% and from 35% to 56%, respectively, between their first and last study visits. At the last study visit blood pressure, A1C, and LDL levels were all below the treatment goals in 13% of the patients.

Physician Experience and Quality of Diabetes Care: Univariate Analysis

A total of 368 physicians who were identified as primary care physicians to the study patients were divided into quartiles based on the annual number of unique diabetic patients treated (Table 2). Physicians in the higher volume quartiles had slightly lower rates of annual A1C and LDL measurements as well as mean A1C levels. Physicians in the highest volume quartile had larger increases between the first and last study encounters in the fraction of patients whose SBP and LDL levels were below the treatment goals, but smaller increases in the fraction of patients whose DBP was below goal. There was no significant association of physician volume quartile and the increase in the fraction of patients with A1C below goal.

Physician Experience and Quality of Diabetes Care: Multivariable Analysis

In the analysis that adjusted for the patients’ demographic characteristics, diagnosis of coronary artery disease and
physician training status and age, the association between patient volume and rates of annual testing remained significant for A1C but not LDL (Table 3). There were no significant relationships between the annual number of diabetic patients seen by the physicians and the probability that blood pressure, A1C and LDL levels of their patients were below the recommended level at the last study visit.

Other measures of physician experience with care of diabetic patients showed similar results. For every extra daily encounter with a diabetic patient, the odds that the physician’s patients would have A1C measured in a given year decreased by 25% (p = 0.03) and the odds of an LDL cholesterol measurement decreased by 20% (p < 0.001). The odds of the last A1C measurement being less than 7.0% increased by 20% for every 1% rise in the fraction of the primary care physician’s encounters with diabetic patients among all of his/her patients (p = 0.009). None of the other associations between the measures of relative experience with diabetes patients and outcomes of diabetes care were statistically significant.

Multivariable analysis of the probability that the patient would have A1C measured in a given year (Figure 1A) showed that the odds of testing rose by 10% (p < 0.001) for every decade increase in the patient’s age. White patients had 22% lower odds to have annual A1C testing (p < 0.001), patients on Medicaid had 21% higher odds of testing than patients with private health insurance (p = 0.006), and the diagnosis of coronary artery disease increased the odds of testing by 45% (p < 0.001).

Multivariable analysis of the odds that the patient’s last A1C level during the study period was below 7.0% (Figure 1B) showed that patients whose first A1C level was below 7.0% were 5.5 times as likely to also have the last A1C level below 7.0% (p < 0.001). The odds of the last A1C below 7.0% rose by 6.8% for every decade of the patient’s age (p = 0.008), by 6.6% for every year of follow-up (p = 0.01), and by 22% for patients whose primary language was English (p = 0.04). The relationships between the odds of the last A1C measurement below 7.0% and patient gender, ethnicity, insurance, and diagnosis of coronary artery disease, physician age and training level, and frequency of A1C measurements did not reach statistical significance.

CONCLUSIONS
In this large observational study, the analysis adjusted for patient and physician characteristics did not demonstrate a consistent relationship with diabetes care outcomes for any of the measures of physician experience. The most commonly used measure of physician experience – annual number of unique patients with diabetes – had a negative association with process measures of quality of diabetes care, such as annual A1C and LDL measurements.

The discrepancies between the results of univariate and adjusted analyses could be explained by the differences in both patient and physician populations(23). Average blood pressure and LDL were lower, and A1C was higher in the lower quartiles. Most physicians in the two lowest patient volume quartiles were residents and it is possible that the residents’ patient populations are distinct from those of attending physicians.

Frequency of A1C measurements increased significantly when patients were at higher risk of cardiovascular events: older age, non-white race and diagnosis of coronary artery disease. It is therefore possible that physicians take these risk factors into account when deciding on how aggressively to treat their patients with diabetes. On the other hand, increased intensity of monitoring did not appear to translate into improved outcomes: there was no association between the rate of A1C measurement and the odds of
A1C levels reaching below the treatment goals. The main predictor of whether a patient’s A1C level was below 7.0% at the end of the study was their A1C level in the beginning of the study. Clearly, despite a large number of new medications and treatment regimens developed to treat diabetes over the last decade, the natural history of diabetes remains difficult to alter.

This study provides evidence that the effectiveness in diabetes care is not achieved by the means of simple repetition. Some of the other studies of the effect of physician volume on treatment of common medical conditions medical treatment corroborate this finding(9), while many investigations of the effect of physician volume on less common diseases do not(10; 11). One possible explanation is that at some point the effect of experience on outcomes reaches a plateau: studies where the lowest annual number of patients was less than one show correlation between physician volume and outcomes, while studies where the lowest annual number of patients is greater than three do not. It appears therefore that physician volume is an imperfect predictor of outcomes and should be used with caution in referral policies(24).

Our study has multiple strengths. First, it included several thousand ethnically diverse patients from two large hospitals that serve patients from all socio-economic strata. Second, the study analyzed the association of physician volume with both process measures and intermediate outcomes of diabetes care in order to investigate potential mechanisms mediating the effects of physician volume on quality of care in diabetes. Third, while the majority of the published investigations of the relationship between physician volume and outcomes focus on inpatient care, our study examined the quality of outpatient treatment of diabetes, where most of the care for this disease takes place. Finally, in our evaluation we used several different measures of physician experience with diabetes care, all of which supported our conclusions.

The study has several limitations. It was restricted in scope to the patients of physicians affiliated with academic hospitals practicing in eastern Massachusetts. This could limit its generalizability to other patient and physician populations. Second, this was a retrospective study that relied on documentation of relevant findings in the electronic medical record. If the accuracy and availability of this documentation varied with physician experience, the study findings could be biased. Finally the study could not account for some factors that could potentially significantly affect outcomes, including patient adherence to the physician’s recommendations, dietary and exercise habits, body mass index, etc.

In conclusion, the volume of diabetic patients cared for by individual physicians did not significantly affect A1C, blood pressure or LDL and was negatively associated with the surveillance of these indicators. Other factors, such as the severity of the pre-existing disease, appear to be more powerful determinants of diabetes outcomes.

ACKNOWLEDGEMENTS

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REFERENCES


### Table 1
#### Patient Characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case patients, n</td>
<td>7,120</td>
</tr>
<tr>
<td>Mean age (± SD), years*</td>
<td>63.7 (± 13.6)</td>
</tr>
<tr>
<td>Women, n (%)</td>
<td>3,971 (55.8)</td>
</tr>
<tr>
<td>Ethnicity, n (%)</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>4,168 (58.5)</td>
</tr>
<tr>
<td>Black</td>
<td>1,200 (16.9)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>1,144 (16.1)</td>
</tr>
<tr>
<td>Other (includes unknown)</td>
<td>608 (8.5)</td>
</tr>
<tr>
<td>English is the primary language, n (%)</td>
<td>5,862 (82.3)</td>
</tr>
<tr>
<td>CAD*, n (%)</td>
<td>2,014 (28.3)</td>
</tr>
<tr>
<td>Health insurance, n (%)**</td>
<td></td>
</tr>
<tr>
<td>Medicare</td>
<td>3,557 (50.0)</td>
</tr>
<tr>
<td>Medicaid***</td>
<td>1,067 (15.0)</td>
</tr>
<tr>
<td>Private</td>
<td>2,403 (34.3)</td>
</tr>
<tr>
<td>No insurance</td>
<td>93 (1.3)</td>
</tr>
<tr>
<td>Mean follow-up period (± SD), years</td>
<td>3.1 (± 1.4)</td>
</tr>
</tbody>
</table>

*At least two billing codes representing coronary artery disease on record prior to the end of the study period
**At the end of the study period
***Includes FreeCare – a program that provides fully or partially (depending on the income) subsidized health care in Massachusetts
<table>
<thead>
<tr>
<th>Variable</th>
<th>Annual Patient Volume Quartile</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>Physicians, n</td>
<td>96</td>
<td>89</td>
</tr>
<tr>
<td>Patients, n</td>
<td>223</td>
<td>475</td>
</tr>
<tr>
<td>Median annual diabetes patients, n (range)</td>
<td>3.67 (0.75-5.33)</td>
<td>7 (5.5-9.33)</td>
</tr>
<tr>
<td>Residents, n (%)</td>
<td>78 (81)</td>
<td>64 (72)</td>
</tr>
<tr>
<td>Process Measures:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual A1C measurements, %</td>
<td>87.6</td>
<td>87.8</td>
</tr>
<tr>
<td>Annual LDL measurements, %</td>
<td>73.6</td>
<td>77.5</td>
</tr>
<tr>
<td>Outcomes:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean SBP* (SD), mm Hg</td>
<td>128.0 (13.7)</td>
<td>130.7 (14.0)</td>
</tr>
<tr>
<td>Mean DBP** (SD), mm Hg</td>
<td>73.8 (7.5)</td>
<td>74.1 (8.6)</td>
</tr>
<tr>
<td>Mean A1C (SD), %</td>
<td>7.8 (1.6)</td>
<td>7.8 (1.5)</td>
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<tr>
<td>Mean LDL (SD), mg/dL</td>
<td>94.7 (29.2)</td>
<td>96.0 (29.6)</td>
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<tr>
<td>Increase in fraction of patients with SBP under control, %</td>
<td>8.1</td>
<td>3.0</td>
</tr>
<tr>
<td>Increase in fraction of patients with DBP under control, %</td>
<td>15.9</td>
<td>8.4</td>
</tr>
<tr>
<td>Increase in fraction of patients with A1C under control, %</td>
<td>5.7</td>
<td>3.7</td>
</tr>
<tr>
<td>Increase in fraction of patients with LDL under control, %</td>
<td>11.5</td>
<td>17.8</td>
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</table>

SBP = systolic blood pressure
**DBP = diastolic blood pressure
<table>
<thead>
<tr>
<th></th>
<th>DM Patients*</th>
<th>DM Encounters**</th>
<th>Fraction of DM Patients***</th>
<th>Fraction of DM Encounters****</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Odds ratio</td>
<td>p-value</td>
<td>Odds ratio</td>
<td>p-value</td>
</tr>
<tr>
<td>A1C Testing</td>
<td>0.96 (0.93-1.0)</td>
<td>0.05</td>
<td>0.75 (0.58-0.97)</td>
<td>0.03</td>
</tr>
<tr>
<td>LDL Testing</td>
<td>NS</td>
<td></td>
<td>0.80 (0.70-0.91)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>SBP Control</td>
<td>NS</td>
<td></td>
<td>0.87 (0.75-1.01)</td>
<td>0.06</td>
</tr>
<tr>
<td>DBP Control</td>
<td>NS</td>
<td></td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>A1C Control</td>
<td>NS</td>
<td></td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>LDL Control</td>
<td>NS</td>
<td></td>
<td>NS</td>
<td>1.19 (1.05-1.36)</td>
</tr>
</tbody>
</table>

95% confidence intervals for odds ratios shown in parentheses
* Per 10 patients with diabetes treated annually
** Per 1 daily encounter with a diabetic patient
*** Per 1% of patients with diabetes among all patients seen annually
**** Per 1% of encounters with diabetic patients among all patient encounters
Figure 1 Relationship of Provider and Patient Factors and A1C Measurements

A. Effect on frequency of A1C measurements  
B. Effect on probability of last A1C < 7.0%

Circles represent the estimates and whiskers the 95% confidence intervals for odds ratios. **Patient Age** and **Provider Age** represent odds ratios for every 10 years increase in age. **Ethnicity** represents the odds ratio for white vs. non-white. **Language** represents the odds ratio for English recorded as the primary language vs. any other primary language. **Insurance** represents the estimate of the effect of Medicaid vs. private insurance. **Physician Training Level** represents the estimate of the effect of the primary care physician being an attending vs. a resident. **DM Patients** represents the effect of a 10-patient increase in the number of unique diabetic patients seen annually. **A1C testing** represents the odds ratio for the patient having A1C testing every single year vs. never.