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ORIGINAL RESEARCH

Quality of Care of the Initial Patient Cohort of the Diabetes Collaborative Registry®

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***Background*—**Although guidelines and performance measures exist for patients with diabetes mellitus, achievement of these metrics is not well known. The Diabetes Collaborative Registry® (DCR) was formed to understand the quality of diabetes mellitus care across the primary and specialty care continuum in the United States.

***Methods and Results*—**We assessed the frequency of achievement of 7 diabetes mellitus–related quality metrics and variability across the Diabetes Collaborative Registry® sites. Among 574 972 patients with diabetes mellitus from 259 US practices, median (interquartile range) achievement of the quality metrics across the practices was the following: (1) glycemic control: 19% (5–47); (2) blood pressure control: 80% (67–88); (3) angiotensin-converting enzyme inhibitors/angiotensin II receptor blockers in patients with coronary artery disease: 62% (51–69); (4) nephropathy screening: 62% (53–71); (5) eye examination: 0.7% (0.0–79); (6) foot examination: 0.0% (0.0–2.3); and (7) tobacco screening/cessation counseling: 86% (80–94). In hierarchical, modified Poisson regression models, there was substantial variability in meeting these metrics across sites, particularly with documentation of glycemic control and eye and foot examinations. There was also notable variation across specialties, with endocrinology practices performing better on glycemic control and diabetes mellitus foot examinations and cardiology practices succeeding more in blood pressure control and use of angiotensin-converting enzyme inhibitors/angiotensin II receptor blockers.

***Conclusions*—**The Diabetes Collaborative Registry® was established to document and improve the quality of outpatient diabetes mellitus care. While target achievement of some metrics of cardiovascular risk modification was high, achievement of others was suboptimal and highly variable. This may be attributable to fragmentation of care, lack of ownership among various specialists concerning certain domains of care, incomplete documentation, true gaps in care, or a combination of these factors. **(*J Am Heart Assoc*. 2017;6:e005999. DOI: 10.1161/JAHA.117.005999.)**

Key Words: diabetes mellitus • quality of care • registry

Because of population growth, aging, urbanization, obesity, and physical inactivity,[1] the prevalence of type 2 diabetes mellitus continues to escalate globally.[2] Diabetes mellitus presently affects an estimated 30 million people in the United States,[3] with increases evident in every age group, in both sexes, in every racial/ethnic group, by all education levels, and in all income brackets.[4] Despite significant advances in treatment and outcomes,[5] the impact of diabetes mellitus continues to be substantial on cardiovascular complications, mortality,[6] and resource use.[7–10] In response to the increasing prevalence and impact of diabetes mellitus, evidence-based care guidelines[11–14] and performance measures have been developed for the care of patients with diabetes mellitus.[15–17] However, mechanisms to evaluate quality of care, to examine the variability in quality care delivery both nationally and among specialties and sites, and to highlight potential opportunities for quality improvement have thus far been limited.

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Clinical Perspective

What Is New?

- We assessed the frequency of achievement of diabetes mellitus–related quality metrics in routine clinical practice and found this to be suboptimal for many of the metrics.
- There was substantial variation in achieving these metrics across both individual sites and across specialties, with specialties having higher achievement of metrics that are more associated with that specialty (eg, endocrinology practices do better at documenting diabetes mellitus foot examinations while cardiology practices control blood pressure better).

What Are the Clinical Implications?

- Achieving quality care in patients with diabetes mellitus requires integration of multiple specialties, which has been hindered by a lack of communication across electronic systems.
- All specialties need to take a greater role in ensuring that critical aspects of diabetes mellitus care are addressed by the care team instead of simply focusing on a defined sliver of clinical care.
- Systems-based approaches are also needed to optimize team-based care, such as an integrated diabetes mellitus care center, to improve the care of these complex patients.

The Diabetes Collaborative Registry® (DCR) is a real-world, quality-oriented registry covering the spectrum from primary to specialty outpatient care in the United States, thereby permitting evaluations of multidisciplinary diabetes mellitus care across the disease process (from diagnosis to complications) and the relationship between treatment patterns and health outcomes. The DCR was developed, in part, to understand the quality of care delivered to patients with diabetes mellitus and adherence to practice guidelines and performance measures. If substantial deficiencies are noted in achievement of particular measures, this could highlight opportunities for quality improvement efforts within the DCR, with the ultimate goal of improving care and outcomes. However, to understand where efforts should be focused, we must first document the current state of care and understand variability in achievement of particular measures across sites and specialties.

Methods

Study Population

The DCR was launched in 2014 as a collaborative effort by the American College of Cardiology, American Diabetes Association, American College of Physicians, American Association of Clinical Endocrinologists, and Joslin Diabetes Center.[18] The DCR is a prospective, office-based, quality-oriented registry of patients with diabetes mellitus, covering the spectrum from primary to specialty outpatient care in the United States. Primary care, endocrinology, multispecialty, and cardiology practices are invited to participate in DCR through a public website (www.thediabetesregistry.org) and through partnering societies. Cardiology and multispecialty practices currently in the American College of Cardiology–National Cardiovascular Data Registry PINNACLE program were targeted as initial sites for DCR because of existing information technology platforms.

Within participating practices, patient data are collected through an automated system integration solution that periodically extracts relevant data elements from electronic health records (EHRs). All protected health information is de-identified at the time of data extraction and stored in a secure facility, in a manner compliant with Health Insurance Portability and Accountability Act regulations. Data collection is standardized using established definitions, uniform data entry and transmission, and quality checks. In addition, rigorous back-end data quality checks are performed on the extracted data, and any data not meeting predefined statistical or clinical plausibility thresholds are quarantined from analyses and flagged for manual review and follow-up with individual practices. Because registry participation requires no data collection beyond that of the routine clinical care, and because of the de-identified nature of the collected information, waiver of written informed consent and authorization for this study was granted by Chesapeake Research Review Incorporated. For patients with more than 1 clinic visit during the monitoring period, the most recent visit was used for analysis.

Selection of Quality Metrics

Diabetes mellitus quality metrics that were selected to be tracked in DCR (Table 1) include 7 metrics established by the American College of Cardiology/American Heart Association Task Force on Performance Measures[19–21] and the Centers for Medicare and Medicaid Services Physician Quality Reporting System[22]: glycemic control (hemoglobin A1c checked in past year and documented to be ≤9%), blood pressure control (hypertension and blood pressure <140/90 or on ≥2 antihypertensive medications), angiotensin-converting enzyme inhibitor (ACE-I) or angiotensin II receptor blocker (ARB) for patients with coronary artery disease, nephropathy screening, diabetes mellitus eye examination, diabetes mellitus foot examination, and tobacco screening and cessation counseling (screened for tobacco and, if a current user, given cessation counseling). For each of the metrics, DCR worked with the individual practice and EHR provider to determine the best mechanisms to map the EHR data to determine whether the

Table 1. Quality Metrics in the DCR

Metric Name	Time Frame for Assessment	Details of Metric
Glycemic control	1 y	Patients ≤75 y with diabetes mellitus who had hemoglobin A1c checked and ≤9.0%
Blood pressure control	Most recent visit	Patients with hypertension who have a blood pressure <140/90 mm Hg or who have a blood pressure ≥140/90 mm Hg and were prescribed ≥2 antihypertensive medications
ACE-I or ARB with coronary artery disease	Most recent visit	Patients with coronary artery disease who were prescribed ACE-I or ARB
Diabetes mellitus: medical attention for nephropathy	1 y	Patients ≤75 y with diabetes mellitus who had a nephropathy screening test (serum creatinine or urinary protein) or evidence of nephropathy
Diabetes mellitus eye exam	1 y	Patients who received an eye exam
Diabetes mellitus foot exam	1 y	Patients who received a foot exam
Tobacco use: screening and cessation intervention	2 y	Patients who were screened for tobacco use and, if identified as a tobacco user, received cessation counseling

For all metrics except blood pressure and ACE-I/ARB, if the patient met the metric at any visit during the time frame for assessment (eg, 1 y from the last clinic visit in DCR), then the metric was considered to be met. ACE-I indicates angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; DCR, Diabetes Collaborative Registry®.

metrics are being met, which included a combination of discrete data fields, billing data, and physician notes.

Statistical Analyses

Demographics, comorbidities, laboratory values, and selected medications were reported for the study cohort as percentages (categorical variables) or means (SDs [continuous variables]). We first examined the average achievement of each metric across all eligible patients in DCR. We then calculated the percentage of patients who met criteria for each of the DCR performance metrics at the practice level. Sites with <10 patients eligible for a metric were excluded from analysis for that metric. We examined the median site-level achievement of each of the quality metrics, plotted the raw rates of adherence across sites, and compared the median rates among primary care physicians, endocrinologists, and cardiologists using χ^2 tests. For each quality metric, we also explored site-level variability with hierarchical Poisson models predicting achievement of each metric, with site included as a random effect. Variability among sites was quantified using the median rate ratio,[23] which estimates the average difference in rates of 2 hypothetical patients achieving the metric if they presented to 2 random sites in the data set. By definition, all median rate ratios are >1, and a median rate ratio >1.2 is generally accepted as indicating significant variability. To examine whether certain sites met quality metrics in multiple areas, we calculated for each site the number of metrics for which the site was in the upper quartile of performance.

To examine the difference in rates of achievement of each metric by specialty, geography, practice specialty, and (for the metrics that included a monitoring period) the number of visits during the monitoring period were then added as fixed effects in the models, with rate ratios calculated for each specialty (with cardiology as the reference). All analyses were performed with SAS version 9.4 (SAS Institute, Cary, NC), R version 3.2.0 (Foundation for Statistical Computing, Vienna, Austria), and IVEWare (Institute for Social Research, University of Michigan).

Results

Study Population

We assessed clinical data from 575 046 patients with diabetes mellitus enrolled in DCR from 272 US practices between 2015 and 2016. We excluded 13 practices that enrolled fewer than 10 patients (total of 74 patients), making our final study sample 574 972 patients from 259 US practices across 3086 providers in 39 states. Of these initial sites in DCR, 146 (56.4%) were primary care practices, 93 (35.9%) were cardiology practices, and 20 (7.7%) were endocrinology practices. Table 2 shows the baseline characteristics of the patients in the study cohort. Mean age was 65.9 years, 50.5% were male, and 83.3% were white race. Cardiac risk factors and conditions were common, with 76.3% having hypertension, 36.3% with known coronary artery disease, 14.3% with chronic heart failure, and 15.1% with peripheral artery disease. Oral glucose-lowering medications were prescribed to 52.0% of patients, and 20.4% were on insulin.

Achievement of Quality Metrics and Site-Level Variability

Analyzing patient-level data across the 574 972 patients in DCR, the number of patients eligible for each of the 7 quality

Table 2. Baseline Characteristics of Analytic Cohort

	All Patients (n=574 972)	Cardiology (n=278 110)	Endocrine (n=95 406)	Primary Care (n=201 456)
Age, y	65.9±13.6	67.4±12.6	63.7±14.7	64.7±14.1
Male sex	50.5%	54.1%	48.20%	46.6%
White race	83.3%	85.6%	85.10%	79.3%
Hemoglobin A1c, %	7.1±1.8	7.4±2.0	6.9±1.5	7.0±1.9
Diabetes mellitus type II	96.0%	95.4%	95.4%	97.0%
On oral glucose-lowering medications	52.0%	59.1%	38.7%	48.4%
On insulin	20.4%	23.9%	14.0%	18.7%
Hypertension	76.3%	86.7%	72.8%	63.9%
Systolic blood pressure, mm Hg	130.5±17.8	130.7±18.4	129.1±16.0	131.0±17.6
Diastolic blood pressure, mm Hg	74.5±10.8	73.7±10.9	75.7±9.9	75.2±10.9
Dyslipidemia	70.7%	80.0%	74.0%	56.6%
Coronary artery disease	36.3%	57.6%	19.8%	14.9%
Prior myocardial infarction	7.8%	13.2%	2.1%	3.0%
Prior coronary bypass graft surgery	7.2%	13.3%	1.9%	1.6%
Heart failure	14.3%	21.8%	6.9%	7.4%
Peripheral arterial disease	15.1%	17.8%	12.9%	12.3%
Prior stroke	11.3%	15.1%	10.8%	6.1%
Atrial fibrillation/flutter	14.4%	22.8%	8.7%	5.6%
Chronic kidney disease	14.2%	9.7%	10.6%	22.0%
Tobacco use				
Never	53.8%	49.4%	58.2%	58.0%
Current	13.9%	13.8%	13.8%	14.2%
Former	32.3%	36.8%	27.9%	27.8%

All comparisons of patients among specialties were significant at $P<0.001$.

metrics and the proportion of eligible patients meeting those metrics are shown in Table 3. Across all eligible patients, the metrics with the highest achievement were documentation of blood pressure control and tobacco screening and cessation counseling (81.8% and 86.3%, respectively) and the lowest was documentation of diabetes mellitus foot examination at 14.8%. After calculating achievement of each metric at the site level and examining these rates across the 259 practices, the median (interquartile range) achievement was as follows: (1) glycemic control: 19.3% (5.0–47%); (2) blood pressure control: 79.8% (66.9–87.5%); (3) ACE-I or ARB with coronary artery disease: 62.4% (50.9–69.0%); (4) nephropathy screening: 61.5% (53.4–71.4%); (5) diabetes mellitus eye examination: 0.7% (0.0–78.5%); (6) diabetes mellitus foot examination: 0.0% (0.0–2.3%); and (7) tobacco screening and cessation counseling: 86.4% (80.0–93.5%) (Table 4). The variability in meeting the metrics across sites is shown in Figure 1. There was only modest variability in sites meeting the metrics for ACE-I/ARB for coronary artery disease, nephropathy screening, tobacco screening and cessation counseling, and blood pressure control, with median rate ratios of 1.29, 1.23, 1.25, and 1.22, respectively. The most variability was evident in glycemic control and in performing diabetes mellitus eye and foot examinations, where many sites did not have any patients meeting these measures but some sites achieved them on nearly all patients. The median rate ratios for these metrics were 4.28, 27.49, and 17.72, respectively. This indicates, for example, that a patient could be 27 times more likely to get a diabetes mellitus eye examination if he or she went to 1 random site versus another site. When examining the number of metrics for which each site was a good performer (in the upper quartile for the metric), the majority of sites met only a few metrics (Figure 2). Only 17% of sites were high performers for 4 or more of the quality metrics.

Achievement of Quality Metrics Across Specialties

The median rates of achievement of the quality metrics according to practice specialty are shown in Table 5.

Table 3. Performance on Quality Metrics (All Patients in DCR)

Quality Metric	Eligible for Metric*	Met Metric
Glycemic control†	428 804 out of 569 626 (75.3%)	139 423 out of 428 804 (32.2%)
Blood pressure control	426 879 out of 528 519 (80.8%)	349 391 out of 426 879 (81.8%)
ACE-I out of ARB with coronary artery disease	198 892 out of 535 861 (37.1%)	133 743 out of 198 892 (67.2%)
Nephropathy screening	439 546 out of 574 941 (76.5%)	289 679 out of 439 546 (65.9%)
Diabetes mellitus eye exam	439 571 out of 574 972 (76.5%)	215 004 out of 439 571 (48.9%)
Diabetes mellitus foot exam	573 670 out of 574 972 (99.8%)	84 698 out of 573 670 (14.8%)
Tobacco screening and cessation counseling‡	563 452 out of 564 677 (99.8%)	486 167 out of 563 452 (86.3%)

ACE-I indicates angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; DCR, Diabetes Collaborative Registry®; HbA1c, hemoglobin A1c.
*Denominators for eligibility differ since some data from particular practices were excluded because of inconsistencies in data or small numbers of eligible patients per practice.
†Not meeting the metric of documentation of glycemic control was because of a lack of HbA1c checked in the past year in 62.6% and HbA1c >9% in 4.8%.
‡Not meeting the metric of documentation of tobacco screening was because of lack of screening for tobacco in 7.1% and not providing cessation counseling to current smokers in 6.6% (48.4% of current smokers were provided cessation counseling).

Endocrinology practices had higher rates of achievement of documentation of glycemic control, diabetes mellitus eye examinations, and diabetes mellitus foot examinations. Cardiology practices had the highest achievement of blood pressure control, ACE-I/ARB among patients with coronary artery disease, and nephropathy screening. In the hierarchical, modified Poisson models that also adjusted for geographical region, physician specialty was significantly associated with achievement of all of the quality metrics except for diabetes mellitus eye examinations, which did not vary significantly among practices (Table 5). Most of these differences were statistically significant but clinically small (rate ratios 0.8–1.1). However, achievement of glycemic control and diabetes mellitus foot examinations did vary substantially among specialties. Patients seen in endocrinology and primary care offices were 3.77 times (95% CI 2.04–6.96) and 2.18 times (95% CI 1.43–3.31), respectively, more likely to achieve documentation of glycemic control as compared with those seen in cardiology practices ($P<0.001$). Patients seen in endocrinology and primary care offices were 9.32 times (95% CI 1.75–49.50) and 3.97 times (95% CI 1.74–9.05), respectively, more likely to have a diabetes mellitus foot examination documented as compared with those seen in cardiology practices ($P=0.001$).

Discussion

In a real-world cohort of >500 000 patients with diabetes mellitus across 259 US practices and 3086 cardiologists, endocrinologists, and primary care physicians, we found substantial variability in documented achievement of quality metrics across individual practices and among the 3 practice specialties. Achievement of some metrics was high, namely, blood pressure control and tobacco screening/cessation counseling, with median rates across the practices of >75%. Documentation of glycemic control and diabetes mellitus eye and foot examinations occurred much less frequently with marked variability across sites and across practice

Table 4. Performance on Quality Metrics Across Sites

Quality Metric	Median Rate of Meeting Metric Across Sites (IQR)	Range	Median Rate Ratio*
Glycemic control	19.3% (5.0–47.0)	0.0 to 89.0	4.28 (3.77–4.99)
Blood pressure control	79.8% (66.9–87.5)	12.0 to 100.0	1.22 (1.20–1.25)
ACE-I/ARB with coronary artery disease	62.4% (50.9–69.0)	5.6 to 100.0	1.29 (1.25–1.33)
Nephropathy screening	61.5% (53.4–71.4)	5.3 to 92.0	1.23 (1.21–1.26)
Diabetes mellitus eye exam	0.7% (0.0–78.5)	0.0 to 100.0	27.49 (20.39–39.58)
Diabetes mellitus foot exam	0.0% (0.0–2.3)	0.0 to 97.0	17.72 (13.62–24.47)
Tobacco screening and cessation counseling	86.4% (80.0–93.5)	0.9 to 100.0	1.25 (1.23–1.29)

ACE-I indicates angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; IQR, interquartile range.
*The median rate ratio estimates the average difference in rates of achieving the metric of 2 hypothetical patients if they presented to 2 random sites in the data set. By definition, all median rate ratios are >1 and ratios >1.2 are generally accepted as indicating significant variability.

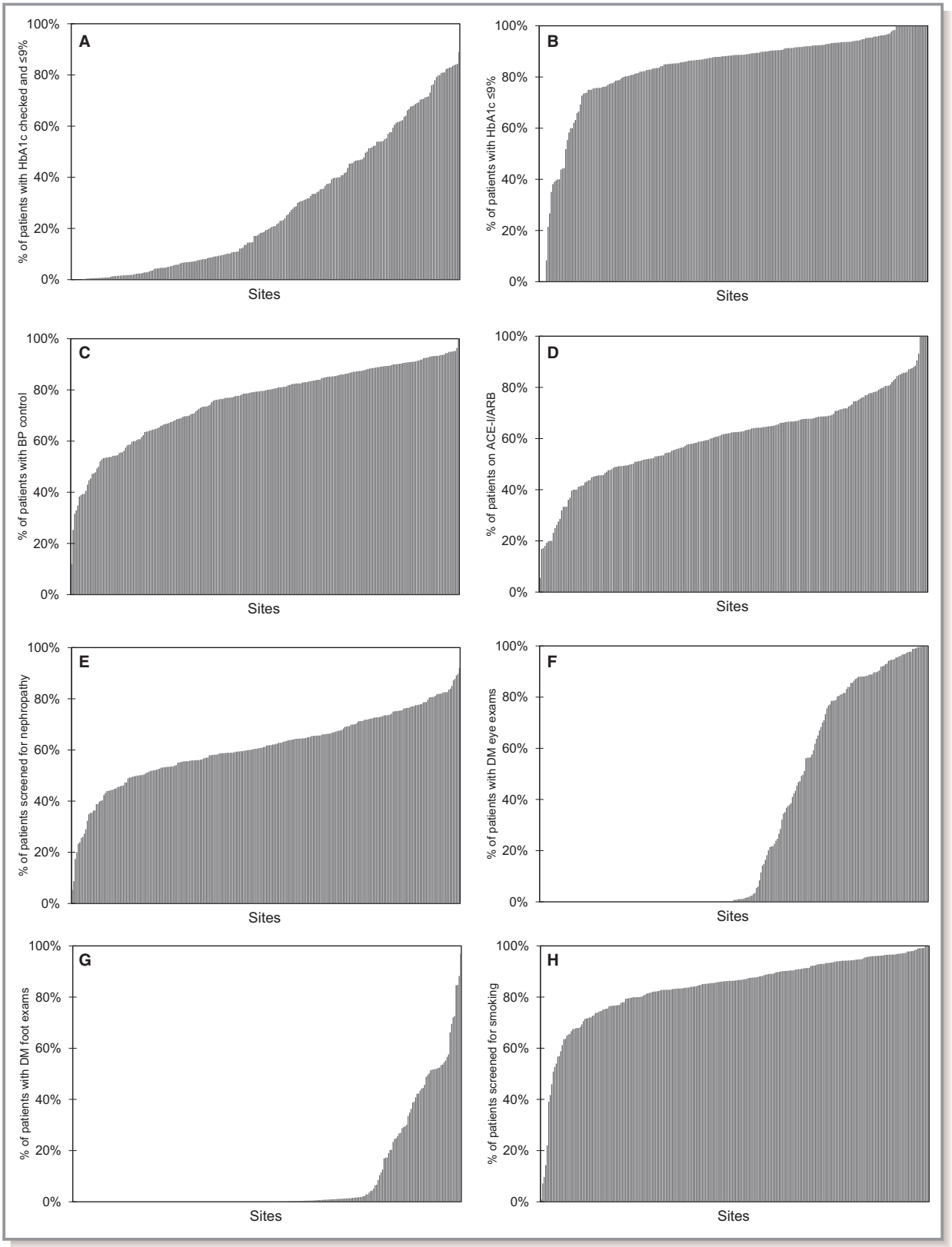

Figure 1. Variability of achievement of quality metrics across sites. A, HbA1c checked and ≤9% (n=241). B, HbA1c ≤9%, if checked (n=241). C, Blood pressure control (n=244). D, ACE-I or ARB with CAD (n=233). E, Nephropathy screening (n=258). F, Diabetes mellitus eye examination (n=259). G, Diabetes mellitus foot examination (n=259). H, Tobacco screening and counseling (n=258). ACE-I indicates angiotensin-converting enzyme-inhibitor; ARB, angiotensin II receptor blocker; BP, blood pressure; CAD, coronary artery disease; DM, diabetes mellitus; HbA1c, hemoglobin A1c.

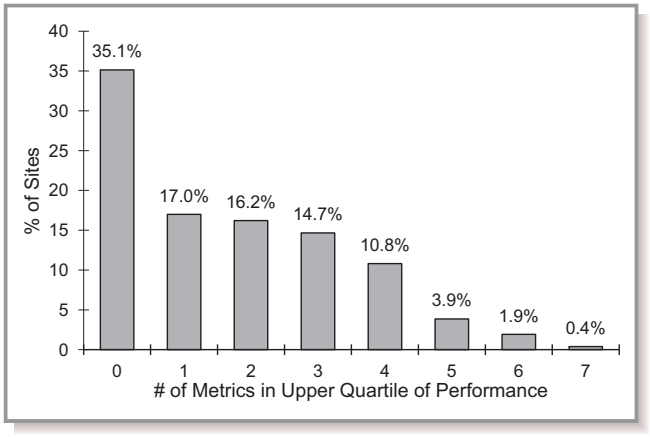

Figure 2. Number of metrics for which each site is in the upper quartile of performance.

specialties. Not surprisingly, endocrinology practices had better achievement of the metrics of documented glycemic control and diabetes mellitus eye and foot examinations, whereas cardiology practices were most successful at documented blood pressure control, nephropathy screening, and use of ACE-I or ARBs in patients with concomitant coronary disease. While it is difficult to determine specific reasons for differences in achievement of these quality metrics, this is likely a combination of a lack of or inadequate documentation (eg, most deficiencies in glycemic control were because of lack of documentation of hemoglobin A1c level in the past year and not because of poor control, when measured), fragmentation of care, ownership of issues (eg, cardiologists not feeling responsible for certain aspects of diabetes mellitus care), and possibly true gaps in care.

Despite guidelines and standards of care for treating patients with diabetes mellitus,[2,12,14,24,25] the practical application of these evidence-based recommendations has been suboptimal.[26] The DCR was developed to document the current quality of care among patients with diabetes mellitus across the spectrum of primary and specialty care. Through collection of data on a national level from providers involved in all phases of diabetes mellitus care and feedback of these data to the practices, we are hopeful that these data will spur improvement of care over time. In this study documenting the initial achievement of the quality metrics, we have identified a number of possible gaps in care. EHRs were designed to improve communication across providers, increase individual provider's ability to manage chronic diseases, and, in turn, improve the quality of medical care. However, the change in quality care has been suboptimal, in part because of use of EHRs simply as a means of documentation, as opposed to management of care. Furthermore, the lack of communication across systems prevents true integration of care, which is of critical importance when dealing with a chronic disease, such as diabetes mellitus, which requires involvement by multiple specialties for optimal management.

Some of the gaps in care that we identified may be simply because of lack of documentation and not a deficiency of care (eg, eye examination was done by primary care but not documented in cardiology record). Although it is unclear as to who "owns" particular aspects of care, a cardiologist would likely not feel responsible for—nor perhaps feel qualified to perform—a diabetes mellitus eye or foot examination. However, given the intersection of diabetes mellitus and cardiovascular health and the complex effects of diabetes mellitus medications on cardiovascular outcomes, the overall care of these patients will likely become increasingly integrated over time, with all specialties needing to take a greater role in ensuring that critical aspects of diabetes mellitus care are addressed by the care team. These data also highlight the importance of developing systems-based

Table 5. Performance on Quality Metrics Across Specialties

Quality Metric	Cardiology (n=93)*	Endocrinology (n=20)*		Primary Care (n=146)*		*P* Value for Specialty in Model
	Median† (IQR)	Median† (IQR)	Rate Ratio‡ (95% CI)	Median† (IQR)	Rate Ratio‡ (95% CI)	
Glycemic control	9.5% (2.3–30.7)	53.1% (18.9–68.2)	3.77 (2.04–6.96)	27.5% (7.2–54.9)	2.18 (1.43–3.31)	<0.001
Blood pressure control	87.3% (77.1–90.9)	76.9% (59.0–82.2)	0.84 (0.73–0.95)	76.9% (64.6–83.8)	0.90 (0.85–0.95)	<0.001
ACE-I/ARB with CAD	66.6% (58.9–74.6)	59.0% (45.7–64.7)	0.79 (0.64–0.98)	58.1% (47.7–68.2)	0.86 (0.80–0.93)	<0.001
Nephropathy screening	68.3% (59.0–74.4)	57.1% (51.5–65.6)	0.85 (0.79–0.92)	58.4% (50.1–64.3)	0.80 (0.76–0.85)	<0.001
Diabetes mellitus eye exam	1.6% (0.0–57.3)	6.1% (0.0–80.1)	0.95 (0.15–6.07)	0.0% (0.0–83.2)	0.84 (0.32–2.19)	0.935
Diabetes mellitus foot exam	0.0% (0.0–0.9)	13.5% (0.0–50.3)	9.32 (1.75–49.50)	0.0% (0.0–12.6)	3.97 (1.74–9.05)	0.001
Tobacco screening and cessation counseling	87.6% (79.3–93.5)	86.3% (82.8–90.9)	1.02 (0.96–1.08)	85.4% (76.9–93.3)	0.93 (0.88–1.00)	0.073

ACE-I indicates angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; CAD, coronary artery disease; IQR, interquartile range.
*N represents the number of sites.
†Median rate of adherence at the practice level.
‡Cardiology practices as reference.

approaches to optimize team-based care, such as an integrated diabetes mellitus care center, and importantly, the clear documentation of achievement of quality metrics through easily retrievable electronic means. In addition, more intensive use of EHRs with structured notes, disease management, and clinical support tools may also be key ways to improve the care of these complex patients.[27]

There have been several prior studies examining quality of care of patients with diabetes mellitus, which have generally been focused on goal attainment of cardiovascular risk factors (eg, cholesterol, hemoglobin A1c, blood pressure, and body mass index).[28–32] For example, an analysis of the National Health and Nutrition Examination Survey survey of patients with self-reported diabetes mellitus showed that 87% of patients had a hemoglobin A1c <9%, 73% and 71% reported having an eye and foot examination in the prior year, respectively, and 72% reported having a blood pressure <140/90.[31] These results were similar in integrated healthcare systems with less fragmentation of care, with data from Kaiser Permanente in 2014 showing 82% of patients with hemoglobin A1c <9%, 75% having a diabetes mellitus eye examination, 96% with nephropathy screening, and 85% with a blood pressure <140/90.[33] While our quality metrics are different from many of these goal-based measures, the disconnect between our results and prior analyses highlight the fractured care that patients with diabetes mellitus often receive. Prior studies either used the patient as the subject of assessment or came from integrated care systems. In contrast, when we examined over 500 000 physician records of patients with diabetes mellitus, documentation of many aspects of diabetes mellitus care were suboptimal. While some of these aspects of care may not be the "responsibility of" the particular physician treating that patient (eg, cardiologists and diabetes mellitus foot and eye examinations), other aspects (eg, glycemic control) likely should be more co-managed. The DCR will be an important part in this integration of care across the specialties and should promote more active co-management of these complicated patients.

There are a number of potential limitations to our study that merit further discussion. First, the selection of diabetes mellitus quality metrics to be assessed in DCR could be debated. The Steering Committee of DCR selected the measures from those approved by the American College of Cardiology/American Heart Association Task Force on Performance Measures[19–21] and based on the existing Centers for Medicare and Medicaid Services Physician Quality Reporting System.[22] Second, other quality metrics are intended to be measured in DCR (eg, counseling on diet and exercise, high-intensity statin use in patients with coronary or peripheral artery disease) but could not be assessed because of current data limitations. We expect that additional registry enhancements will allow these measures to be tracked in the future. Third, because of the established mapping infrastructure with cardiology sites already participating in the PINNACLE registry, there was a predominance of cardiology practices in our initial analytic sample and only a small minority of endocrinology practices. We were able to identify some key practice patterns across the different specialties; however, these analyses will become more robust as the proportion of noncardiology practices increases in DCR.

In conclusion, the initial examination of cardiology, endocrinology, and primary care practices in the DCR demonstrated substantial variability in achievement of diabetes mellitus quality metrics. These data highlight important potential gaps in care, which are likely multifactorial (documentation, fragmentation of care, ownership issues). Further work is needed to integrate diabetes mellitus care across primary and specialty care so as to minimize any true gaps in care. The DCR is uniquely positioned to facilitate this process and will hopefully result in improvement in the quality of care and, ultimately, the outcomes of patients with diabetes mellitus.

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References

1. Wild S, Roglic G, Green A, Sicree R, King H. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. *Diabetes Care*. 2004;27:1047–1053.
2. World Health Organization. Diabetes Fact Sheet 312. 2013; Available at: http://www.who.int/mediacentre/factsheets/fs312/en. Accessed November 2, 2014
3. Boyle JP, Thompson TJ, Gregg EW, Barker LE, Williamson DF. Projection of the year 2050 burden of diabetes in the US adult population: dynamic modeling of incidence, mortality, and prediabetes prevalence. *Popul Health Metr*. 2010;8:29.
4. Menke A, Casagrande S, Geiss L, Cowie CC. Prevalence of and trends in diabetes among adults in the United States, 1988–2012. *JAMA*. 2015;314:1021–1029.
5. Israili ZH. Advances in the treatment of type 2 diabetes mellitus. *Am J Ther*. 2011;18:117–152.
6. Roglic G, Unwin N, Bennett PH, Mathers C, Tuomilehto J, Nag S, Connolly V, King H. The burden of mortality attributable to diabetes: realistic estimates for the year 2000. *Diabetes Care*. 2005;28:2130–2135.
7. ADA. Economic costs of diabetes in the U.S. in 2002. *Diabetes Care*. 2003;26:917–932.
8. Caro JJ, Ward AJ, O'Brien JA. Lifetime costs of complications resulting from type 2 diabetes in the U.S. *Diabetes Care*. 2002;25:476–481.
9. Dall TM, Zhang Y, Chen YJ, Quick WW, Yang WG, Fogli J. The economic burden of diabetes. *Health Aff (Millwood)*. 2010;29:297–303.
10. Alexander GC, Sehgal NL, Moloney RM, Stafford RS. National trends in treatment of type 2 diabetes mellitus, 1994–2007. *Arch Intern Med*. 2008;168:2088–2094.
11. American Diabetes A. Standards of medical care in diabetes—2014. *Diabetes Care*. 2014;37(suppl 1):S14–S80.
12. Handelsman Y, Mechanick JI, Blonde L, Grunberger G, Bloomgarden ZT, Bray GA, Dagogo-Jack S, Davidson JA, Einhorn D, Ganda O, Garber AJ, Hirsch IB, Horton ES, Ismail-Beigi F, Jellinger PS, Jones KL, Jovanovic L, Lebovitz H, Levy P, Moghissi ES, Orzeck EA, Vinik AI, Wyne KL; Plan ATFfDDCC. American Association of Clinical Endocrinologists Medical Guidelines for Clinical Practice for developing a diabetes mellitus comprehensive care plan. *Endocr Pract*. 2011;17(suppl 2):1–53.
13. Qaseem A, Humphrey LL, Sweet DE, Starkey M, Shekelle P; Clinical Guidelines Committee of the American College of P. Oral pharmacologic treatment of type 2 diabetes mellitus: a clinical practice guideline from the American College of Physicians. *Ann Intern Med*. 2012;156:218–231.
14. Authors/Task Force M, Ryden L, Grant PJ, Anker SD, Berne C, Cosentino F, Danchin N, Deaton C, Escaned J, Hammes HP, Huikuri H, Marre M, Marx N, Mellbin L, Ostergren J, Patrono C, Seferovic P, Uva MS, Taskinen MR, Tendera M, Tuomilehto J, Valensi P, Zamorano JL; Guidelines ESCCfP, Zamorano JL, Achenbach S, Baumgartner H, Bax JJ, Bueno H, Dean V, Deaton C, Erol C, Fagard R, Ferrari R, Hasdai D, Hoes AW, Kirchhof P, Knuuti J, Kolh P, Lancellotti P, Linhart A, Nihoyannopoulos P, Piepoli MF, Ponikowski P, Sirnes PA, Tamargo JL, Tendera M, Torbicki A, Wijns W, Windecker S; Document R, De Backer G, Sirnes PA, Ezquerra EA, Avogaro A, Badimon L, Baranova E, Baumgartner H, Betteridge J, Ceriello A, Fagard R, Funck-Brentano C, Gulba DC, Hasdai D, Hoes AW, Kjekshus JK, Knuuti J, Kolh P, Lev E, Mueller C, Neyses L, Nilsson PM, Perk J, Ponikowski P, Reiner Z, Sattar N, Schachinger V, Scheen A, Schirmer H, Stromberg A, Sudzhaeva S, Tamargo JL, Viigimaa M, Vlachopoulos C, Xuereb RG. ESC guidelines on diabetes, pre-diabetes, and cardiovascular diseases developed in collaboration with the EASD: the Task Force on diabetes, pre-diabetes, and cardiovascular diseases of the European Society of Cardiology (ESC) and developed in collaboration with the European Association for the Study of Diabetes (EASD). *Eur Heart J*. 2013;34:3035–3087.
15. O'Connor PJ, Bodkin NL, Fradkin J, Glasgow RE, Greenfield S, Gregg E, Kerr EA, Pawlson LG, Selby JV, Sutherland JE, Taylor ML, Wysham CH. Diabetes performance measures: current status and future directions. *Diabetes Care*. 2011;34:1651–1659.
16. Fleming BB, Greenfield S, Engelgau MM, Pogach LM, Clauser SB, Parrott MA. The Diabetes Quality Improvement Project: moving science into health policy to gain an edge on the diabetes epidemic. *Diabetes Care*. 2001;24:1815–1820.
17. Shojania KG, Ranji SR, Shaw LK, Charo LN, Lai JC, Rushakoff RJ, McDonald KM, Owens DK. Closing the quality gap: a critical analysis of quality improvement strategies volume 2—diabetes mellitus care. AHRQ Technical Reviews. 2004 September. Report No.: 04-0051-2.
18. Arnold SV, Inzucchi SE, McGuire DK, Mehta SN, Goyal A, Sperling LS, Maddox TM, Einhorn D, Wong ND, Ratner RE, Hammar N, Fenici P, Sheehan JJ, Wong JL, Kosiborod M. Evaluating the quality of comprehensive cardiometabolic care for patients with type 2 diabetes in the U.S.: the Diabetes Collaborative Registry. *Diabetes Care*. 2016;39:e99–e101.
19. Drozda J Jr, Messer JV, Spertus J, Abramowitz B, Alexander K, Beam CT, Bonow RO, Burkiewicz JS, Crouch M, Goff DC Jr, Hellman R, James T III, King ML, Machado EA Jr, Ortiz E, O'Toole M, Persell SD, Pines JM, Rybicki FJ, Sadwin LB, Sikkema JD, Smith PK, Torcson PJ, Wong JB. ACCF/AHA/AMA-PCPI 2011 performance measures for adults with coronary artery disease and hypertension: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Performance Measures and the American Medical Association-Physician Consortium for Performance Improvement. *J Am Coll Cardiol*. 2011;58:316–336.
20. Krumholz HM, Anderson JL, Bachelder BL, Fesmire FM, Fihn SD, Foody JM, Ho PM, Kosiborod MN, Masoudi FA, Nallamothu BK. ACC/AHA 2008 performance measures for adults with ST-elevation and non-ST-elevation myocardial infarction: a report of the American College of Cardiology/American Heart Association Task Force on Performance Measures (writing committee to develop performance measures for ST-elevation and non-ST-elevation myocardial infarction) developed in collaboration with the American Academy of Family Physicians and American College of Emergency Physicians Endorsed by the American Association of Cardiovascular and Pulmonary Rehabilitation, Society for Cardiovascular Angiography and Interventions, and Society of Hospital Medicine. *J Am Coll Cardiol*. 2008;52:2046–2099.
21. Olin JW, Allie DE, Belkin M, Bonow RO, Casey DE Jr, Creager MA, Gerber TC, Hirsch AT, Jaff MR, Kaufman JA, Lewis CA, Martin ET, Martin LG, Sheehan P, Stewart KJ, Treat-Jacobson D, White CJ, Zheng ZJ, Masoudi FA, Bonow RO, DeLong E, Erwin J III, Goff DC Jr, Grady K, Green LA, Heidenreich PA, Jenkins KJ, Loth AR, Peterson ED, Shahian DM; American College of Cardiology F, American Heart A, American College of R, Society for Cardiac Angiography I, Society for Interventional R, Society for Vascular M, Society for Vascular N, Society for Vascular S. ACCF/AHA/ACR/SCAI/SIR/SVM/SVN/SVS 2010 performance measures for adults with peripheral artery disease: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Performance Measures, the American College of Radiology, the Society for Cardiac Angiography and Interventions, the Society for Interventional Radiology, the Society for Vascular Medicine, the Society for Vascular Nursing, and the Society for Vascular Surgery (writing committee to develop clinical performance measures for peripheral artery disease). *J Am Coll Cardiol*. 2010;56:2147–2181.
22. Centers for Medicare & Medicaid Services. PQRS 2015 measure list. Available at: Https://www.Cms.Gov/medicare/quality-initiatives-patient-assessment-instruments/pqrs/measurescodes.Html. Accessed November 9, 2015.
23. Larsen K, Petersen JH, Budtz-Jorgensen E, Endahl L. Interpreting parameters in the logistic regression model with random effects. *Biometrics*. 2000;56:909–914.
24. Standards of medical care in diabetes–2013. *Diabetes Care*. 2013;36(suppl 1):S11–S66.
25. Haas L, Maryniuk M, Beck J, Cox CE, Duker P, Edwards L, Fisher EB, Hanson L, Kent D, Kolb L, McLaughlin S, Orzeck E, Piette JD, Rhinehart AS, Rothman R, Sklaroff S, Tomky D, Youssef G; Standards Revision Task F. National standards for diabetes self-management education and support. *Diabetes Care*. 2014;37(suppl 1):S144–S153.
26. Dentzer S. Going the distance to improve the care span. *Health Aff (Millwood)*. 2012;31:1150.
27. Linder JA, Schnipper JL, Middleton B. Method of electronic health record documentation and quality of primary care. *J Am Med Inform Assoc*. 2012;19:1019–1024.
28. Lafeuille MH, Grittner AM, Gravel J, Bailey RA, Martin S, Garber L, Sheng Duh M, Lefebvre P. Quality measure attainment in patients with type 2 diabetes mellitus. *Am J Manag Care*. 2014;20:s5–s15.

29. Stark Casagrande S, Fradkin JE, Saydah SH, Rust KF, Cowie CC. The prevalence of meeting A1c, blood pressure, and LDL goals among people with diabetes, 1988–2010. *Diabetes Care*. 2013;36:2271–2279.

30. Vouri SM, Shaw RF, Waterbury NV, Egge JA, Alexander B. Prevalence of achievement of A1c, blood pressure, and cholesterol (ABC) goal in veterans with diabetes. *J Manag Care Pharm*. 2011;17:304–312.

31. Ali MK, Bullard KM, Saaddine JB, Cowie CC, Imperatore G, Gregg EW. Achievement of goals in U.S. diabetes care, 1999–2010. *N Engl J Med*. 2013;368:1613–1624.

32. Saaddine JB, Cadwell B, Gregg EW, Engelgau MM, Vinicor F, Imperatore G, Narayan KM. Improvements in diabetes processes of care and intermediate outcomes: United States, 1988–2002. *Ann Intern Med*. 2006;144:465–474.

33. Kaiser Foundation Health Plan of the Northwest HEDIS. Northwest region HEDIS performance by medical office. 2014. Available at: https://healthy.kaiserpermanente.org/static/health/pdfs/quality_and_safety/nw/nw_quality_perfbymedoff.pdf. Accessed April 24, 2017.