Consistency of Hemoglobin A1c Testing and Cardiovascular Outcomes in Medicare Patients With Diabetes

Philip P. Goodney, MD, MS; Karina A. Newhall, MD; Kimon Bekelis, MD; Daniel Gottlieb, MD; Richard Comi, MD; Sushela Chaudrain, MD; Adrienne E. Faerber, PhD; Todd A. Mackenzie, PhD; Jonathan S. Skinner, PhD

Background—Annual hemoglobin A1c testing is recommended for patients with diabetes mellitus. However, it is unknown how consistently patients with diabetes mellitus receive hemoglobin A1c testing over time, or whether testing consistency is associated with adverse cardiovascular outcomes.

Methods and Results—We identified 1,574,415 Medicare patients (2002–2012) with diabetes mellitus over the age of 65. We followed each patient for a minimum of 3 years to determine their consistency in hemoglobin A1c testing, using 3 categories: low (testing in 0 or 1 of 3 years), medium (testing in 2 of 3 years), and high (testing in all 3 years). In unweighted and inverse propensity-weighted cohorts, we examined associations between testing consistency and major adverse cardiovascular events, defined as death, myocardial infarction, stroke, amputation, or the need for leg revascularization. Overall, 70.2% of patients received high-consistency testing, 17.6% of patients received medium-consistency testing, and 12.2% of patients received low-consistency testing. When compared to high-consistency testing, low-consistency testing was associated with a higher risk of adverse cardiovascular events or death in unweighted analyses (hazard ratio [HR] = 1.21; 95% CI, 1.20–1.23; P < 0.001), inverse propensity-weighted analyses (HR = 1.16; 95% CI, 1.15–1.17; P < 0.001), and weighted analyses limited to patients who had at least 4 physician visits annually (HR = 1.15; 95% CI, 1.15–1.16; P < 0.001). Less-consistent testing was associated with worse results for each cardiovascular outcome and in analyses using all years as the exposure.

Conclusions—Consistent annual hemoglobin A1c testing is associated with fewer adverse cardiovascular outcomes in this observational cohort of Medicare patients with diabetes mellitus. (J Am Heart Assoc. 2016;5:e003566 doi: 10.1161/JAHA.116.003566)

Key Words: cardiovascular outcomes • diabetes mellitus • health disparities • health outcomes • hemoglobin A1c
national cohort of Medicare patients with diabetes mellitus and followed each patient for a minimum of 3 years to determine the consistency with which they received hemoglobin A1c testing. We then examined associations between testing consistency and cardiovascular outcomes in subsequent years, using unweighted and inverse propensity-weighted analyses, as well as analyses targeting patients observed at least 4 times per year, to allow adequate opportunities for physicians to order hemoglobin A1c testing.

Methods

Creating a Cohort of Medicare Patients With Diabetes Mellitus

We used the Medicare Physician and Supplier file as well as the Medicare Denominator file, in the years 2002–2009, to identify all patients with diagnosis codes indicative of the presence of diabetes mellitus during that time period. Each patient was followed forward in time for a minimum of 3 calendar years, through the year 2012. Patients were required to have a diagnosis codes for diabetes mellitus in 2 of 3 consecutive years for inclusion in the cohort. We used the year in which the patient entered our cohort to establish the patient’s comorbidities using the Charlson score. Because having diabetes mellitus was a requirement for cohort inclusion, we did not include diabetes mellitus with or without end organ damage within the overall Charlson score calculation.17

We excluded patients less than 65 years of age, greater than 99 years of age, and those not enrolled in fee-for-service Medicare plans. Further information was obtained using the denominator file, which contains information about Medicare and Medicaid eligibility, age, sex, race, and disability. We recorded patient ZIP code and the hospital referral region of residence, as described by the Dartmouth Atlas of Health Care.18 We also linked zip code to the American Community Survey (2006–2010 aggregation) to identify local area median income and poverty status. We used county-level data from countyhealthrankings.org to obtain measures of area level health: healthy days, smoking, and obesity as described in previous work.19 Patients left the cohort when they died or ceased enrollment in Medicare’s Part A or Part B programs, such as in those who joined a Medicare HMO program such as Medicare Advantage.

Measuring Consistency in Hemoglobin A1c Testing

Hemoglobin A1c testing is recommended at least annually for patients with diabetes mellitus.20 Within our cohort, we examined whether or not patients had ever undergone hemoglobin A1c testing. We used the CPT codes available for this laboratory test (Data S1). This variable has been used in previous studies using administrative datasets.20–22

To determine our exposure variable, consistency in hemoglobin A1c testing, we examined how consistently hemoglobin A1c testing was performed for each patient during the first 3 years they were followed in our cohort. Testing consistency was categorized as low (testing in none or 1 year of the first 3 years), medium (testing in any 2 years of the first 3 years), and high (testing in all 3 of the first 3 years).

Our analysis considered only patients who had at least 1 physician visit per year during the first 3 years, given that a physician visit would allow for an opportunity for patients to receive hemoglobin A1C testing. Sensitivity analyses where none or 1 test during the first 3 years were analyzed independently were performed, and our findings were similar to those presented herein.

We excluded any patients who died within the first 3 years. Sensitivity analysis were performed, which required a minimum of 4 physician visits per year during the first 3 years. We also performed analyses that considered testing consistency during the entire time each patients appeared in fee-for-service Medicare, rather than using the first 3 years of testing as an exposure variable and examining outcomes using survival analysis thereafter. Because findings were similar between these analyses and our outcomes reported herein, we present only the latter strategy in this article.

Measuring Cardiovascular Outcomes, by Consistency Category

After using the first 3 years in the cohort to measure the exposure variable, we used all remaining years patients appeared in Medicare claims to measure major adverse cardiovascular events, beginning on the first day of the fourth year. We searched for evidence of death, as well as any of the following cardiovascular events: myocardial infarction, stroke, amputation, and need for a lower-extremity vascular procedure (codes are shown in Data S1). Death was assessed using the Denominator file. Myocardial infarction was defined using International Classification of Diseases, Ninth Revision (ICD-9) diagnosis codes as in previous reports.23 Stroke was defined using ICD-9 codes, as published previously. We used a 1-year look back to exclude patients in whom any of the cardiovascular events occurred in the past year.23,24 We recorded the occurrence of a major lower-extremity amputation at the patient level, using current procedural terminology codes indicative of above- or below-knee amputation. We excluded toe and forefoot amputations, and traumatic amputations, although in sensitivity analyses, our results remained similar.
when we included toe or forefoot amputations in our analysis. Leg revascularization procedures were also measured using diagnosis and procedure codes reported in our previous work.20,25 A composite outcome of a major adverse cardiac event (MACE) was analyzed as well, defined as the occurrence of any of the following: death, myocardial infarction, stroke, major leg amputation, or need for lower-extremity revascularization.

All cardiovascular outcomes were assessed using time-to-event analyses, with the initial time period beginning on the first day of the fourth year; the first 3 years in the cohort were used to assign the exposure. Death was allowed in the fourth in the cohort and thereafter. Any major adverse cardiovascular events occurring in the first 3 years were excluded. If patients left fee-for-service Medicare claims for Medicare Advantage or other non-fee-for-service programs during this interval, they were censored on the date they ceased to appear in the fee-for-service Medicare program.

Statistical Analyses
We began by examining the consistency in hemoglobin A1c testing among Medicare patients with diabetes mellitus between 2002 and 2012. We created Cox survival models to understand associations between the consistency of testing and cardiovascular outcomes. These models were adjusted for age, sex, race, Medicaid eligibility, disability status, and Charlson score as well as regional variables indicative of health status, income, and poverty.

Crude results were examined using linear analyses before examining our 3 consistency categories and over time. Because patient characteristics differed across the categories of consistency in hemoglobin A1c testing (Table 1), we used multilevel inverse propensity weighting to develop a matched cohort of patients, based on the patient’s likelihood to receive low-, medium-, and high-consistency testing.26,27 We developed multinomial logistic models that identified patient and structural factors associated with each category of consistency in hemoglobin A1c testing. We then used the inverse of these probabilities to weight patients and balance the testing groups. Models were run using both baseline information only, as well as allowing covariates, including the year of testing, to change annually as the patient progressed through each year in the study. Both efforts produced similar results, and therefore the baseline-adjusted models are presented herein. P values are reported across all three categories.

All analyses were performed using SAS (SAS Institute Inc., Cary, NC) and STATA software (StataCorp LP, College Station, TX). The Geisel School of Medicine’s Center for the Protection of Human Subjects approved our study. Informed consent was waived as part of the study, because it involved only secondary data-set analyses.

Results
Patient Characteristics and Unadjusted Outcomes, by Testing Consistency
Between 2002 and 2009, we identified 1,574,415 individual Medicare patients with diabetes mellitus. These patients were followed for a mean of 6.3 years in our cohort, with a range from 3 to 11 years. Overall, 70.2% of patients received high-consistency testing, 17.6% of patients received medium-consistency testing, and 12.2% of patients received low-consistency testing. Testing consistency in the first 3 years was reflected in testing in later years. For example, those with high-consistency testing in the first 3 years had testing in 88% of later years, and those with low-consistency testing during the first 3 years had testing in 49% of later years.

Patients were who received low-consistency testing were older than patients receiving high-consistency testing when they entered the cohort; the mean age was nearly 2 years older for those receiving low-consistency testing when compared to those receiving high-consistency testing (76.3 vs 74.6 years; P<0.001; Table 1). Differences by race were evident as well, as 14.3% of low-consistency testing patients were black, whereas 10.0% of high-consistency testing patients were black (P<0.0001). Finally, a larger proportion of patients getting low-consistency testing were on disability when compared to high-consistency testing (15.5% vs 11.9%; P<0.0001).

Because a patient clinic visit is an opportunity for a physician to order hemoglobin A1c testing, we examined patient visit patterns in our cohort. Overall, patients had an average of 17 physician visits in each year during the study period. Of these visits, an average of 8 were with a primary care physician. Patients were seen often by physicians; only 9% of Medicare enrollees in the cohort had fewer than 4 physician visits annually. Differences in the number of visits were evident across categories of testing consistency (Table 1). For example, patients who received low-consistency testing had a higher number of physician visits than those receiving high-consistency testing (19.7 vs 16.3 visits; P<0.001), but were also more likely to have fewer than 4 physician visits per year (11.1% vs 8.6%; P<0.001).

Cardiovascular Outcomes, by Testing Consistency
In unweighted analyses, we found 62.3% of patients treated with low-consistency testing experienced death or a major adverse cardiovascular event within 7 years of follow-up (Figure A). The rate of death or an adverse cardiovascular event was 13.2% lower, in absolute terms, for patients treated with high-consistency testing (49.0%), a difference that was highly significant across testing consistency categories (log
Table 1. Patient Characteristics, by Consistency Category, in Both Crude and Inverse Propensity Weighted Cohorts

|                        | All Patients | Low Consistency Testing | Medium Consistency Testing | High Consistency Testing | P Value | All Patients | Low Consistency Testing | Medium Consistency Testing | High Consistency Testing | P Value |
|------------------------|--------------|-------------------------|----------------------------|----------------------------|---------|--------------|-------------------------|----------------------------|----------------------------|---------|
| Person-years (percent of total) | 1 051 072 (100.0) | 128 000 (12.2) | 185 514 (17.6) | 737 558 (70.2) | <0.0001 | 3 132 810 (100.0) | 1 032 290 (33.0) | 1 044 699 (33.3) | 1 055 821 (33.7) | <0.0001 |
| No. of years in cohort | 7.5          | 7.1                     | 7.4                         | 7.6                         | <0.0001 | 7.4          | 7.1                     | 7.4                         | 7.7                         | <0.0001 |
| Age at entry into cohort | 75.0         | 76.3                    | 75.6                         | 74.6                         | <0.0001 | 75.0         | 75.1                    | 75.0                         | 74.9                         | <0.0001 |
| Percent black          | 10.9         | 14.3                    | 12.5                         | 10.0                         | <0.0001 | 11.0         | 11.1                    | 11.0                         | 11.0                         | 0.0429  |
| Percent female         | 55.3         | 51.0                    | 54.8                         | 56.2                         | 0.0002  | 55.3         | 55.4                    | 55.4                         | 55.2                         | <0.0001 |
| Percent disabled at entry into cohort | 12.7 | 15.5 | 13.6 | 11.9 | <0.0001 | 12.7 | 12.8 | 12.7 | 12.7 | <0.0001 |
| Percent Hispanic       | 2.2          | 2.9                     | 2.7                          | 1.9                          | <0.0001 | 2.2          | 2.2                     | 2.2                          | 2.2                          | 0.8734  |
| Percent not Hispanic or black | 0.9 | 0.8 | 0.9 | 0.9 | <0.0001 | 0.9 | 0.9 | 0.9 | 0.9 | 0.0418 |
| Percent Medicaid       | 18.4         | 24.8                    | 21.7                         | 16.4                         | <0.0001 | 18.6         | 19.0                    | 18.6                         | 18.3                         | 0.6847  |
| Regional surgical intensity quintile (1=lowest, 5=highest) | 3.3 | 3.3 | 3.3 | 3.3 | <0.0001 | 3.3 | 3.3 | 3.3 | 3.3 | <0.0001 |
| Percent of patients at ≤150% of poverty level | 23.5 | 25.5 | 24.2 | 22.9 | <0.0001 | 23.6 | 23.7 | 23.5 | 23.4 | <0.0001 |
| Charlson score (mean)  | 1.5          | 1.9                     | 1.6                          | 1.3                          | <0.0001 | 1.5          | 1.5                     | 1.5                          | 1.4                          | <0.0001 |
| Regional mean number of unhealthy days per month | 3.6 | 3.7 | 3.7 | 3.6 | <0.0001 | 3.6 | 3.6 | 3.6 | 3.6 | <0.0001 |
| Mean number of adults with a BMI >30 (county level) | 28.5 | 28.7 | 28.5 | 28.4 | <0.0001 | 28.5 | 28.5 | 28.5 | 28.4 | <0.0001 |
| Percent of adults who smoke (county level) | 19.8 | 20.0 | 19.8 | 19.8 | <0.0001 | 19.8 | 19.9 | 19.8 | 19.8 | <0.0001 |
| Median household income in 2011 (in thousands of dollars) | 53.5 | 51.2 | 52.8 | 54.1 | <0.0001 | 53.5 | 53.5 | 53.6 | 53.4 | 0.0297  |
| All Patients | Unweighted | Inverse Propensity Weighted | P Value |
|--------------|------------|----------------------------|---------|
|               | No. of primary care provider visits per year |               |         |
| Low Consistency Testing | 7.8 | 9.1 | 8.2 | 7.5 | <0.0001 | 7.9 | 8.2 | 7.9 | 7.7 | <0.0001 |
| Medium Consistency Testing | 17.0 | 19.7 | 17.7 | 16.3 | <0.0001 | 17.3 | 18.0 | 17.1 | 16.7 | <0.0001 |
| High Consistency Testing | 9.2 | 11.1 | 10.1 | 8.6 | <0.0001 | 10.3 | 12.0 | 10.5 | 8.5 | <0.0001 |
| Percent of patients with fewer than 4 physician visits per year (after having a visit in each of the 3 years during the period used to define testing categories) | 7.8 | 11.9 | 8.3 | 7.0 | <0.0001 | 9.2 | 12.4 | 8.4 | 7.0 | <0.0001 |
| Percent of patients with no physician visits in any year in the analysis (after having a visit in each of the 3 years during the period used to define testing categories) | 9.2 | 11.1 | 10.1 | 8.6 | <0.0001 | 10.3 | 12.0 | 10.5 | 8.5 | <0.0001 |

BMI indicates body mass index.
From the American Community Survey of the US Census (https://www.census.gov/programs-surveys/acs/).
*Source: 2012 county health rankings (all county level). Smoking is % of adults currently smoking. Unhealthy days is the mean number of physically unhealthy days per month.
†2006–2010 aggregated American community survey. Derived from census-tract-level data.
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components (Table 2). We calculated unweighted hazard ratios, with surrounding 95% CIs, for each outcome, across consistency categories. These demonstrated an inverse relationship between testing consistency and the risk of death or a major adverse cardiovascular event, as well as each of its individual components (Table 2).

Cardiovascular Outcomes, by Testing Consistency in Inverse Propensity-Weighted Analyses

Because of the differences in patient characteristics across categories of testing consistency, we used inverse propensity weighting to generate 3 groups, which were similar across patient characteristics (Table 1). Many of these differences remained statistically significant given our large sample size, but all patient demographic characteristics in the inverse propensity weighted analyses varied by less than 1% across testing consistency categories.

As with our unweighted findings, Cox proportional hazards models derived from the inverse propensity-weighted cohort again demonstrated that low-consistency testing remained associated with worse cardiovascular outcomes, both in our composite outcome (MACE) and its individual components (Table 2). For example, patients receiving low-consistency testing were 16% more likely to experience a cardiovascular adverse event than those who had high-consistency testing (adjusted hazard ratio [HR]=1.16; 95% CI, 1.15–1.17; P<0.001). These findings were again similar for each of the components of our composite outcome.

Last, to ensure we accounted for differences in patient visit type and frequency, we repeated these analyses, but limited to patients who were seen by physicians at least 4 times per year to ensure that physicians had several opportunities to order hemoglobin A1c testing. As with our unweighted and inverse propensity-weighted analyses, we again found that low-consistency testing was associated with a higher risk of death and major adverse cardiovascular events (Table 2), with little change in the effect size evident in this sensitivity analysis.

Discussion

Hemoglobin A1c testing has been shown to be an important tool in guiding the care of patients with diabetes mellitus. Because of this, hemoglobin A1c testing has been established as an important quality measure for both physicians and health care systems. Success toward this effort is evident in our analysis, given that two thirds of patients received high-consistency testing. However, for one third of patients with diabetes mellitus in our analysis, testing did not occur in each year, and for 1 in 9, testing occurred in fewer than half of the years. These “missed opportunities” for hemoglobin A1c testing were associated with significant disparities in cardiovascular outcomes. Patients who received the least-consistent testing had the most cardiovascular complications, including significantly higher rates of myocardial infarction, stroke, amputation, and death.

These results are undoubtedly subject to the limitations of observational analyses using administrative data sets, wherein clinical details, such as the absolute value of the hemoglobin A1c test and its changes over time, are not available. However, our findings were remarkably similar and consistent across multiple endpoints and in several sensitivity analyses, suggesting that a simple confounding variable is unlikely to explain these findings directly.

Broad support for annual hemoglobin A1c testing, and for the use of annual testing as a quality metric, exists in national society guidelines, physician groups, and quality improvement organizations. However, our study, as well as others, suggests that translating these recommendations into practice has met with varying success. For example, a recent report from the US National Ambulatory Medical Care Survey suggested that more than 25% of patients followed for diabetes mellitus have missed testing opportunities. These results are consistent with our observational findings in this large, national analysis of diabetic care provided to Medicare patients in the last decade.

Our results suggest that the consistency of hemoglobin A1c testing could be an important way to measure of the quality of care provided to patients with diabetes mellitus. Despite widespread endorsement and adoption, using annual hemoglobin A1c testing rates as a quality measure has little, if any, direct relationship to better cardiovascular outcomes. Our work, though observational in nature, suggests that more-consistent testing over time is associated with better cardiovascular outcomes.

Is this relationship plausible, especially given that administrative data sets that allow examination of testing patterns do not current allow actual measurement of A1c testing results? A theoretical framework proposing an explanatory mechanism has been described by Presseau et al., wherein they hypothesized that highly consistent hemoglobin A1c testing is a derivative of the consistent patient and physician interactions that occur in the setting of clinical trials. Our results are consistent with this view. Whereas Presseau et al. strike a cautionary note—that raising consistency alone will not necessarily improve the quality of patient-physician interactions—testing consistency allows a determination of
Freedom From Major Adverse Cardiovascular Event (MACE) or Death

All standard errors <0.10. Log rank between groups <0.001

Number at Risk

| Consistency of Testing | 1 Year | 2 Years | 3 Years | 4 Years | 5 Years | 6 Years | 7 Years |
|------------------------|--------|---------|---------|---------|---------|---------|---------|
| High                   | 783512 | 629628  | 506388  | 409302  | 316961  | 239241  | 174619  |
| Medium                 | 200885 | 156148  | 122615  | 97333   | 73556   | 54092   | 37613   |
| Low                    | 139295 | 102215  | 78058   | 60493   | 44590   | 31994   | 21529   |

Freedom From Death

All standard errors <0.10. Log rank between groups <0.001

Number at Risk

| Consistency of Testing | 1 Year | 2 Years | 3 Years | 4 Years | 5 Years | 6 Years | 7 Years |
|------------------------|--------|---------|---------|---------|---------|---------|---------|
| High                   | 810077 | 668678  | 550591  | 454852  | 359459  | 277417  | 206442  |
| Medium                 | 209636 | 168021  | 135574  | 110339  | 85312   | 64219   | 45715   |
| Low                    | 146229 | 110923  | 87245   | 69542   | 52507   | 38547   | 26592   |

Figure. A, Freedom from major adverse cardiac events, by testing consistency category. B, Freedom from death, by testing consistency category. C, Freedom from myocardial infarction, by testing consistency category. D, Freedom from stroke, by testing consistency category. E, Freedom from leg vascular procedure, by testing consistency category. F, Freedom from amputation, by testing consistency category.
which patients were most commonly engaged with their
health care providers and are thereby likely to achieve
stronger relationships with their health care team over time.

These stronger relationships could potentially manifest in
better outcomes, an increasingly common theme in cardio-
vascular care.\textsuperscript{30,31}
Quality metrics for providers and health care systems who care for patients with diabetes mellitus could be designed to help reach this goal. At present, only annual rates are reported in most care settings, and the longitudinal nature of hemoglobin A1C testing is not emphasized. The direct association between higher-consistency testing and fewer
deaths, myocardial infarctions, strokes, and amputations—all outcomes of significant importance to patients—makes this an important opportunity.

Building longitudinal quality measures for patients with diabetes mellitus will have obvious challenges. These metrics will measure engagement from patients as well as providers. Success would require patient compliance over time, just as much as physician compliance. These challenges, however, would also bring opportunities. For example, the clarity offered to patients from metrics emphasizing consistent testing may be easier to for patients to understand (eg, get your flu shot every year, a common Centers for Disease Control and Prevention public health message34) than guidelines emphasizing targeting A1c levels, which often are poorly understood by patients.35,36 This could help patients and physicians achieve better adherence and health care engagement as they manage this challenging chronic disease. And finally, though a longitudinal “consistency” metric may be difficult to collect, new information technology systems will likely make measures of this nature easier to design and implement in future years.

As mentioned previously, our study has several important limitations. First, testing the value of testing, especially in a longitudinal sense, requires not just the evidence that hemoglobin A1C testing has been performed, but also the actual testing results. Current efforts to use “enriched” claims-based data sets that have the actual values, rather than just the use of testing for just this purpose, will help us to attain this goal.37 Second, the main “preventive measure” we studied was hemoglobin A1C testing, which is a valuable tool for measuring diabetic care, but certainly not the only tool available for prevention of diabetic complications. Third, though our study closely examined the cardiovascular complications that occur with diabetes mellitus, we were prevented by data limitations from analyzing other types of complications, such as nephropathy and retinopathy. Fourth, hemoglobin A1c targeted diabetes mellitus management has shown variable effectiveness in limiting cardiovascular complications in randomized trials38–40 and has shown the most efficacy in trials of patients with type 1 diabetes mellitus, a population unlikely to be specifically reflected in our population of older Medicare patients.

In summary, though more than two thirds of Medicare patients with diabetes mellitus receive hemoglobin A1c testing every year, nearly one third of these patients were not tested each year. For nearly 1 in 9 diabetic patients, hemoglobin A1c testing occurred in fewer than half of the

| Table 2. Hazard Ratios for Adverse Outcomes, by Hemoglobin A1C Testing Category |
|---------------------------------|------------------|------------------|------------------|------------------|
|                                  | Low Consistency Testing | 95% Confidence Intervals | Medium Consistency Testing | 95% CIs |
| Unweighted, all patients         |                   |                   |                   |                   |
| Any leg vascular procedure       | 1.12              | 1.08              | 1.15              | 1.09          | 1.06              | 1.11              |
| Myocardial infarction            | 1.19              | 1.15              | 1.22              | 1.14          | 1.12              | 1.17              |
| Death                            | 1.21              | 1.20              | 1.23              | 1.12          | 1.11              | 1.13              |
| Amputation                       | 1.31              | 1.23              | 1.39              | 1.12          | 1.06              | 1.19              |
| Stroke                           | 1.20              | 1.16              | 1.23              | 1.14          | 1.11              | 1.16              |
| Major adverse cardiovascular event | 1.21              | 1.20              | 1.23              | 1.13          | 1.12              | 1.14              |
| Inverse propensity weighted, all patients |                   |                   |                   |                   |
| Any leg vascular procedure       | 1.08              | 1.07              | 1.10              | 1.06          | 1.05              | 1.08              |
| Myocardial infarction            | 1.12              | 1.11              | 1.13              | 1.10          | 1.09              | 1.12              |
| Death                            | 1.16              | 1.15              | 1.17              | 1.08          | 1.08              | 1.09              |
| Amputation                       | 1.26              | 1.22              | 1.30              | 1.09          | 1.06              | 1.13              |
| Stroke                           | 1.16              | 1.14              | 1.17              | 1.11          | 1.09              | 1.12              |
| Major adverse cardiovascular event | 1.16              | 1.15              | 1.17              | 1.09          | 1.09              | 1.10              |
| Inverse propensity weighted, with all patients having at least four physician visits per year |                   |                   |                   |                   |
| Any leg vascular procedure       | 1.05              | 1.04              | 1.07              | 1.06          | 1.05              | 1.08              |
| Myocardial infarction            | 1.08              | 1.06              | 1.09              | 1.09          | 1.08              | 1.11              |
| Death                            | 1.17              | 1.16              | 1.17              | 1.09          | 1.08              | 1.09              |
| Amputation                       | 1.23              | 1.19              | 1.27              | 1.08          | 1.05              | 1.12              |
| Stroke                           | 1.13              | 1.12              | 1.15              | 1.09          | 1.08              | 1.11              |
| Major adverse cardiovascular event | 1.15              | 1.15              | 1.16              | 1.09          | 1.08              | 1.10              |
years in which we studied their care. Given that differences in testing consistency are associated with poorer cardiovascular outcomes, multiyear quality metrics for hemoglobin A1c testing may help improve cardiovascular care for patients with diabetes mellitus. Future efforts to limit cardiovascular complications for patients with diabetes mellitus should consider quality metrics that incentivize longitudinal approaches toward ensuring high-quality diabetic care.

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Disclosures

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SUPPLEMENTAL MATERIAL
**Data S1:** ICD9 and CPT codes used to identify patients with diabetes, as well as major adverse cardiovascular outcomes in our analysis.

| **Diabetes Diagnosis Codes:** |  |
|-----------------------------|--|
| 249.xx | Secondary diabetes mellitus |
| 250.xx | Diabetes mellitus |

| **Myocardial Infarction Diagnosis Codes:** |  |
|---------------------------------------------|--|
| 410.xx: Acute myocardial infarction |  |
| 411.xx: Other acute and subacute forms of ischemic heart disease |  |
| 412.xx: Old myocardial infarction |  |
| 413.xx: Angina pectoris |  |
| 414.xx: Other forms of chronic ischemic heart disease |  |

| **Stroke Diagnosis Codes:** |  |
|-----------------------------|--|
| 433.00 to 433.91: occlusion/stenosis, precerebral artery |  |
| 342 or 438: history of previous stroke |  |
| 435 or 781.4: transient ischemic attack |  |
| 362.34 or 368.12: amaurosis fugax |  |
| 997.0, 997.00, 997.01, and 997.09: In-hospital stroke. |  |

| **Amputation Procedure Codes** |  |
|-------------------------------|--|
| 27590 AMPUTATION THIGH THROUGH FEMUR ANY LEVEL |  |
| 27591 AMP THI THRU FEMUR LVL IMMT FITG TQ W/1ST CST |  |
| 27592 AMPUTATION THIGH THRU FEMUR OPEN CIRCULAR |  |
| 27880 AMPUTATION LEG THROUGH TIBIA&FIBULA |  |
| 27881 AMP LEG THRU TIBFIB W/IMMT FITG TQ W/1ST CST |  |
| 27882 AMPUTATION LEG THRU TIBIA&FIBULA OPEN CIRCULAR |  |

| **Leg Vascular Procedure Codes** |  |
|----------------------------------|--|
| 36200 INTRODUCTION CATHETER AORTA |  |
| 36245 SLCTV CATHJ EA 1ST ORD ABDL PEL/LXTR ART BRNCH |  |
| 36246 SLCTV CATHJ 2ND ORDER ABDL PEL/LXTR ART BRNCH |  |
| 36247 SLCTV CATHJ 3RD+ ORD SLCTV ABDL PEL/LXTR |  |
| Code  | Description |
|-------|-------------|
| BRNCH | 36248 SLCTV CATHJ EA 2ND+ ORD ABDL PEL/LXTR ART BRNCH |
|       | 0238T TRLUML PERIPHERAL AHERECTOMY ILIAC ARTERY EA |
|       | 35452 TRLUML BALO ANGIOPLASTY OPEN AORTIC |
|       | 35454 TRLUML BALO ANGIO OPN ILIAC |
|       | 35456 TRLUML BALO ANGIO OPN FEM-POP |
|       | 35459 TRLUML BALO ANGIO OPN TIBIOPRONEAL TRNK&BRNCH |
|       | 35470 TRLUML BALO ANGIO PRQ TIBPRNL TRNK/BRNCH EA |
|       | 35472 TRLUML BALO ANGIOPLASTY PERCUTANEOUS AORTIC |
|       | 35473 TRLUML BALO ANGIO PRQ ILIAC |
|       | 35474 TRLUML BALO ANGIO PRQ FEMPOP |
|       | 35481 TRLUML PRPH ATHRC OPN AORTIC |
|       | 35482 TRLUML PRPH ATHRC OPN ILIAC |
|       | 35483 TRLUML PRPH ATHRC OPN FEMPOP |
|       | 35485 TRLUML PRPH ATHRC OPN TIBPRNL TRNK&BRNCH |
|       | 35491 TRLUML PRPH ATHRC PRQ AORTIC |
|       | 35492 TRLUML PRPH ATHRC PRQ ILIAC |
|       | 35493 TRLUML PRPH ATHRC PRQ FEMPOP |
|       | 35495 TRLUML PRPH ATHRC PRQ TIBPRNL TRNK&BRNCH |
|       | 37205 TCAT PLMT IV STENT PERCUTANEOUS 1ST VESSEL |
|       | 37206 TCAT PLMT IV STENT PERCUTANEOUS EACH ADDL VESSEL |
|       | 37207 TCAT PLMT IV STENT OPEN 1ST VESSEL |
|       | 37208 TCAT PLMT IV STENT OPEN EACH ADDL VESSEL |
|       | 37220 REVASCULARIZATION ILIAC ARTERY ANGIO 1ST VSL |
|       | 37221 REVSC OPN/PRQ ILIAC ART W/STNT PLMT & ANGIOPLSTY |
|       | 37222 REVASCULARIZATION ILIAC ART ANGIO EA IPSI VSL |
|       | 37223 REVSC OPN/PRQ ILIAC ART W/STNT & ANGIO IPSILATL |
|       | 37224 REVSC OPN/PRG FEM/POP W/ANGIOPLASTY UNI |
|       | 37225 REVSC OPN/PRQ FEM/POP W/ATHRC/ANGIO SM VSL |
|       | 37226 REVSC OPN/PRQ FEM/POP W/STNT/ANGIOOP |
| Code   | Description                                      |
|--------|--------------------------------------------------|
| 37227  | REVSC OPN/PRQ FEM/POP W/STNT/ATHRC/ANGIOP SM VSL |
| 37228  | REVSC OPN/PRQ TIB/PERO W/ANGIOPLASTY UNI         |
| 37229  | REVSC OPN/PRQ TIB/PERO W/ATHRC/ANGIOP SM VSL     |
| 37230  | REVSC OPN/PRQ TIB/PERO W/STNT/ANGIOP SM VSL     |
| 37231  | REVSC OPN/PRQ TIB/PERO W/STNT/ATHR/ANGIOP SM VSL|
| 37232  | REVSC OPN/PRQ TIB/PERO W/ANGIOPLASTY UNI EA VSL |
| 37233  | REVSC OPN/PRQ TIB/PERO W/ATHRC/ANGIOP UNI EA VSL|
| 37234  | REVSC OPN/PRQ TIB/PERO W/STNT/ANGIOP UNI EA VSL |
| 37235  | REVSC OPN/PRQ TIB/PERO W/STNT/ATHR/ANGIOP EA VSL|
| 35302  | TEAEC W/GRAFT SUPERFICIAL FEMORAL ARTERY          |
| 35303  | TEAEC W/GRAFT POPLITEAL ARTERY                   |
| 35304  | TEAEC W/GRAFT TIBIOPERONEAL TRUNK ARTERY         |
| 35305  | TEAEC W/GRAFT TIBIAL/PERONEAL ART 1ST VESSEL     |
| 35306  | TEAEC W/GRAFT EA ADDL TIBIAL/PERONEAL ART        |
| 35351  | TEAEC W/WO PATCH GRAFT ILIAC                     |
| 35355  | TEAEC W/WO PATCH GRAFT ILIOFEMORAL               |
| 35361  | TEAEC W/WO PATCH GRAFT COMBINED AORTOILIAC       |
| 35363  | TEAEC W/WO PATCH GRAFT COMBINED AORTOILIOFEMORAL |
| 35371  | TEAEC W/WO PATCH GRAFT COMMON FEMORAL            |
| 35372  | TEAEC W/WO PATCH GRAFT DEEP PROFUNDA FEMORAL     |
| 35521  | BYPASS W/VEIN AXILLARY-FEMORAL                  |
| 35533  | BYPASS W/VEIN AXILLARY-FEMORAL-FEMORAL          |
| 35538  | BYPASS W/VEIN AORTOBI-ILIAC                     |
| 35539  | BYPASS W/VEIN AORTOFEMORAL                      |
| 35540  | BYPASS W/VEIN AORTOBIFEMORAL                    |
| 35541  | BYP W/VEIN AORTOILIAC/BI-ILIAC                  |
| 35546  | BYP W/VEIN AORTOFEM/BIFEM                       |
| Code   | Description                                      |
|--------|--------------------------------------------------|
| 35548  | BYP W/VEIN AORTOILIOFEM UNI                      |
| 35549  | BYP W/VEIN AORTOILIOFEM BI                       |
| 35551  | BYP W/VEIN AORTOFEMPOP                           |
| 35556  | BYPASS W/VEIN FEMORAL-POPLITEAL                 |
| 35558  | BYPASS W/VEIN FEMORAL-FEMORAL                   |
| 35563  | BYPASS W/VEIN Ilioiliac                         |
| 35565  | BYPASS W/VEIN ILIOFEMORAL                       |
| 35566  | BYP FEM-ANT TIBL PST TIBL PRONEAL ART/OTH DSTL  |
| 35571  | BYP W/VEIN POP-TIBL-PRONEAL ART/OTH DSTL VSL    |
| 35583  | IN-SITU VEIN BYPASS FEMORAL-POPLITEAL           |
| 35585  | IN-SITU FEM-ANT TIBL PST TIBL/PRONEAL ART       |
| 35587  | IN-SITU VEIN BYP POP-TIBL PRONEAL               |
| 35621  | BYP OTH/THN VEIN AXILLARY-FEMORAL               |
| 35623  | BYP OTH/THN VEIN AXILLARY-POPLITEAL/-TIBIAL     |
| 35637  | BYP OTH/THN VEIN AORTOILLIAC                    |
| 35638  | BYP OTH/THN VEIN AORTOBI-ILIAC                  |
| 35646  | BYP OTH/THN VEIN AORTOBIFEMORAL                 |
| 35647  | BYP OTH/THN VEIN AORTOFEMORAL                   |
| 35651  | BYP OTH/THN VEIN AORTOFEMPOP                    |
| 35654  | BYP OTH/THN VEIN AXILLARY-FEMORAL-FEMORAL      |
| 35656  | BYP OTH/THN VEIN FEMORAL-POPLITEAL              |
| 35661  | BYP OTH/THN VEIN FEMORAL-FEMORAL                |
| 35663  | BYP OTH/THN VEIN Ilioiliac                      |
| 35665  | BYP OTH/THN VEIN ILIOFEMORAL                    |
| 35666  | BYP OTH/THN VEIN FEM-ANT TIBL PST TIBL/PRONEAL  |
| 35671  | BYP OTH/THN VEIN POPLITEAL-TIBIAL/-PERONEAL ART |
| 35681  | BYPASS COMPOSITE GRAFT PROSTHETIC & VEIN       |
| 35682  | BYP AUTOG COMPOSIT 2 SEG VEINS FROM 2 LOCATIONS |
| 35683  | BYP AUTOG COMPOSIT 3/> SEG FROM 2/> LOCATION   |
| 35687  | REVJ LXTR ARTL BYP OPN VEIN PATCH ANGIOP        |
| 35681  | REVJ LXTR ARTL BYP OPN W/SGMTL VEIN INTERPOS    |
| 35683  | REVISION FEMORAL ANAST OPEN NONAUTOG GRAFT      |
| 35684  | REVISION FEMORAL ANAST OPEN W/AUTOG GRAFT       |