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Effects of Receipt of Guideline-Recommended Care on Onset of Diabetic Retinopathy and Its Progression

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Abstract

Objective—To determine whether persons in a community setting diagnosed with diabetes who received recommended patterns of care experience improved vision outcomes over a 3-year time period.

Design—Retrospective, longitudinal, cohort analysis.

Participants—Persons diagnosed with diabetes mellitus (DM), with no prior diagnosis of diabetic retinopathy (DR; n = 5989) from the Medicare Current Beneficiary Survey (1992–2004). Persons diagnosed with DM were followed up to 3 years.

Intervention—Propensity score matching was used to compare vision outcomes between persons who received guideline-recommended care and those who did not. Receipt of recommended levels of care was defined as receiving each of the following services 0.75 times annually on average: physician examination, ophthalmologist or optometrist examination, hemoglobin A1c level, lipid levels, and urinalysis.

Main Outcome Measures—Outcome measures were indicators of DR disease progression: no diagnosed DR to diagnosed background DR, proliferative DR, macular edema, proliferative DR complications, and use of a low-vision aid or blindness.

Results—Persons with diagnosed diabetes receiving guideline-recommended care experienced earlier onset of background DR (average treatment effects on the treated [ATT] at 3 years, 0.118; 95% confidence interval [CI], −0.005 to 0.240). There were no differences between those receiving recommended care and others in time to onset of proliferative DR, macular edema, or proliferative DR complications. However, persons who received care consistent with recommendations experienced much lower rates of onset of low vision/blindness than did others (ATT at 3 years, −0.109; 95% CI, −0.189 to −0.030).

Conclusions—Low vision/blindness was substantially reduced over a 3-year period among persons diagnosed with DM who received recommended levels of care.

Diabetes mellitus (DM) affects >20% of persons aged ≥65 in the United States[1] and >6% of the overall population in developed countries.[2] The prevalence of DM is rising throughout the world.[2,3] Diabetic retinopathy (DR), a common complication of diabetes,[4] is a leading

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cause of new cases of blindness among working age adults in the United States.[5] The Eye Diseases Prevalence Research Group[6] estimates that 40% of adults with DM have retinopathy and 8% have vision-threatening retinopathy. The impact of DM also has important health care cost and policy implications. Developing DR increased Medicare spending by >$1000 per beneficiary in the first year after diagnosis.[7] Cost increases have also been documented with European data.[8]

Studies have repeatedly indicated that much of this loss can be prevented by adherence to recommended care patterns, including those released annually by the American Diabetes Association.[9–11] Yet, despite these guidelines, receipt of the recommended care remains quite low.[9–15] As such, significant attention has been devoted to DM management and care of DM and its complications in recent years in an attempt to improve care patterns. Such effort has resulted in an improvement in glycemic control as indicated by trends in National Health and Nutrition Examination Study data and other results.[16]

With this emphasis and increased attention, it is important to assess whether this effort has resulted in improved DM outcomes, such as reduced rates of vision loss. In this study, we report results of the first observational study to analyze how adherence to recommended care for screening and secondary prevention, including prescription drug use for lipid control and hypertension, screening measures for glycemic control, blood pressure, lipids, and urinalysis, general physician visits, and ophthalmologic and optometric visits, has affected rates of onset of DR and its progression. Using Medicare claims and the Medicare Current Beneficiary Survey (MCBS), we created a merged database that included detailed information on diagnoses from Medicare claims and data on several potentially important socioeconomic variables from the MCBS interviews. The data were first examined to determine whether or not persons with a DM diagnosis received recommended care. Second, using propensity score matching, we assessed how rates of DR onset and progression differ among persons with diagnosed DM who receive recommended levels of care versus those who do not.

Methods

Data

We used data from the MCBS from 1992 to 2004 merged by a unique identifier with Medicare claims data and demographic information providing dates of death for each MCBS participant. The MCBS is a household survey, sponsored by the United States Centers for Medicare and Medicaid and conducted since 1991, containing questions on demographic characteristics, income, insurance, health services, health status, and prescription drug use. A sample page of the MCBS questionnaire can be found in Appendix 1 (available at http://aaojournal.org). The sample is randomly selected from the population of Medicare beneficiaries. Data on beneficiaries aged ≥65 years are nationally representative of the US population of this age. Persons in Medicare fee-for-service and in Medicare risk plans (health maintenance organizations [HMOs]) are interviewed 3 times annually. The MCBS uses a rotating panel design replacing one third of the sample annually. Participants are interviewed for 4 years or until death or withdrawal from the sample. During our study period (1991–2004) approximately 12 500 Medicare beneficiaries were surveyed each year. Diagnosis (International Classification of Diseases, 9th Revision Clinical Modification [ICD-9-CM]) and procedure (Current Procedural Terminology; Healthcare Common Procedure Coding System) codes were used for identification of diabetes and diabetes eye-related complications. Institutional Review Board/Ethics Committee approval was obtained.

Sample Selection

Beneficiaries were included in our sample after 1 inpatient or 2 outpatient diabetes diagnoses, based on criteria set forth in previous studies, who also had no prior diagnosis recorded in the Medicare claims data (ICD-9-CM codes in parentheses) of background DR (BDR: 362.01), proliferative DR (PDR: 362.02), macular edema (362.53, 362.83), any PDR complication (PDR complication: vitreous hemorrhage [379.23], tractional retinal detachment [361.81], rubeosis iridis [364.42]), or blindness/low vision (369.xx; Current Procedural Terminology code 92392; Healthcare Common Procedure Coding System codes V2600, V2610, V2615). Blindness/low vision was defined as a person with vision loss in 1 or both eyes, or in use of a low vision aid. Individuals were required to have had an eye examination to ensure that, as of their DM diagnosis date, they did not have any of the study eye complications. Examinations were required to have taken place within 1 year before the index DM diagnosis date. If the individual did not have an eye examination in the 1 year prior, then an eye examination with no DM complication of the eye after the index DM diagnosis was required for admission into the sample. If the examination occurred after DM diagnosis, the eye examination date replaced the initial DM diagnosis date as the index admission date into the sample. Individuals were excluded if enrolled in a Medicare risk plan (HMO) for >6 months before the DM diagnosis date. Individuals enrolled in an HMO after the index diagnosis date were immediately censored. After exclusions, our sample consisted of 5989 persons.

Logit Analysis of the Probability of Receiving Recommended Levels of Care

Using logit analysis (with Stata 10.0; Statacorp, College Station, TX), we calculated the probability that an individual received recommended care. Explanatory variables used in the analysis are listed in Table 1. Physicians have an important role in providing recommended care; however, patients share the responsibility of scheduling and keeping appointments. We measured receipt of recommended care by utilization in 5 categories of service: physician examination, ophthalmologist or optometrist examination, hemoglobin A1c test, lipid test, and urinalysis test beneficiaries received annually during the study period. Data on utilization of drugs were used to supplement the information of examinations and testing. Beneficiaries who did not see a physician during a given year but were taking an antihypertensive drug were assumed to have seen a physician recently and persons not having a lipid test, but who were taking a statin, were assumed to have had a lipid test during that year. Binary variables were created for each of the 5 categories. Individuals receiving 0.75 examinations annually were coded 1. Fewer than 0.75 examinations on average annually were coded 0. Individuals scoring 1 in all 5 categories were deemed to have received recommended levels of care. Such persons accounted for just 15% of the sample, or 903 of the 5989 individuals.

Hypertension was identified by both self report and diagnosis codes (401.xx). Persons were then coded 0 if no evidence of hypertension existed, 0.5 if an individual had either a self-report of hypertension or a physician’s diagnosis, and 1 if an individual had both a diagnosis and a self-report of hypertension. Self-reports were important to use because we had no claims data before the person entering the sample. Insulin-dependent persons were identified by ICD-9-CM codes (250.01, 250.03) and from information on insulin drug use obtained by the MCBS. The variable for insulin dependence was 0 if no evidence of insulin use existed for the individual, 0.5 if the individual was assigned the relevant ICD-9-CM codes or reported using insulin drugs to the MCBS, or 1 if the person had both an ICD-9-CM code for insulin use and reported insulin use to the MCBS.

One concern is that persons who experienced visual impairment may have been more likely to have visited an ophthalmologist or optometrist or visited such eye care professionals more

frequently. If eye care visits were endogenous to vision outcomes for this reason, we would expect a bias toward the null—that is, we would understate the improvement in vision attributable to following care recommendations. In sensitivity analysis, to account for endogeneity, we performed the analysis excluding eye care visits as an element of receipt of recommended care. A drawback of this sensitivity analysis test is that, if having regular eye care reduces the probability of onset of DR and its complications, excluding eye care visits from the analysis reduces the estimated effect of vision on following care recommendations.

Propensity Score Matching: A Comparison of Visual Outcomes among Persons with Diabetes Who Received Recommended Care versus Persons with Diabetes Who Did Not

To compare rates of onset of DR, the development of vision-threatening DR, or actual vision loss, between persons who received recommended levels of care with those who did not, we used propensity score analysis. The propensity score is the probability of receiving an intervention or treatment, conditional on values of the covariates. Matching on propensity scores reduces treatment selection bias in an observational study.[17,18] Using predicted probabilities that a beneficiary was adherent from the logit analysis described, we used propensity score matching to pair beneficiaries who received recommended care with the nearest match of an individual who did not. We sought to match an individual receiving guideline-recommended care with the closest individual who did not, using propensity score values based on the individual's baseline characteristics. Individuals were matched based on propensity score with a caliper of 0.06, excluding all beneficiaries without a match within that range. Greedy matching[19,20] paired beneficiaries who received recommended care based on propensity score to the first beneficiary who did not satisfying the matching conditions. Matching was performed without replacement; thus, all observations could only be matched once.

We successfully matched 849 pairs in the initial 2-month analysis. Owing to sample attrition caused by beneficiaries rotating out of the MCBS, we matched 119 pairs in the 3-year analysis. We then compared differences in complication rates of BDR, PDR, macular edema, PDR complications, and low vision/blindness between matched subjects by calculating average treatment effects on the treated (ATT) for time periods 2, 3, and 6 months, and 1, 2, and 3 years. We also report the number of individuals diagnosed with study complications in each of the time periods listed.

Results

Population Receiving Recommended Levels of Care

The logit analysis revealed that beneficiaries who received recommended levels of care tended to be younger than those who did not (odds ratio [OR], 0.97; 95% confidence interval [CI], 0.96–0.99; Table 1). They were also more likely to have a higher household income (OR, 1.07; 95% CI, 1.03–1.11). An increase in household income of $10,000 would increase the likelihood a beneficiary received guideline-recommended care by 7%. Prior diagnosis of glaucoma (OR, 1.28; 95% CI, 1.07–1.53) and lipidemia (OR, 1.63; 95% CI, 1.38–1.94), insulin dependence (OR, 2.00; 95% CI, 1.36–2.93), and BMI >30 (OR, 1.22; 95% CI, 1.03–1.44) were also associated with higher probabilities of receiving recommended levels of care. However, race/ethnicity, gender, marital status, educational attainment, and supplemental insurance were not significantly associated with receipt of recommended care.

Before propensity score matching, persons who received recommended care differed from others on several variables (Table 2). The sample receiving recommended care was more likely to be married, younger, better educated, have higher household income, supplemental insurance, been diagnosed with a prior cataract, or lipidemia, or have a BMI >30 than those

not receiving recommended care. Additionally, beneficiaries who received recommended levels of care were less likely to be a Medicaid recipient or have fair or poor health than those who did not. After propensity score matching, there were no standardized differences >10%, making the sample well balanced.[20,21]

Retinopathy Outcomes

After propensity score matching, persons receiving recommended care with no prior study eye complications were more likely to develop BDR than were persons who did not (Table 3). This ATT ranged from 0.012 at 2 months (95% CI, 0.001–0.023) to 0.118 at 3 years (95% CI, −0.005 to 0.240). These results were statistically significant in all periods except at 3 years.

However, and more important, for persons receiving recommended levels of care, the likelihood of developing vision loss or using a visual aid was reduced by 0.005 at 6 months (95% CI, −0.012 to 0.002) and 0.109 at 3 years (95% CI, −0.189 to −0.030) compared with others. This effect was statistically significant for the 1-, 2-, and 3-year periods. Results for PDR, macular edema, and PDR complications were not statistically significant during any of the study periods (Table 4; available online at http://aaojournal.org).

Excluding eye examinations from the measure of recommended levels of care had very little effect on the ATT for BDR, PDR, or macular edema (Tables 3 and 4). However, omitting eye examinations from the analysis decreased the reduction in the probability of PDR complications, and low vision or blindness, lowering the reduction in low vision or blindness to 0.040 at year 3 (95% CI, −0.109 to 0.029).

Overall, costs for diagnostic examinations and physician visits were higher for the group receiving recommended levels of care during the study period ($7465 vs $5399; $P < 0.001$). This implies that any reduction in cost from reduced or deferred rates of eye complications did not fully offset the added cost of screening, at least over the time span captured by our data.

Discussion

Medicare beneficiaries who received recommended care were more likely to be diagnosed with BDR than were others. However, beneficiaries receiving guideline-recommended care levels were no more likely to develop PDR, macular edema, or PDR complications. Most important, beneficiaries whose care more closely followed recommended care patterns were significantly less likely to develop low vision or blindness over a 3-year period than were beneficiaries not receiving recommended care who had been diagnosed with DM. Removing eye examinations from the measure of receiving recommended care reduced the reductions in PDR complications and low vision or blindness, but the benefit of reduced vision loss was still present.

The increase in BDR within the first 3 years is to be expected; beneficiaries receiving recommended care levels visited ophthalmologists and optometrists more frequently, providing more opportunity to diagnose the disease. Furthermore, this result comports with the findings of the Diabetes Control and Complications Trial,[22] in which the benefits of treatment appear after 3 years of intensive therapy compared with conventional therapy, and intensive therapy is associated with a higher rate of development of retinopathy within the first 3 years. As such, an important finding is that within a short study period of 3 years with the MCBS and controlling for other major causes of low vision and blindness such as age-related macular degeneration, glaucoma, and cataract/cataract surgery, there was a higher

incidence of vision loss among individuals not receiving recommended levels of care compared with their counterparts who did.

Our study contributes to the literature by using longitudinal data from a representative sample of elderly persons in the United States to track the effects of receipt of guideline-recommended levels of care on rates of DR complications. The MCBS data permitted consideration of demographic, socioeconomic, and supplemental insurance variables in the logit analysis of correlates of receipt of recommended care and for matching beneficiaries on the basis of receipt of recommended care, as well as providing prescription drug data on antihypertensive and statin drugs used for measuring receipt of care.

Previous studies of adherence were conducted with data from randomized controlled trials focusing on only 1 or 2 elements of recommended care. Or, if observational data were used, the focus was on 1 geographic location, with much smaller sample sizes than used in our analysis. Only 2 previous studies used measures of receipt of care similar to ours,[14,23] but neither performed outcome-based analyses.

McGlynn et al,[14] using survey data combined with medical records, studied diabetes using 13 indicators of care. They reported diabetics received 45% of recommended care. Using our definition and sample, we found that only 15% of Medicare beneficiaries who had been diagnosed with DM received recommended care as we measured it. This difference can be explained by our differing methodologies. The McGlynn study reported the percent of care received by all persons diagnosed with DM. For example, if a person received 5 of 13 types of care, the person was considered to have received 38% of recommended care, whereas in our study the person would not be deemed to have received recommended levels of care unless all measures of recommended care were received annually.

In a study conducted at ophthalmic clinics in Australia,[23] researchers reported 80% of persons with diagnosed DR did not adhere to guidelines for glycemic and blood pressure control, despite government-funded and freely accessible health care. That study obtained a similar rate of nonreceipt of recommended care to our study, although it included just 2 measures of adherence. Insurance coverage is a significant predictor of receiving eye care[24]; however, we found that in a population of Medicare beneficiaries, supplemental insurance did not affect rates of receipt of guideline-recommended care. Also, more important, all beneficiaries in our sample had at least basic insurance coverage, yet >80% of insured persons still failed to receive levels of care recommended by the guidelines.

Martin et al[25] studied adherence to guidelines in Oakland, California, in a predominantly African-American population. However, their sample consisted of only 378 persons. Although complication rates were presented in their study, their study did not explore the association between adherence and complication rates. Furthermore, it is unclear whether these complications were newly recorded or if they had been present for many years. Similar to McGlynn et al,[23] the authors measured receipt of recommended care on a scale from 1 to 8, rather than reporting how many persons adhered to all guidelines, making a comparison with our results difficult.

Persons receiving recommended levels of care were more likely to have higher income, BMI >30, prior diagnoses of lipidemia and glaucoma, and insulin-dependent DM. After matching, we found that persons who received recommended care were less likely to suffer severe vision loss. An inference is that those who may regard themselves as more vulnerable to diabetes and its complications were more likely to seek recommended care and/or their physicians were more likely to provide it. This implication is subject to the limitation that our data are observational.

Although associated with quicker and higher incidence rates of BDR in our study, beneficiaries receiving recommended care levels with DM experienced better long-term vision outcomes, in particular with regard to rates of low vision and blindness, which were substantial even in this study's short follow-up period (maximum of 3 years). This is consistent with the Early Treatment Diabetic Retinopathy Study,[26] which reported lower rates of vision loss for persons undergoing early photocoagulation treatment for DR, despite differences in study composition.

Improved outcomes from persons diagnosed with BDR earlier in the progression of the complication raise the question of whether more aggressive initial screening for DM and DR is necessary. Previous researchers have questioned the effectiveness of current screening protocols for diabetes[27] because nearly one third of all cases of diabetes are undiagnosed.[11] In another study, Singer et al[28] called for more accurate initial screening for DR owing to lack of sensitivity of ophthalmoscopic examinations. The earlier diagnosis of DR in individuals previously diagnosed with diabetes may encourage beneficiaries to seek regular treatment and better manage the disease,[14,28–30] which ultimately may reduce the risk of blindness associated with DR.

Better diabetes management, including stricter adherence by patients and doctors to best practice guidelines, could have an enormous protective impact on cases of vision loss caused by DR. More stringent testing would raise Medicare costs short-term for both beneficiaries and the Medicare program, but may pay dividends long-term both in medical costs incurred owing to the progression of DR, as well as improved quality of life value.[7,8,30–32] We calculated costs per beneficiary of physician visits and receiving diagnostic examinations, after propensity score matching, to be $7465 for individuals who received recommended care and $5399 for those who did not. However, our data are limited to up to a 3-year time interval. It is possible the offsets are greater over the longer term. Furthermore, offsets to the Medicare program fall short of total societal cost.

We acknowledge several limitations. First, we only used survey and claims data. We did not access data from medical records. However, the measures of receipt of recommended care we used, while lacking specific chart data such as hemoglobin A1c values, are an acceptable proxy to whether or not a person is effectively managing their diabetes.

Second, claims data are designed for administrative use. Claims data, although highly specific, lack sensitivity and often fail to identify all persons with the outcome of interest.[33,34] However, by requiring that beneficiaries receive a visit to an ophthalmologist or optometrist to be entered into our sample, we have reduced the likelihood of unreported study outcomes.

Third, MCBS is a short-term survey that rotates members out after 4 years. This is a relatively short period of time to study retinopathy; the risk of developing retinopathy is associated with the duration of diabetes.[28,29] However, the vast majority of Medicare beneficiaries have type 2 diabetes; thus, it is much more common for DR to be present at diagnosis or develop soon after DM diagnosis than in type 1 diabetes, because diabetes may have been present for many years before the initial diagnosis.[1,29] Because individuals may have had DM and received recommended care before entry into the MCBS, it is likely a pattern of recommended care received in years before the study period accounts, at least partly, for the benefits in reduced rates of low vision or blindness demonstrated during our study period. Furthermore, owing to the censoring of individuals leaving the sample, dying, or joining HMOs, by year 3 of our analysis, the sample size was appreciably reduced, causing inadequate matches for 4 variables in the 3-year analysis. All matches were within 10% in analyses for time periods shorter than this.

Fourth, our sensitivity analysis, which eliminated eye examinations from the measure of receipt of recommended care, did not yield results as strong as those from the original analysis, especially in terms of low vision or blindness. Persons with specific symptoms or failing eyes may be more prone to seeing an ophthalmologist or optometrist. Therefore, it is not surprising that excluding eye examinations as a criterion from receipt of recommended care led to a reduction in the magnitude of the association between the receipt of guideline-recommended care and rates of low vision or blindness.

In summary, improved diabetes care has a protective effect on long-term vision loss, despite being well below recommended levels. With rates of DR climbing over the past decades,[35] and the clear benefit of following best care recommendations demonstrated by this study, the need for improved rates of receipt of recommended care is more important than ever. To increase rates of receipt of recommended levels of care will require a multipronged strategy, including programs that stress the importance of these examinations and provide reminders to physicians to order all the recommended testing. Furthermore, patient education DM control programs would also increase rates of receipt of best care and lead to better outcomes. In some cases, it may be advisable for ophthalmologists to make referral appointments to facilitate receipt of recommended care.

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References

1. Cowie CC, Rust KF, Byrd-Holt DD, et al. Prevalence of diabetes and impaired fasting glucose in adults in the U.S. population: National Health and Nutrition Examination Survey 1999–2002. Diabetes Care. 2006; 29:1263–8. [PubMed: 16732006]
2. King H, Aubert RE, Herman WH. Global burden of diabetes, 1995–2025: prevalence, numerical estimates, and projections. Diabetes Care. 1998; 21:1414–31. [PubMed: 9727886]
3. Wild S, Roglic G, Green A, et al. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. Diabetes Care. 2004; 27:1047–53. [PubMed: 15111519]
4. Kohner EM, Aldington SJ, Stratton IM, et al. United Kingdom Prospective Diabetes Study. United Kingdom Prospective Diabetes Study, 30: diabetic retinopathy at diagnosis of non-insulin-dependent diabetes mellitus and associated risk factors. Arch Ophthalmol. 1998; 116:297–303. [PubMed: 9514482]
5. Klein, R.; Klein, BE. National Diabetes Data Group. Diabetes in America. 2. Bethesda, MD: National Institutes of Health; 1995. Vision disorders in diabetes; p. 293-338.NIH publication no. 95-1468. Available at: http://diabetes.niddk.nih.gov/dm/pubs/America/pdf/chapter14.pdf
6. Eye Diseases Prevalence Research Group. The prevalence of diabetic retinopathy among adults in the United States. Arch Ophthalmol. 2004; 122:552–63. [PubMed: 15078674]
7. Salm M, Belsky D, Sloan FA. Trends in cost of major eye diseases to Medicare, 1991 to 2000. Am J Ophthalmol. 2006; 142:976–82. [PubMed: 17157582]
8. Williams R, Van Gaal L, Lucioni C. CODE-2 Advisory Board. Assessing the impact of complications on the costs of type II diabetes. Diabetologia. 2002; 45:S13–7. [PubMed: 12136406]
9. Lee PP, Feldman ZW, Ostermann J, et al. Longitudinal rates of annual eye examinations of persons with diabetes and chronic eye diseases. Ophthalmology. 2003; 110:1952–9. [PubMed: 14522771]
10. Saaddine JB, Engelgau MM, Beckles GL, et al. A diabetes report card for the United States: quality of care in the 1990s. Ann Intern Med. 2002; 136:565–74. [PubMed: 11955024]
11. Sloan FA, Bethel MA, Lee PP, et al. Adherence to guidelines and its effects on hospitalizations with complications of type 2 diabetes. Rev Diabet Stud. 2004; 1:29–38. [PubMed: 17491662]

12. Koro CE, Bowlin SJ, Bourgeois N, Fedder DO. Glycemic control from 1988 to 2000 among U.S. adults diagnosed with type 2 diabetes: a preliminary report. Diabetes Care. 2004; 27:17–20. [PubMed: 14693960]
13. McClellan WM, Millman L, Presley R, et al. Improved diabetes care by primary care physicians: results of a group-randomized evaluation of the Medicare Health Care Quality Improvement Program (HCQIP). J Clin Epidemiol. 2003; 56:1210–7. [PubMed: 14680672]
14. McGlynn EA, Asch SM, Adams J, et al. The quality of health care delivered to adults in the United States. N Engl J Med. 2003; 348:2635–45. [PubMed: 12826639]
15. Zoorob RJ, Hagen MD. Guidelines on the care of diabetic nephropathy, retinopathy and foot disease. Am Fam Physician. 1997; 56:2021–8. [PubMed: 9390097]
16. Hoerger TJ, Gregg EW, Segel JE, Saaddine JB. Is glycemic control improving in U.S. adults? Diabetes Care. 2008; 31:81–6. [PubMed: 17934153]
17. D'Agostino RB Jr. Propensity score methods for bias reduction in the comparison of a treatment to a non-randomized control group. Stat Med. 1998; 17:2265–81. [PubMed: 9802183]
18. Rosenbaum PR, Rubin DB. The central role of the propensity score in observational studies for causal effects. Biometrika. 1983; 70:41–55.
19. Austin PC. Propensity-score matching in the cardiovascular surgery literature from 2004 to 2006: a systematic review and suggestions for improvement. J Thorac Cardiovasc Surg. 2007; 134:1128–35. [PubMed: 17976439]
20. Normand SL, Landrum MB, Guadagnoli E, et al. Validating recommendations for coronary angiography following acute myocardial infarction in the elderly: a matched analysis using propensity scores. J Clin Epidemiol. 2001; 54:387–98. [PubMed: 11297888]
21. Austin PC, Grootendorst P, Anderson GM. A comparison of the ability of different propensity score models to balance measured variables between treated and untreated subjects: a Monte Carlo study. Stat Med. 2007; 26:734–53. [PubMed: 16708349]
22. Diabetes Control and Complications Trial Research Group. Progression of retinopathy with intensive versus conventional treatment in the Diabetes Control and Complications Trial. Ophthalmology. 1995; 102:647–61. [PubMed: 7724182]
23. Tikellis G, Wang S, Wong N, et al. Poor metabolic and blood pressure control in patients with diabetic retinopathy attending a tertiary ophthalmic hospital in Australia. Diabetes Res Clin Pract. 2008; 80:208–12. [PubMed: 18207279]
24. Schoenfeld ER, Greene JM, Wu SY, Leske MC. Patterns of adherence to diabetes vision care guidelines: baseline findings from the Diabetic Retinopathy Awareness Program. Ophthalmology. 2001; 108:563–71. [PubMed: 11237912]
25. Martin TL, Selby JV, Zhang D. Physician and patient prevention practices in NIDDM in a large urban managed-care organization. Diabetes Care. 1995; 18:1124–32. [PubMed: 7587847]
26. Early Treatment Diabetic Retinopathy Study Research Group. Early photocoagulation for diabetic retinopathy: ETDRS report number 9. Ophthalmology. 1991; 98(suppl):766–85. [PubMed: 2062512]
27. Dallo FJ, Weller SC. Effectiveness of diabetes mellitus screening recommendations. Proc Natl Acad Sci U S A. 2003; 100:10574–9. [PubMed: 12925739]
28. Singer DE, Nathan DM, Fogel HA, Schachat AP. Screening for diabetic retinopathy. Ann Intern Med. 1992; 116:660–71. [PubMed: 1546868]
29. Nathan DM. Long-term complications of diabetes mellitus. N Engl J Med. 1993; 328:1676–85. [PubMed: 8487827]
30. O'Brien JA, Shomphe LA, Kavanagh PL, et al. Direct medical costs of complications resulting from type 2 diabetes in the U. S Diabetes Care. 1998; 21:1122–8.
31. Javitt JC, Aiello LP. Cost-effectiveness of detecting and treating diabetic retinopathy. Ann Intern Med. 1996; 124:164–9. [PubMed: 8554212]
32. Javitt JC, Aiello LP, Chiang YP, et al. Preventive eye care in people with diabetes is cost-saving to the federal government: implications for health-care reform. Diabetes Care. 1994; 17:909–17. [PubMed: 7956643]
33. Coleman AL, Morgenstern H. Use of insurance claims databases to evaluate the outcomes of ophthalmic surgery. Surv Ophthalmol. 1997; 42:271–8. [PubMed: 9406373]

34. Javitt JC, Zhou Z, Maguire MG, et al. Incidence of exudative age-related macular degeneration among elderly Americans. Ophthalmology. 2003; 110:1534–9. [PubMed: 12917168]

35. Lee PP, Feldman ZW, Ostermann J, et al. Longitudinal prevalence of major eye diseases. Arch Ophthalmol. 2003; 121:1303–10. [PubMed: 12963614]

Table 1

Results of Logit Analysis of Adherence to Recommended Care

	Odds Ratio	95% Confidence Interval
Male	0.93	0.78–1.10
African American	1.10	0.86–1.41
Other race/ethnicity	1.01	0.70–1.46
Marital status	1.19	0.99–1.42
Age	0.97*	0.96–0.99
Educational attainment years	1.02	0.99–1.04
Income ($10 000s)	1.07*	1.03–1.11
Supplemental private insurance	1.14	0.88–1.49
Medicaid	1.03	0.75–1.42
Fair or poor health	0.90	0.76–1.06
Insulin dependent	2.00*	1.36–2.93
Prior cataract	1.28*	1.07–1.53
Prior cataract surgery	1.13	0.91–1.40
Prior glaucoma	1.19	0.99–1.42
Prior age-related macular degeneration	0.95	0.76–1.18
Hypertension	0.84	0.68–1.04
Lipidemia	1.63*	1.38–1.94
Body mass index > 30	1.22*	1.03–1.44
Observations (n)	5989	

*$P < 0.05$.

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Table 2

Standardized Differences (S Diff) of Full Sample and Matched Sample

	Before Matching			After Matching		
	Adhered	Did Not Adhere	S Diff	Adhered	Did Not Adhere	S Diff
Male	0.44	0.41	7.34	0.44	0.43	2.14
African American	0.13	0.13	−1.30	0.12	0.13	−2.82
Other race/ethnicity	0.05	0.05	−0.23	0.05	0.05	−1.09
Marital status	0.56	0.47	18.53	0.57	0.55	3.08
Age	75.64	77.51	−27.26	75.53	75.40	2.08
Educational attainment years	11.14	10.32	20.09	11.15	11.04	2.79
Income ($10 000s)	2.95	2.36	26.70	2.95	2.85	3.98
Supplemental private insurance	0.75	0.67	16.09	0.75	0.75	−0.54
Medicaid	0.15	0.20	−13.93	0.15	0.15	−0.33
Fair or poor health	0.37	0.42	−10.94	0.37	0.37	−0.24
Insulin dependent	0.11	0.10	4.54	0.11	0.11	−0.56
Prior cataract	0.69	0.60	16.88	0.70	0.71	−1.81
Prior cataract surgery	0.17	0.15	5.74	0.17	0.17	−0.31
Prior glaucoma	0.24	0.21	9.06	0.25	0.24	0.55
Prior age-related macular degeneration	0.15	0.16	−2.11	0.15	0.13	5.37
Hypertension	0.57	0.59	−4.72	0.57	0.56	1.29
Lipidemia	0.34	0.21	29.86	0.33	0.32	2.51
Body mass index >30	0.35	0.26	18.86	0.35	0.36	−2.22
Observations	903	5086		849	849	

Table 3

Average Treatment Effects on Treated (ATT) Observations of Individuals Receiving Recommended Care Compared to Those Not Receiving Recommended Care[†]

	Background Diabetic Retinopathy				Low Vision or Blindness			
	Yes	**No**	**ATT**	**95% CI**	**Yes**	**No**	**ATT**	**95% CI**
Baseline analysis								
2 month (n = 849)	0.020 (17)	0.008 (7)	**0.012**[†]	0.001–0.023	0.001 (1)	0.005 (4)	−0.004	−0.009 to 0.002
3 month (n = 830)	0.029 (24)	0.014 (12)	**0.014**[†]	0.000–0.028	0.001 (1)	0.006 (5)	−0.005	−0.011 to 0.001
6 month (n = 763)	0.045 (34)	0.025 (19)	**0.020**[†]	0.001–0.038	0.003 (2)	0.008 (6)	−0.005	−0.012 to 0.002
1 year (n = 577)	0.099 (57)	0.061 (35)	**0.038**[†]	0.007–0.069	0.009 (5)	0.024 (14)	**−0.016**[†]	−0.030 to −0.001
2 year (n = 329)	0.234 (77)	0.161 (53)	**0.073**[†]	0.012–0.134	0.015 (5)	0.055 (18)	**−0.040**[†]	−0.067 to −0.012
3 year (n = 119)	0.681 (81)	0.563 (67)	0.118	−0.005–0.240	0.059 (7)	0.168 (20)	**−0.109**[†]	−0.189 to −0.030
Sensitivity analysis[*]								
2 month (n = 903)	0.019 (17)	0.010 (9)	0.009	−0.002–0.020	0.001 (1)	0.006 (5)	−0.004	−0.010 to 0.001
3 month (n = 885)	0.027 (24)	0.012 (11)	**0.015**[†]	0.002–0.028	0.001 (1)	0.008 (7)	**−0.007**[†]	−0.013 to −0.001
6 month (n = 818)	0.042 (34)	0.022 (18)	**0.020**[†]	0.003–0.037	0.002 (2)	0.010 (8)	−0.007	−0.015 to 0.000
1 year (n = 618)	0.092 (57)	0.044 (27)	**0.049**[†]	0.021–0.076	0.010 (6)	0.029 (18)	**−0.019**[†]	−0.035 to −0.004
2 year (n = 348)	0.218 (76)	0.135 (47)	**0.083**[†]	0.027–0.140	0.017 (6)	0.040 (14)	−0.023	−0.048 to 0.002
3 year (n = 125)	0.680 (85)	0.576 (72)	0.104	−0.016–0.224	0.064 (8)	0.104 (13)	−0.040	−0.109 to 0.029

CI = confidence interval.

No significant results for proliferative diabetic retinopathy (PDR), macular edema, or PDR complications.

Results available in Table 4 (available at http://aaojournal.org).

Numbers in parentheses are numbers of cases in the cell.

[*] Sensitivity analysis excluded eye examinations from adherence calculation.

[†] Boldface indicates statistical significance at the 5% level.

Table 4

Average Treatment Effects on Treated (ATT) Observations of Individuals Receiving Recommended Care Compared with Those Not Receiving Recommended Care

	PDR				Macular Edema				PDR Complications			
	Yes	**No**	**ATT**	**95% CI**	**Yes**	**No**	**ATT**	**95% CI**	**Yes**	**No**	**ATT**	**95% CI**
Baseline analysis												
2 month (n = 849)	0.00 (0)	0.00 (4)	0.00	−0.01 to 0.00	0.00 (3)	0.00 (3)	0.00	−0.01 to 0.01	0.00 (0)	0.00 (0)	0.00	0.00 to 0.00
3 month (n = 830)	0.00 (2)	0.00 (1)	0.00	0.00 to 0.01	0.00 (4)	0.00 (3)	0.00	−0.01 to 0.01	0.00 (1)	0.00 (0)	0.00	0.00 to 0.00
6 month (n = 763)	0.01 (4)	0.01 (4)	0.00	−0.01 to 0.01	0.01 (9)	0.01 (6)	0.00	−0.01 to 0.01	0.00 (3)	0.01 (4)	0.00	−0.01 to 0.01
1 year (n = 577)	0.01 (7)	0.02 (10)	−0.01	−0.02 to 0.01	0.02 (13)	0.01 (8)	0.01	−0.01 to 0.02	0.01 (3)	0.01 (3)	0.00	−0.01 to 0.01
2 year (n = 329)	0.04 (12)	0.05 (15)	−0.01	−0.04 to 0.02	0.06 (20)	0.04 (12)	0.02	−0.01 to 0.06	0.03 (9)	0.03 (10)	0.00	−0.03 to 0.02
3 year (n = 119)	0.10 (12)	0.13 (16)	−0.03	−0.12 to 0.05	0.18 (22)	0.15 (18)	0.03	−0.06 to 0.13	0.08 (9)	0.09 (11)	−0.02	−0.09 to 0.05
Sensitivity analysis *												
2 month (n = 903)	0.00 (0)	0.00 (4)	0.00	−0.01 to 0.00	0.00 (3)	0.00 (4)	0.00	−0.01 to 0.00	0.00 (0)	0.00 (0)	0.00	0.00 to 0.00
3 month (n = 885)	0.00 (2)	0.00 (3)	0.00	−0.01 to 0.00	0.00 (4)	0.01 (6)	0.00	−0.01 to 0.00	0.00 (1)	0.00 (1)	0.00	0.00 to 0.00
6 month (n = 818)	0.00 (4)	0.01 (5)	0.00	−0.01 to 0.01	0.01 (9)	0.01 (7)	0.00	−0.01 to 0.01	0.00 (3)	0.00 (2)	0.00	0.00 to 0.01
1 year (n = 618)	0.01 (7)	0.01 (7)	0.00	−0.01 to 0.01	0.02 (13)	0.01 (5)	0.01	0.00 to 0.03	0.00 (3)	0.00 (3)	0.00	−0.01 to 0.01
2 year (n = 348)	0.03 (12)	0.02 (8)	0.01	−0.01 to 0.04	0.06 (20)	0.04 (14)	0.02	−0.01 to 0.05	0.03 (9)	0.03 (9)	0.00	−0.02 to 0.02
3 year (n = 125)	0.10 (12)	0.14 (18)	−0.05	−0.13 to 0.03	0.18 (22)	0.16 (20)	0.02	−0.08 to 0.11	0.07 (9)	0.06 (8)	0.01	−0.05 to 0.07

CI = confidence interval; PDR = proliferative diabetic retinopathy.

Numbers in parentheses are numbers of cases in the cell.

* Sensitivity analysis excluded eye examinations from adherence calculation.