Early Detection of Poor Adherers to Statins: Applying Individualized Surveillance to Pay for Performance

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Early Detection of Poor Adherers to Statins: Applying Individualized Surveillance to Pay for Performance

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Abstract

Background: Medication nonadherence costs $300 billion annually in the US. Medicare Advantage plans have a financial incentive to increase medication adherence among members because the Centers for Medicare and Medicaid Services (CMS) now awards substantive bonus payments to such plans, based in part on population adherence to chronic medications. We sought to build an individualized surveillance model that detects early which beneficiaries will fall below the CMS adherence threshold.

Methods: This was a retrospective study of over 210,000 beneficiaries initiating statins, in a database of private insurance claims, from 2008-2011. A logistic regression model was constructed to use statin adherence from initiation to day 90 to predict beneficiaries who would not meet the CMS measure of proportion of days covered 0.8 or above, from day 91 to 365. The model controlled for 15 additional characteristics. In a sensitivity analysis, we varied the number of days of adherence data used for prediction.

Results: Lower adherence in the first 90 days was the strongest predictor of one-year nonadherence, with an odds ratio of 25.0 (95% confidence interval 23.7-26.5) for poor adherence at one year. The model had an area under the receiver operating characteristic curve of 0.80. Sensitivity analysis revealed that predictions of comparable accuracy could be made only 40 days after statin initiation. When members with 30-day supplies for their first statin fill had predictions made at 40 days, and members with 90-day supplies for their first fill had predictions made at 100 days, poor adherence could be predicted with 86% positive predictive value.

Conclusions: To preserve their Medicare Star ratings, plan managers should identify or develop effective programs to improve adherence. An individualized surveillance approach can be used to target members who would most benefit, recognizing the tradeoff between improved model performance over time and the advantage of earlier detection.

Introduction

Poor medication adherence costs the U.S. healthcare system up to nearly $300 billion[1-3] each year. Patients who adhere to prescribed medication have fewer hospitalizations, lower costs[4], and lower mortality[5], as compared to their non-adherent counterparts. Nonadherence is common; in studies of statin adherence, only around 50% of subjects remain fully adherent 6 months after initiation[6,7]. However, interventions to improve adherence are often cost- and time-intensive[8,9].

In 2012, as required by the Patient Protection and Affordable Care Act, the Centers for Medicare and Medicaid Services (CMS) began using star ratings to award substantive bonus payments to privately-run Medicare Advantage and stand-alone Medicare prescription drug plans[8,10,11]. Higher star ratings are also associated with higher plan enrollment[12]. An important component of assigning these ratings is the...
proportion of plan beneficiaries who achieve a proportion of
days covered (PDC) of 0.8 or above[11], for three classes of
medications: statins, renin angiotensin system antagonists, and
oral hypoglycemic agents. The adherence measures for these
classes are obtained from prescription fulfillment data and are
measured over a one-year period. We sought to develop a
predictive model of poor adherence to statins so that plan
managers, early in the year, can efficiently implement and
target programs to the right patients.

Methods

Design

This was a retrospective database study using de-identified
medical and pharmacy claims, on all Aetna commercial
members with at least one year of continuous medical and
pharmacy coverage from 2008-2011. Patients were included if
they received a statin prescription and met criteria for
dyslipidemia, where dyslipidemia was defined as: 2 claims with
a diagnosis of lipid disorder (International Classification of
Diseases, Ninth Revision (ICD-9) diagnosis code of 272.x)
unrelated to a laboratory claim, or low-density lipoprotein
cholesterol >130 mg/dL (to convert to millimoles per liter,
multiply by 0.0259), or total cholesterol >200 mg/dL, or HDL
cholesterol <40 mg/dL, or triglycerides >150 mg/dL (to convert
to millimoles per liter, multiply by 0.0113), or a claim with a
Current Procedural Terminology Category II code for a lipid
disorder (3049F, 3050F, 4013F, 0556F, or 4002F). Raw data
are available upon request.

Members with unknown gender or with ages <0 or >100
years were excluded, as were members who received high fill
quantities (>100 days) likely to be in error or not reflective of
true days covered. The members (<0.1% of total) taking
lovastatin were excluded from final analysis because this very
low prevalence category destabilized the model. Members
were excluded if they had less than 90 days of continuous
eligibility after statin initiation. Finally, to provide a "wash out"
period that would separate those truly initiating statins from
those merely continuing statins after switching plans, members
were excluded if the time from first eligibility to first statin
prescription was less than 180 days. The data were divided
into training and validation subsets (two thirds and one third of
members, respectively).

Ethics statement

The study was reviewed and approved by the Committee on
Human Studies of Harvard Medical School. Consent was
waived by the Committee, which identified the study as not
involving human subjects per Federal regulations.

Adherence measurement

For each member, we calculated PDC for days 91-365
(PDC91-365), dichotomized at the 0.8 level, to be used as the
outcome variable. This measure calculates adherence in a
period that does not overlap with the early detection period.
Day 1 (index date) is defined as the fill date for the first statin
prescription for that member. All PDC calculations were
performed according to methods described by CMS[11]
Specifically, PDC was defined as the number of days that the
member was covered by at least one statin, divided by the
number of days in the measurement period. PDC over 100%
(when the member fills more than expected) is expressed as
100%. Days of overlap between two fills counted toward PDC,
but only if the two fills were for the same statin. If prescriptions
in days 1-90 had days of supply that extended into the days
91-365 period, those days of supply contributed toward
PDC91-365. The days covered and the duration of the
measurement period were adjusted for inpatient stays
according to the CMS methods ("drug coverage during the
inpatient stay is shifted to subsequent days of no supply;" and
"the days of inpatient stay are deleted from the measurement
period")[11]. For members with less than one year of eligibility
after the index date, PDC91-365 could not be calculated.

Baseline variables used to predict adherence

The primary independent measure was PDC for days 1-90,
analyzed as a continuous variable (PDC1-90). Model building
was similar to a prior analysis, on a different population,
predicting medication possession ratio[13]. We considered 15
additional variables focusing on those previously shown to be
associated with adherence[1,6,7,14]. Age, gender, and statin
name were available from claims data. For statin name,
simvastatin was designated as the comparator for all other
categories. We calculated the following variables from the first
90 days only after the index date (Figure 1): proportion of statin
fills at retail pharmacies, proportion of formulary statin fills,
proportion of generic statin fills, average days supply per statin
prescription, average statin reimbursement per prescription,
average statin copayment per prescription, and average statin
dose per prescription. Finally, we calculated the following
variables to describe the period from the first non-statin
prescription to the index date (Figure 1): average pills per day,
average non-statin reimbursement per day, average non-statin
copayment per day, presence of acute coronary syndrome
within 30 days prior to index date (defined as hospitalization for
unstable angina or myocardial infarction, ICD-9 codes 411.x or
410.x), and time from first eligibility to index date.

Analyses

Using logistic regression, bivariate associations were explored
between baseline variables and PDC91-365
dichotomized at 0.8). For continuous baseline variables, units
for the odds ratios were set equal to 2 standard deviations of
the variable. This method allows comparison of continuous
variables' impact on model discrimination[15]. A multivariable
logistic regression model was developed on the training set,
using continuous PDC1-90 and the 15 additional variables to
predict probability of poor adherence (PDC91-365
dichotomized at 0.8). All baseline variables were included, and
no further selection of variables was performed.

The trained model was applied to the validation set, and a
receiver operating characteristic (ROC) curve was plotted.
Odds ratios with 95% confidence intervals were determined for
each variable. For continuous variables, units for the odds
ratios were set equal to 2 standard deviations of the variable.
We applied the model to all beneficiaries in the validation set. However, those who left the plan before year’s end had censored data. For those with censored data, model predictions can be made but not classified as true or false; therefore members with censored data do not contribute to sensitivity and specificity calculations. However, we report numbers of members with censored data because, from the plan manager’s perspective, resources would be devoted toward those at risk for nonadherence, and it would not be known in advance which members would leave the plan before one year.

Our primary multivariable model requires 90 days of data to predict future nonadherence, but in practice an insurance plan manager may be willing to sacrifice model performance for a prediction sooner than 90 days. Thus, we performed a sensitivity analysis, varying the date of prediction from 0 to 270 days, and examining impact on prediction AUC. We stratified this analysis by the days’ supply of the first statin fill (≤30 days versus >30 days). We inspected the performance vs. time curves for both subsets and also calculated performance characteristics that would result if predictions were made at different time points for the two subsets (as opposed to our single 90-day time point used in the primary model). All analyses were performed using SAS statistical software, version 9.3 (SAS Institute Inc, Cary, NC).

**Results**

A total of 624,781 members met inclusion criteria. After exclusion criteria were applied, 217,928 remained (Figure 2). Table 1 shows baseline characteristics of the members.

Table 2 shows the pairwise associations between baseline variables and PDC91-365. Early PDC had the strongest effect of all variables (odds ratio for poor adherence 19.9 per 2 standard deviation decrease in early PDC, 95% confidence interval 19.0-20.9).

In multivariable analysis, the model had an AUC of 0.80 for the training set and validation set both. Adjusted odds ratios and 95% confidence intervals for all variables are shown in Table 2. Early PDC had the strongest effect of all variables in the model. Specifically, patients with a lower PDC at 90 days had an odds ratio of 25.0 (95% confidence interval 23.7-26.5) for poor adherence from days 91 to 365. The positive predictive value for poor adherence is 87.7%, and negative predictive value is 53.4%. The model can predict the CMS definition of statin nonadherence with 69.5% sensitivity and 78.2% specificity. For every 1000 beneficiaries, the model predicts poor adherence for 562. Of those, 335 are true positives, 47 are false positives and 180 are censored (eligibility ends within a year of statin initiation). The model predicts good adherence for 438 beneficiaries, of whom 168 are true negatives, 147 are false negatives, and 123 are censored.
In the sensitivity analysis, models did not perform well if they were based on less than 30 days of early adherence monitoring (AUCs near 0.6). Model performance increases sharply from days 30 to 31 (from AUC 0.62 to 0.71) for those members whose first prescription was for a 30-day supply or less, and it improved steadily thereafter. For those members whose first prescription was for more than 30 days, (most of whom received 90-day supplies,) AUC did not increase until after day 90 (Figure 3). When members with 30-day supplies for their first statin fill had predictions made at 40 days, and members with 90-day supplies for their first fill had predictions made at 100 days, poor adherence could be predicted with 86% positive predictive value, 50% negative predictive value, 69% sensitivity, and 74% specificity.

Discussion

Early PDC is a strong indicator of future nonadherence, and, in fact stronger than variables identified in prior studies[8] which have shown relatively low predictive power of insurance claims, with AUCs under 0.64[14]. We show, however, that while claims data have limited value prior to initiation of the medication, they contain important information after several weeks of filling behavior, as they become an indicator of personal behavior[16].

Because CMS now uses adherence to award bonus payments, adherence is tied to direct financial incentives as well as incentives to prevent morbidity and mortality. We show that the CMS metric of PDC can be predicted far in advance; therefore plan managers could apply an individualized surveillance model to target adherence improvement programs to their Medicare Advantage members who are at risk for nonadherence and who are likely to benefit from such programs.

Prediction of PDC improves with time. Our primary model, which uses 90 days of adherence data, performs well, but sensitivity analysis demonstrates the utility of early monitoring as early as day 31. Little improvement in model performance is gained from monitoring adherence before the first prescription fill is expected to run out. A plan manager can account for the tradeoff between early detection of poor adherers and accuracy, based on the cost and characteristics of the intervention.

A limitation of this study, in common with much claims-based adherence research, and in fact with the very PDC metric used by CMS, is that it treats medication fills as essentially the same as adherence, which is a simplified conception[8]. Our model does not address self-report, pill counts, or other measures of adherence, and further research should use these measures as outcome variables, either singly or in combination. Similarly, all purely claims-based adherence research, including this study, cannot address underlying reasons for treatment discontinuations, including discontinuations that are recommended by the prescriber. Adherence is commonly defined as “the extent to which patients take medications as prescribed by their health care providers,”[1] and this cannot strictly be assessed with prescription claims data alone. Second, there is only slim evidence that the 0.8 PDC threshold is clinically meaningful[8,17]. Third, it may be difficult to separate any true effect of 90-day prescription supplies on adherence from the effect of days supply on the PDC.

Figure 2. Study flow diagram showing exclusion criteria. The sum of members who met each individual exclusion criterion does not equal the total number excluded because one member can meet more than one exclusion criterion.
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Further study is particularly needed to determine the effect of days supply on pill taking, not just on metrics of prescription filling. Finally, our source population is commercial insurance members who were initiating statins; we did not study the Medicare population or those who were already taking statins when they entered our dataset. These populations are important for the proposed application of our model, and its performance should be confirmed in these populations.

To further increase accuracy of detection, the use of additional data sources, including electronic medical record information and patient-reported adherence, should be explored.
Table 2. Bivariate and multivariable associations between baseline variables and outcome (poor adherence)a.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds ratio (95% CI)</th>
<th>P value</th>
<th>Adjusted odds ratio (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDC days 1-90</td>
<td>0.04 (0.04-0.05)</td>
<td>&lt;.001</td>
<td>0.04 (0.04-0.04)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Age</td>
<td>0.54 (0.53-0.55)</td>
<td>&lt;.001</td>
<td>0.64 (0.62-0.66)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Mail order source of majority of statins, days 1-90</td>
<td>0.42 (0.40-0.44)</td>
<td>&lt;.001</td>
<td>0.67 (0.63-0.71)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Pills per day, prior to statin initiation</td>
<td>0.64 (0.62-0.66)</td>
<td>&lt;.001</td>
<td>0.78 (0.75-0.81)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Brand-name status of majority of statins, days 1-90</td>
<td>1.08 (1.05-1.11)</td>
<td>&lt;.001</td>
<td>0.86 (0.69-1.05)</td>
<td>0.140</td>
</tr>
<tr>
<td>Average reimbursed amount per day, prior to statin initiation</td>
<td>0.71 (0.69-0.74)</td>
<td>&lt;.001</td>
<td>0.97 (0.93-1.00)</td>
<td>0.088</td>
</tr>
<tr>
<td>Average copayment per day, prior to statin initiation</td>
<td>0.75 (0.71-0.79)</td>
<td>&lt;.001</td>
<td>0.98 (0.96-1.01)</td>
<td>0.265</td>
</tr>
<tr>
<td>Average statin dose, first 90 days of statin era</td>
<td>0.97 (0.95-1.00)</td>
<td>0.020</td>
<td>1.09 (1.06-1.13)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Days from eligibility to statin initiation</td>
<td>1.05 (1.02-1.08)</td>
<td>0.004</td>
<td>1.10 (1.06-1.14)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Average reimbursed amount, first 90 days of statin era</td>
<td>0.71 (0.69-0.73)</td>
<td>&lt;.001</td>
<td>1.10 (1.04-1.16)</td>
<td>0.001</td>
</tr>
<tr>
<td>Nonformulary status of majority of statins, days 1-90</td>
<td>1.09 (1.06-1.13)</td>
<td>&lt;.001</td>
<td>1.09 (0.94-1.27)</td>
<td>0.238</td>
</tr>
<tr>
<td>Average copayment, first 90 days of statin era</td>
<td>0.97 (0.94-0.99)</td>
<td>0.011</td>
<td>1.12 (1.08-1.16)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Female sex</td>
<td>1.12 (1.09-1.15)</td>
<td>&lt;.001</td>
<td>1.18 (1.14-1.21)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>No ACS within 30 prior days</td>
<td>2.27 (2.08-2.48)</td>
<td>&lt;.001</td>
<td>1.42 (1.28-1.58)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Average days supply, first 90 days of statin era</td>
<td>0.58 (0.57-0.60)</td>
<td>&lt;.001</td>
<td>1.63 (1.56-1.70)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Medication (Simvastatin is the comparator for all categories.)</td>
<td>1.18 (1.09-1.18)</td>
<td>0.479</td>
<td>1.07 (0.88-1.29)</td>
<td>0.129</td>
</tr>
<tr>
<td>Atorvastatin</td>
<td>1.13 (1.09-1.18)</td>
<td>0.405</td>
<td>1.08 (0.87-1.33)</td>
<td>0.212</td>
</tr>
<tr>
<td>Rosuvastatin</td>
<td>1.06 (1.03-1.10)</td>
<td>0.003</td>
<td>2.40 (1.52-3.82)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Pravastatin</td>
<td>1.84 (1.23-2.74)</td>
<td>0.486</td>
<td>1.26 (0.90-1.76)</td>
<td>0.552</td>
</tr>
<tr>
<td>Fluvastatin</td>
<td>1.18 (0.94-1.49)</td>
<td>0.68 (0.62-0.74)</td>
<td>&lt;.001</td>
<td>0.73 (0.62-0.86)</td>
</tr>
</tbody>
</table>

aUnits for continuous variable odds ratios: PDC, 0.5; age, 20 years; pills per day, 5; reimbursement per day, $20; copayment per day, $6; average statin days supply, 40; time from eligibility to index, 520 days; average statin reimbursement, $140, average statin copayment, $50, average statin dose, 30 mg. Abbreviations: PDC, proportion of days covered; ACS, acute coronary syndrome.

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Figure 3. **Model performance versus time of prediction.** Separate curves are presented for members whose first statin fill was for 30 days or less (circles), and for members whose first statin fill was for more than 30 days (triangles). For the ≤30 day subset, performance improves sharply between days 30 and 31, and it improves steadily thereafter. However, for the >30 day subset, (most of whom had 90-day fills,) performance improves sharply only after day 90. Each Y coordinate expresses the performance of a model that uses prescription fills from days 1 to X to predict adherence from days X to 365.

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References


Author Contributions

Conceived and designed the experiments: AJZ CMS JF VAF NPP SS ISK MAJ KDM. Performed the experiments: AJZ. Analyzed the data: AJZ ISK KDM. Contributed reagents/materials/analysis tools: AJZ CMS JF ISK KDM. Wrote the manuscript: AJZ KDM. Critical revision of the manuscript for important intellectual content: CMS JF VAF NPP SS ISK MAJ.