Analyzing medication non-adherence using predictive modeling

Highlights

- Lack of adherence to medication regimen is a growing concern to healthcare systems across geographies
- A predictive analytics solution for detecting medication non-adherence can help reduce costs associated with adverse health outcomes, enable physicians to identify potential non-adherent patients, and possibly prevent the onset of secondary complications

Introduction

Lack of adherence to prescribed medication regimen (not taking the medications at all or not taking them as per the prescribed dosage schedule; in other words, skipping / altering doses or delaying refills) is a growing concern to healthcare systems across geographies. According to the National Report on Adherence (released by National Community Pharmacists Association), non-adherence can threaten patients' health individually as well as add significant costs to the healthcare system (an estimated U.S. $290 billion annually).[1] The availability of electronic health records (EHR) with longitudinal patient data facilitates the development of prediction and detection models that identify patients at risk for various medical conditions, including non-adherence. This paper discusses the application of predictive modeling for tracking the non-adherence to medication in diabetics.

Background

Growing recognition of the problem of medication non-adherence has resulted in multiple studies that have tried to define and find the underlying causes of non-adherence. Common reasons for medication non-adherence include behavioral, life style attributes, life transition events as well as socio-economic background of the patient. However, the underlying fact is that non-adherence affects the overall health/ wellness of the patient, aggravates the disease condition and puts enormous cost burden on the healthcare system.

Studies show that 20 percent to 80 percent of patients make errors in taking medication and that 20 percent to 60 percent stop taking medications before being instructed to do so. With older populations, the literature concerning adherence reports that compliance rates range roughly from 38 percent to 57 percent, with an average rate of less than 45 percent. Patients forget to take their medications, creatively alter their medications, engage in unendorsed polypharmacy, mix their medications, and take medications in combinations that may have adverse drug-drug interaction effects.[2] Premature discontinuation of medication is common and results in re-admission due to disease complications.

Choice of diabetes for the study

In diabetes, non-adherence to oral hypoglycemic medications may partly explain why only 43 percent of patients with diabetes mellitus have Glycated Haemoglobin (HbA1c) below the 7 percent level recommended by the American Diabetes Association.[3] Past studies of adherence in the diabetic population focused on its economic burden, its complications and the cost effectiveness of anti-diabetic drugs. There are wide variations reported in the percent of patients being "non-adherent," ranging from 13 percent to 64 percent for oral agents and from 19 percent to 46 percent for users of insulin.[4] Additionally, important variations in the coefficient estimations for costs have been reported, which might be related to differences in the design, population, variables included in the analysis and statistical analyses. Diabetes is often present with other concomitant diseases such as hypertension and coronary heart disease. Therefore, non-adherence in diabetes patients has been considered as a good candidate to explore as it directly affects the overall wellness of the patient.

Predictive analytics in healthcare

Predictive analytics solutions are based on statistical techniques that are able to learn patterns present in historical data. They can subsequently apply the obtained knowledge to detect or predict trends in new data. The IBM SPSS Modeler is an extensive predictive analytics platform designed to bring predictive intelligence to decisions made by individuals, groups, systems and the enterprise.

With EHR becoming commonplace, IBM SPSS Modeler—by providing a range of advanced algorithms and techniques that include text analytics, entity analytics, decision management and optimization—together with expert knowledge allows for faster and more precise decision-aid tools for healthcare providers in the diagnosis and treatment of various diseases. For example, by knowing in advance that a group of patients are at a low or high risk for a disease or condition, data mining and predictive analytics are helping healthcare providers create targeted treatment measures for different populations. Healthcare providers can devise different strategies to keep low risk patients at low risk, while mitigating the risk associated with high risk patients. At the same time, healthcare payers also benefit by focusing on reduced spend on hospitalization and related costs.

Medication adherence modeling approach

Multiple approaches have been proposed to measure the extent of medication adherence. Some of the direct methods include measuring metabolite levels in body fluids, or direct monitoring or observation of a patient's medicine intake. There are also various indirect approaches in the field of measuring medication adherence—pill counts, querying patients, patient diaries and patient survey questionnaires. Some of the commonly used approaches based on prescription fills are proportion of days covered (PDC) and medication possession ratio (MPR). However, there is no universally accepted standard procedure for measuring medication non-adherence. Specific techniques are adopted after thoroughly considering parameters like direct access to patients, cost and reliability of data and various legal and ethical aspects.

This paper describes an implementation of an indirect approach for detecting a potential medication non-adherence using analytical likelihood techniques. This work is an extension and implementation of the white paper, *"Detecting possibly non-adherent patients by identifying unexpected response to medication regimen"*[5]. This paper details the findings of the implementation based on the Linear Regression – p Value Statistic as proposed in the white paper.

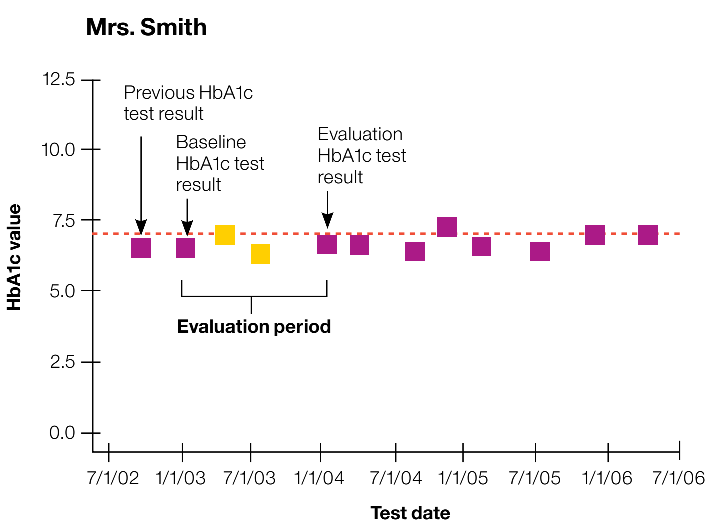
The data preparation

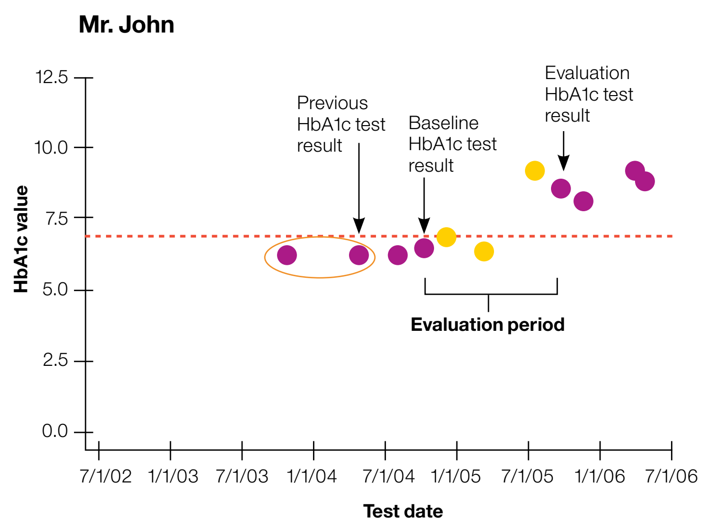
We identified a sample data set of 2000 diabetic patients with at least 6 months of medication history on oral hypoglycemics and information along key dimensions such as demographics, prescription fills, International Classification of Diseases (ICD) codes, laboratory test results including specifically the Glycated Haemoglobin (HbA1c) test and treatment facility (emergency, inpatient, outpatient, doctor or clinic).

At the start of the evaluation period, when the patient visited the treatment facility and took the HbA1c test, the HbA1c test result value was termed as the *"Baseline HbA1c test result."* To keep his/her HbA1c levels in control, the patient was prescribed medication (oral hypoglycemics) and HbA1c testing at periodic intervals. Data on HbA1c test results during a 6 to 12 month period was considered as the *"Within Evaluation Period Levels"*. At the end of the Evaluation Period, the patient took another HbA1c test and the HbA1c test result was termed as *"Evaluation HbA1c test result"*. In other words the patient's historical data was reconstructed such that his *"Baseline HbA1c test result"* is termed as his starting state, from where he underwent medication regimen and laboratory testing procedures, which led him to his end state, the *"Evaluation HbA1c test result."* This reconstructed data was used to build and train the predictive model.

Building the model

Building a model with a large set of features is infeasible and poor practice, as such a data matrix may be sparse. Therefore, we used a "feature selection" technique to identify features that contribute significantly towards model estimation. Using this technique, sixty features were identified and a simple linear regression model was trained using the features. Given the values for an input feature set, such a regression model can be used to predict the *"Expected HbA1c test result"*. At the end of the evaluation period, every patient had two HbA1c values; an *"Evaluation HbA1c test result,"* which was the actual result and an *"Expected HbA1c test result"* (calculated from the regression model). Using these two test values and certain population estimates, we derived the p-Value statistic for the patient, which is the likelihood of observing an HbA1c test value at least comparable to the expected evaluation *"Expected HbA1c test result."* The following table and the graphs represent the values for two representative patients Mrs. Smith and Mr. John.





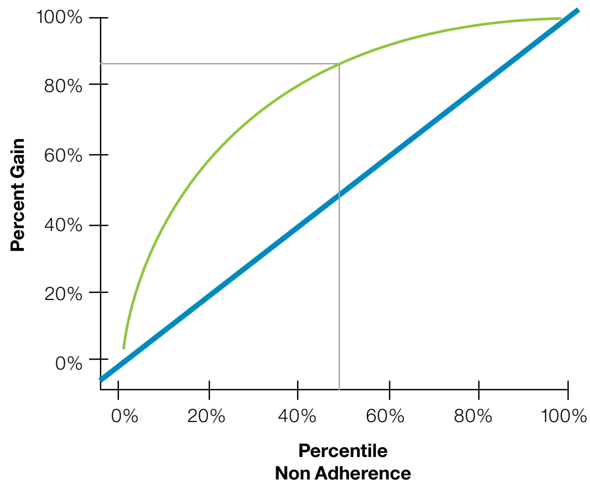
As shown in the table, it is observed that for Mr. John, under normal circumstances, the likelihood of observing HbA1c value as high as 8.4 on evaluation test date is 0.006. This being an extremely remote probability, we inferred that this patient was possibly non-adherent to his prescribed medication. For Mrs. Smith, the likelihood of observing HbA1c value of 6.6 on evaluation test date is 0.266. This was higher than a p-Value of 0.05, which was set as the significance level. Hence, she was inferred to be possibly adherent to her prescribed medication.

	PATIENTS	
	Mrs. Smith	**Mr. John**
Baseline HbA1c test date	12-Jan-03	3-Oct-04
Baseline HbA1c test result	6.80	6.90
Evaluation HbA1c test date	10-Jan-04	18-Sept-05
Evaluation HbA1c test result (ACTUAL)	6.6	8.4
Evaluation HbA1c test result (PREDICTED)	6.3	6.6
p-value	0.266	0.006

Measuring the model effectiveness

With the linear regression technique, we observed an R squared value of 0.371. We also plotted a Gains Chart for demonstrating the model effectiveness. In the Gains Chart for the regression model, we observed that there was a significant gain in predicting non-adherence using a model, as opposed to plain guess work. The key benefit of predicting medication non-adherence is that outliers can be identified early and a targeted approach to care coordination initiatives is possible. This is expected to drive improved clinical outcomes and thereby reduce unnecessary cost on the healthcare system.

Measuring the model effectiveness.



Note: The graph shown here is a means to demonstrate that there is some perceivable gain. However, such a Gains Chart should not be considered as a measure of extent of effectiveness of the model.

Aspects to consider while modeling

It is recommended to consider the following aspects in terms of applicability, implementation and interpretation to improve the effectiveness of the model.

1. Patients need to be stabilized on a therapy (drug, dosage) regimen before they are included in this predictive modeling exercise. This helps eliminate fluctuating test results that could occur while the prescriber or provider is trying out therapies.
2. This method is relevant to chronic diseases where long-term therapy is required, rather than acute conditions where duration of therapy and clinical response has a short window.
3. Determining the right clinical parameters to correlate the impact of medication is essential to build a robust model.
4. The model is specific to a given disease and a given dataset. This means that we cannot reuse the model trained for diabetes to other diseases, but have to re-build a new model.
5. Diabetes can cause secondary diseases such as cardiovascular, renal, cerebral and ophthalmic complications. As the primary disease progresses, patients are often seen with secondary complications and multiple therapy regimens. All these can be built out on this model to enhance its utility in broader care coordination initiatives.

IBM—Unmatched commitment and proven solutions

IBM has deep expertise in managing and integrating complex systems, and IBM specialists have subject matter experience in healthcare, life sciences, bioinformatics and social care. By bringing these together, IBM is enabling a foundation for transforming 21st century care systems. The predictive analytics model for detecting medication non-adherence has been developed with the intent of reducing costs associated with adverse health outcomes arising out of non-adherence (thereby addressing the payer perspective), enabling physicians to identify potential non-adherent patients for further investigation and course correction (thereby addressing the physician perspective), and possibly preventing onset of secondary complications resulting from medication non-adherence (thereby addressing the patient perspective).

Conclusion

This paper describes implementation of an indirect approach for detecting potential medication non-adherence using analytical likelihood techniques for diabetic patients. The regression model described here estimates the expected HbA1c test result. Combining this with certain population estimates and observed values, the “p-Value statistic” can be derived for a patient that can be used in detecting possible medication non-adherence.

About the authors

Jayashree Thacker is the Industry Leader for Healthcare across IBM’s Globally Integrated Capabilities (GIC) network of delivery centers. A pharmacist undergraduate and business management post graduate, she has over 28 years of experience in the healthcare and life sciences industries.

Madhusmita Patil is the Lead Architect for the healthcare industry, Global Delivery, IBM India. Madhu is a computer engineering graduate and has more than 15 years of experience in software architecture, design and development in the healthcare and life sciences industries.

Vipin Nair is a Managing Consultant in the IBM Strategy and Analytics service line. He has over 14 years of industry experience in software development, analytics and machine learning implementations across various domains like banking, telecom, healthcare and retail.

Laxmi Harikumar is a Data Specialist in Advanced Analytics in the IBM Strategy and Analytics service line. She has close to 12 years of experience across software development and analytics in the telecom, retail and healthcare domains.

IBM Corporation
Global Business Services
Route 100
Somers, NY 10589

Produced in the United States of America
November 2014

References

1. “Thinking Outside The Pillbox: A System-wide Approach to Improving Patient Adherence for Chronic Disease.” NEHI. 2009. http://www.nehi.net/writable/publication_files/file/pa_issue_brief_final.pdf
2. http://www.akmhcweb.org/ncarticles/Medication%20Nonadherence.htm
3. http://www.ispor.org/sigs/medcompliance/Diabetes-SalasHughes.pdf
4. Costs of Medication Non-adherence in Patients with Diabetes Mellitus: A Systematic Review and Critical Analysis of the Literature, Maribel Salas, Dyfrig Hughes, Alvaro Zuluaga, Kawitha Vardeva and Maximilian Lebmeier. http://onlinelibrary.wiley.com/doi/10.1111/j.1524-4733.2009.00539.x/full
5. “Detecting possibly non-adherent patients by identifying unexpected response to medication regimen.” Michal Ozery-Flato, Liat Ein-Dor, Martin S. Kohn, Jianying Hu.

GBW03257-USEN-00