A Predictive Model to identify Individuals with Diabetes At High Risk for Developing Foot Wounds Using Administrative Data and Medical Records

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Background

Approximately 15% of individuals with diabetes develop a foot wound over their lifetime.[1] Diabetic foot ulcers (DFUs) can seriously affect health and well-being. Foot wounds precede 50% to 70% of all lower extremity amputations.[1] Five-year mortality rates of 43% to 55%, and 74% for patients with amputation, have been reported.[2]

Objective

To develop, test and validate a predictive model that quantifies risk of developing a new foot wound within the next 12 months within in a Medicare Advantage population with diabetes.

Methods

Study Design: Model development

Data Source:

- Medical and pharmacy claims (including laboratory data), prior authorization records, and enrollment records from Humana Inc., a multistate healthcare organization that offers Medicare Advantage, stand-alone prescription drug, and commercial plans.
- Data from surveys administered to Humana members and from special health programs.
- Electronic medical records (EMRs) and nurse notes supplied by an external vendor. Text analytic methods were used for abstraction of information such as vital signs, clinical conditions, family history, and medications.
- Consumer information from an external vendor.

Patient Selection Criteria:

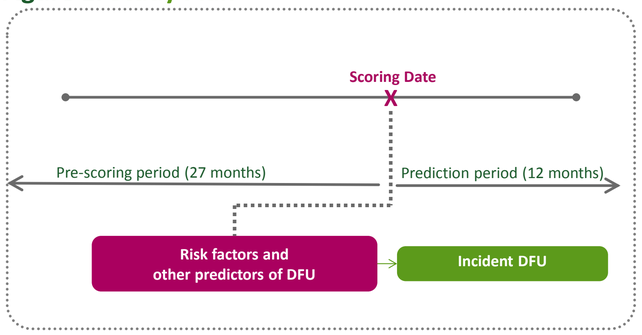
- Medicare Advantage Prescription Drug (MAPD) plan
- Active as of December 2014, January 2015, or February 2015.
- Diagnosis of diabetes according to ≥ 1 of the following criteria, assessed on the next day following each of the three 27-month time frames (see Figure 1):
  - Claims-based diagnosis during physician visits within the previous 27 months
  - Diabetes-related prescription filled within previous 27 months
  - At least one inpatient stay or outpatient visit within the previous 27 months, accompanied by 1 of 9 diabetes diagnostic codes designating the reason for the encounter

Dependent Variable: Claims-based diagnosis of diabetic foot ulcer (DFU) in the next 12 months following scoring

Predictor Variables: >3000 potential risk factors . See Figure 1.

Modeling Methods: The combined datasets were divided into development (65% of observations), testing (20%), and validation (15%) sets. The >3000 potential predictor variables were subjected to least angles regression (LARS) for selection of the most important predictors. Various modeling techniques and combinations of techniques were then tested. Receiver operator curve (ROC) analysis of area under curve (AUC) was used to measure model performance and select the final model.

Figure 1. Study Plan



Humana.

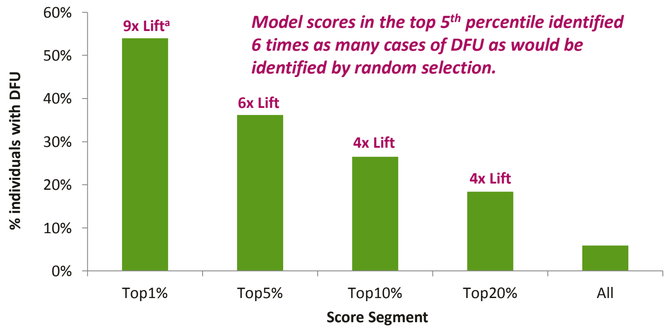
Results

*Table 1. Population Characteristics

Measure	Mean or Proportion
N	918,565
Age, mean ± SD (years)	71.4 ± 9.4
Male sex, n (% of total)	434,941 (47.4%)
CCI > 3 (moderate-high comorbidity)	533,884 (58.1%)
DCSI >3 (moderate-high risk)	229,141 (24.9%)
Prevalence of DFU, % of population or subpopulation	
Overall (n=918,565)	5.9%
Female (n=483,624)	6.0%
Male (n=434,941)	7.2%
White race (n=712,167)	6.2%
Black race (n=154,467)	5.0%
Other race (n=47.168)†	2.2%-6.1%
DCSI >3 (n=229,141)	8.1%-47.6%

CCI, Charlson Comorbidity Index; DCSI, Diabetes Complications Severity Index; DFU, diabetic foot ulcer

*Figure 3. Model Performance



Model scores in the top 5th percentile identified 6 times as many cases of DFU as would be identified by random selection.

[a]Relative prevalence compared with random selection

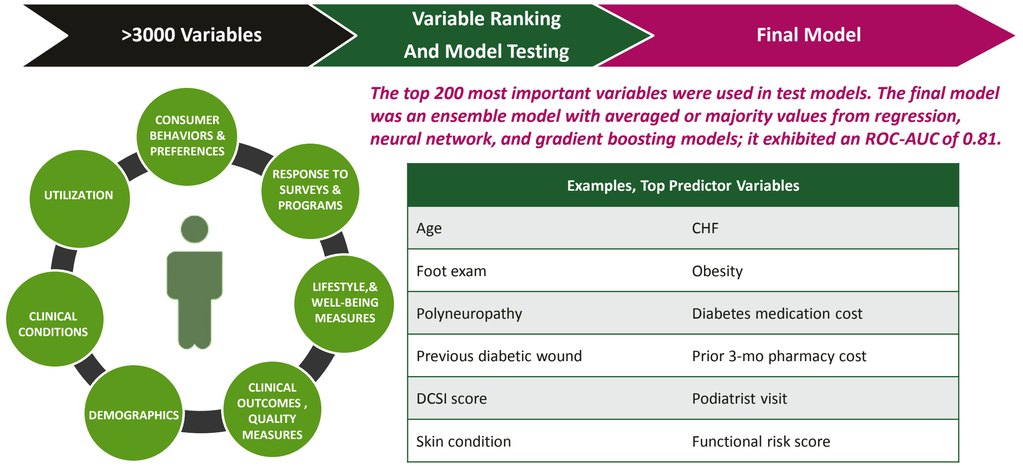
*Table 2. Model Predictions by Score Segment

Model Score Segment	Capture Rate[a]	New DFU Incidence	Mean Time to DFU (days)[b]
Top 1%	9.2%	54.0%	109.3
Top 5%	30.7%	36.2%	118.9
Top 10%	44.9%	26.5%	124.0
Top 20%	62.4%	18.4%	130.1
Overall	100%	5.9%	153.2

[a](Number of Individuals with DFU in the Score Segment) / (Number of Individuals with DFU in Dataset)

[b]Among those who had a DFU within 12 months

Figure 2. Model Development

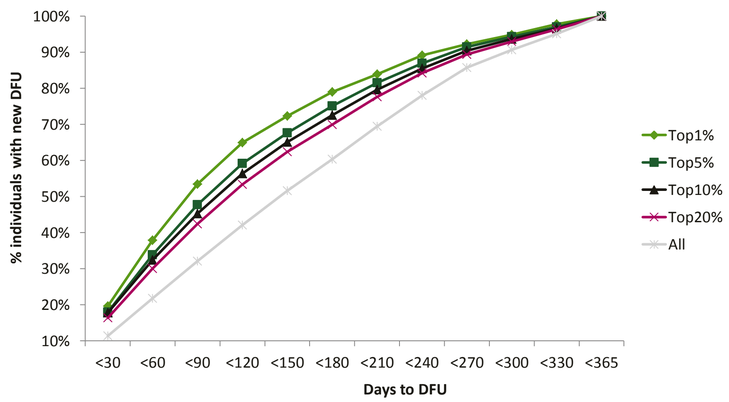


The top 200 most important variables were used in test models. The final model was an ensemble model with averaged or majority values from regression, neural network, and gradient boosting models; it exhibited an ROC-AUC of 0.81.

Examples, Top Predictor Variables	
Age	CHF
Foot exam	Obesity
Polyneuropathy	Diabetes medication cost
Previous diabetic wound	Prior 3-mo pharmacy cost
DCSI score	Podiatrist visit
Skin condition	Functional risk score

CHF, congestive heart failure; DCSI, Diabetes Complications Severity Index

*Figure 4. Distribution of Times to Wound Occurrence



- *Individuals with model scores in the top 5th percentile accounted for 30.67% of all individuals with DFU.*
- *Time to DFU occurrence values followed a similar pattern across score segments.*
- *Mean time to DFU was 109 to 153 days.*

*Based on the December 31, 2014 score date.

Conclusions and Application

- The model builds on other work conducted within our organization revealing modifiable risk factors for DFU and amputation.
- The model has good accuracy for identification of individuals with diabetes who will have a DFU in the next 12 months. The typical time to DFU from the time of scoring would provide opportunity for preventive intervention.
- Work is currently underway to use this model for identification of high risk individuals for disease management programs to enable early intervention.
- Future work may build on this work to develop a diabetic amputation model.

Limitations

- As in all analyses based on claims data, this analysis was subject to missing or incorrect values.
- Results may not be generalizable to younger populations, to populations with a different racial mix, or to populations with a different level of comorbidity.

References

1. Yazdanpanah L, Nasiri M, Adarvish S. Literature review on the management of diabetic foot ulcer. *World J Diabetes*. 2015;6(1):37-53.
2. Robbins JM, Strauss G, Aron D, et al. Mortality rates and diabetic foot ulcers: is it time to communicate mortality risk to patients with diabetic foot ulceration? *J Am Podiatr Med Assoc*. 2008;98(6):489-93.

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