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Use of Administrative Data to Risk Adjust Amputation Rates in a National Cohort of Medicare-Enrolled Veterans With Diabetes

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Background: A reduction in diabetes-related lower extremity amputations is a national health care priority.

Objective: To develop a risk adjustment model for total amputation rates, using claims data.

Research Design: A retrospective longitudinal cohort analysis of veteran clinical users of the Veterans Health Administration (VHA)—veterans with diabetes who were Medicare nonhealth maintenance organization enrolled in 1997 or 1998. Baseline risks ascertained in 1997 to 1998 were used to adjust Veterans Integrated Service Networks (VISN) amputation rates in 1999.

Measures: Individual-level amputation outcome in VHA and private hospitals in 1999; VISN-level amputation rates adjusted for age, gender, race, foot risk factors, and macro- and microvascular complications; and rankings of 22 VISNs on amputation rates.

Results: A total of 218,528 patients incurred 3077 (14.1 per 1000) amputations in 1999, with 10.6 to 18.0 amputations per 1000 across 22 VISNs. Age, gender, race, prior amputation, infections, ulcers, peripheral vascular disease, and vascular complications were significant independent predictors of amputation (R^2 = 0.20); demographic variables accounted for < 1% of the variance. The C statistic of the final model was 0.83. VISN rankings using age-, gender-, and race-adjusted rates were not substantially altered compared with rankings using the full risk-adjusted model (Spearman rank correlation, 0.85).

Conclusion: Addition of foot risk and comorbidity variables increased the discrimination of a predictive model for total amputations in an elderly, largely male population of veterans with diabetes compared with use of demographic data alone. The authors suggest that this model be validated in other settings with availability of individual-level claims data.

Key Words: diabetes mellitus, amputations, risk adjustment

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Diabetes-related foot complications inflict enormous individual and societal burden.[1–6] Consequently, a nationwide reduction in amputation rates is the goal of several current government initiatives.[7–9] Amputation rates are considered a prevention quality indicator that is reflective of the quality of foot care delivered within a health care system.[10]

However, existing methodologies to calculate amputation rates have significant shortcomings, including ascertainment of race and ethnicity.[11] Because rates represent hospital discharges and not individual persons, patients with multiple amputations within 1 year are counted multiple times, which may result in an overestimation of hospital discharge rates.[11] Furthermore, the prevalence of persons with diabetes has markedly increased since the 1990s,[12] and may affect the estimation of amputation rates over time. Currently, cross-sectional rates are age, gender,[7,8] and sometimes race adjusted,[13] but do not incorporate other important case mix factors that influence risk, including foot-specific and medical comorbidities.[14] In this context, risk adjustment that relies solely on existing administrative data would be valuable.[15]

The primary objective of this study was to develop a longitudinal risk adjustment model for total amputations that has both clinical validity and statistical reliability, using administrative data available on a national registry of veteran clinical users with diabetes of the Veterans Health Administration (VHA). We used information from fiscal year 1997 (FY97) and FY98 to identify the sample and describe baseline risk to adjust FY99 amputation rates. To capture all amputation events, we studied only those users with diabetes who were dually enrolled in both VHA and Medicare.

Methods

Data Sources

As reported previously, we used merged national Veteran's Administration and Centers for Medicaid and Medicare Services administrative inpatient, outpatient, and pharmacy databases to identify veterans in FY97 or FY98 with diabetes.[16] A criterion of 2 or more diabetes ICD-9 codes from inpatient or outpatient physician visits (VHA and Medicare) over a 24-month period had high sensitivity (73%) and specificity (98%) against patient self-report, comparable with prior reports using the Medicare Current Beneficiary Survey.[17] Deaths in FY97 and FY98 were identified using the

VHA Beneficiary Identification and Records Locator Subsystem[18] and the Medicare Denominator File. Our institutions' institutional review boards approved the protocol.

Sample Selection

We identified 218,689 patients enrolled for both VHA and Medicare services who had 1999 Medicare Part A and VHA claims data and were not health maintenance organization participants. Of these patients, 62 had missing race information and 99 had no face-to-face clinical encounter in the claims data, resulting in a final sample of 218,528 subjects for analysis.

Definition of Outcome

We defined FY99 total amputation hospitalizations as those with an ICD-9 procedure code for any lower extremity amputation (84.11–84.19) in any field in either VHA Patient Treatment Files or Medicare Part A files.[11] Multiple procedures with the same ICD-9 code or 2 amputation codes during the same operation were considered to be a single amputation, because there are no modifiers to enable identification of bilateral amputations.

Independent Variables

We identified potential risk factors for lower extremity ulcers and amputations based on prospective cohort studies,[14,19] classifying them into demographic variables, foot risk factors, and medical comorbidities. Demographic variables consisting of age, gender, and race were obtained from Medicare files, because race was self-reported.[20]

We created 5 categoric baseline foot risk adjustment variables: peripheral neuropathy, chronic infections, peripheral vascular diseases, foot deformity, and amputation in FY97 or FY98. The ICD-9-CM codes used to construct these variables are presented in Table 1. Variables were 0/1 binary except for peripheral vascular disease, which had 4 categories of severity (0 indicating not present). The peripheral neuropathy variable was not included in risk adjustment models because of possible substantial undercoding problems. The presence of cardiovascular, cerebrovascular, and renal disease, derived from ICD-9 codes, were also entered into the models to risk adjust for diabetes-related complications.[21]

Model Development

We first created a full model containing all independent variables and a priori interaction terms, all of which were significant except for foot deformity ($P < 0.5$); therefore, foot deformity was removed from our final model. We used the 0.632 bootstrapping method[22,23] by creating 100 bootstrap samples to validate our final model as well as a demographic model containing only age, gender, and race.

Rankings

To assess the value of improved amputation risk adjustment, we compared the ratio of the observed number of amputations with the sum of the predicted risk of amputation estimated by the 2 models for patients grouped by Veterans Integrated Service Networks (VISN). We used the network level, rather than the facility level, because there was a small

TABLE 1. ICD-9-CM Codes for High-Risk, Foot-Specific Conditions Present in FY97 to FY98 Operationalized Into Covariates

Variable Name	ICD-9-CM Codes Used to Construct Variable	Categorization of Variable
Peripheral neuropathy	250.60–250.63 (diabetic neuropathy), 337.1 (peripheral neuropathy)	1
Chronic skin infections	707.1 (chronic, nonhealing wound of lower extremity), 730.7 (osteomyelitis, 7 ankle, foot, 6 leg)	1
Peripheral vascular disease	440.21–24, 443 (peripheral vascular disease); 440.8, 440.9 (generalized atherosclerotic vascular disease); 444.22 (embolism); 443.81, 250.7 (peripheral vascular disease in diabetes)	1
	39.50, 39.59 (peripheral angioplasty); 39.25 (peripheral bypass procedure other than aorta–iliac femoral bypass); 39.29 (peripheral bypass procedure involving the aorta–iliac femoral vessels); 39.41, 39.49 (revision of bypass procedures); 996.1, 996.52, 996.52 (complication from bypass)	2
	785.4 (gangrene, nonspecific)	3
Foot deformity	94.0, 713.5 (Charcot foot); 727.1 (bunion deformity), 735.0, 735.2, 735.4–735.9 (hammer toe or claw toe deformity)	1
Amputations lower extremity	84.11 (toe), 84.12 (transmetatarsal), 84.15 (transtibial), 84.17 (transfemoral)	1

ICD-9 codes 700.x (corns, callus), 6810–1 (cellulites, paronychia of toe) and 682.7 (cellulites, abscess of foot) were not independently associated with amputation risk, thus they were counted in the 0 (not present) category.

number of amputations per facility and their catchment areas could not be determined accurately. They were identified as outliers if the 95% confidence interval for the O-E ratios did not include 1.[24]

Results

Cohort Description

The 218,528 diabetic veterans in the study sample incurred 3077 amputations (14.1 events per 1000 diabetes patients; range, 10.6 to 18.0 per 1000 across 22 VISNs) in both VHA and private sector hospitals in FY99.

Multivariate Models

Table 2 presents the parameter estimates and model performance of the final model as well as the demographic model applied to the full analytic sample. For the demographic model, the internally validated C-statistic and R^2 values were 0.521 ± 0.004 (standard deviation; range, 0.512–0.531) and 0.005 ± 0.001 (range, 0.003–0.007) respectively. For the final model they were 0.774 ± 0.005 (range, 0.762–0.787) and 0.184 ± 0.005 (range, 0.171–0.195) respectively. The larger C-statistic and R^2 values from the final model compared with the demographic

TABLE 2. Parameter Estimates and Model Performance From the Demographic and Final Risk Adjustment Models

Variable	The Demographic Model Estimate (SE)	The Final Model Estimate (SE)
Age, years	$P < 0.001$	$P = 0.018$
55–64 versus < 55	0.471 (0.085)†	0.147 (0.089)
65–74 versus < 55	0.113 (0.074)	−0.042 (0.077)
75+ versus < 55	0.223 (0.076)†	0.012 (0.079)
Race	$P < 0.001$	$P \leq 0.001$
Blacks versus whites	0.497 (0.044)†	0.418 (0.047)†
Other races versus whites	0.110 (0.085)	0.127 (0.088)
Women versus men	−0.780 (0.220)†	−0.632 (0.224)*
Chronic skin infection versus others		2.057 (0.058)†
Prior amputation versus none		1.737 (0.232)†
Peripheral vascular diseases (PVD)		$P < 0.001$
ASVD/embolism versus no PVD		1.088 (0.071)†
Angioplasty/bypass versus no PVD		1.438 (0.100)†
Gangrene versus no PVD		2.545 (0.145)†
Chronic infection × Prior amputation		−0.641 (0.181)†
Chronic infection × PVD		$P < 0.001$
Chronic infection × ASVD/embolism		−0.409 (0.103)†
Chronic infection × angioplasty/bypass		−0.592 (0.145)†
Chronic infection × gangrene		−1.142 (0.164)†
Prior amputation × PVD		$P < 0.001$
Prior amputation × ASVD/embolism		−0.286 (0.201)†
Prior amputation × angioplasty/bypass		−1.189 (0.306)†
Prior amputation × gangrene		−1.195 (0.183)†
Stroke		0.328 (0.106)*
Cardiac conditions		0.139 (0.044)*
Congestive heart failure		0.326 (0.043)†
End-stage renal failure		0.553 (0.045)†
Intercept	−5.375 (0.077)†	−5.556 (0.080)†
C statistic	0.553	0.825
R^2	0.006	0.197

*$P < 0.01$; †$P < 0.001$.

Two types of P values are reported: P values for individual effect/parameter estimates (eg, women versus men), which appear in each corresponding cell; and P values for the type III test of the overall effect estimates (more than 1 effect/parameter estimate) of the categoric variables (which appear in actual values with rounding errors). Note that for categoric variables with 2 levels (eg, gender) and continuous variables, these 2 P values are identical. For categoric variables with more than 2 levels (eg, race), these 2 P values are not the same (the former is for individual race–group effect/parameter and the latter is for the 2 race–group effects/parameters).

model demonstrated that the former is a superior model. Based on the final model, the odds ratios of amputation for women versus men, and blacks versus whites were 0.53 and 1.52 respectively. Individuals who were 55 to 64 years of age had higher odds of amputations than those older than 64 years. Peripheral vascular disease, chronic infections, and prior amputations contributed significantly to the amputation outcome and affected the odds of amputation by interacting with each other. The combination of these effects was thus slightly less than simple addition of the main effects. As expected from the epidemiologic literature and our a priori hypothesis, having any of the included micro- and macrovascular conditions was associated with a greater odds of amputations.

Ranking

In comparing ranks derived from the final model and the demographic model (Table 3), we observed few dramatic changes in the ranks of VISNs, and correlations between ranks were high (Spearman correlation coefficient, 0.85; $P < 0.001$). Nonetheless, some potentially important changes in rank did occur. For example, using the final model compared with the demographic model, VISN B dropped from rank 1 to rank 4, which in this small sample of 22 removed it from the top 10% of performance. VISN K became the top performer, up from rank 3 using only age, gender, and race adjustment.

Comment

Recent reports using individual level results[6,13] have only adjusted for demographic factors such as age, gender, and/or race. Our results demonstrate that administrative claims data can be used to develop a risk adjustment model for total lower extremity amputations that has significant improvements in both clinical validity and statistical reliability than adjustment for race, gender, and age alone. Our results, with respect to amputation rates and the significance of included risk factors, are consistent with previous epidemiologic studies of amputations in the veteran[14] and US population.[1]

However, we observed little variability in observed total amputation rates (range, 10.6–18.0/1000 diabetes patients), in marked contrast to reports in Medicare data that demonstrated 8.6-fold variability in major amputation rates across hospital service areas.[13] This finding may explain why

TABLE 3. Ranking of VISNs Using Standardized Amputation Ratios

VISN	No. Study Sample Patients With Diabetes	No. Amputations (O)	Observed Amputation Rates per 1000 Diabetes Patients	Rank With Crude Amputation Rate	Rank With Age, Gender, and Race Adjustment (O/E_1)*	Rank With Full Adjustment (O/E_2)*	O/E_1, Age, Gender, and Race Adjusted*	95% CI for O/E_1	O/E_2, Fully Adjusted*	95% CI for O/E_2
A	11,563	184	15.9	20	21	20	1.20	1.18, 1.22	1.13	1.09, 1.17
B	7671	81	10.6	1	1	4	0.79	0.77, 0.81	0.87	0.82, 0.92
C	11,980	164	13.7	10	7	3	0.94	0.92, 0.96	0.86	0.82, 0.90
D	13,055	183	14.0	12	14	9	1.02	0.01, 1.04	0.95	0.92, 0.99
E	5485	84	15.3	17	11	11	0.98	0.95, 1.01	0.97	0.92, 1.03
F	11,796	178	15.1	15	13	8	1.01	0.99, 1.03	0.95	0.91, 0.99
G	13,543	217	16.0	21	17	17	1.05	1.04, 1.07	1.11	1.07, 1.14
H	18,423	223	12.1	4	5	6	0.88	0.87, 0.90	0.91	0.88, 0.94
I	11,952	180	15.1	14	18	19	1.08	1.06, 1.10	1.13	1.09, 1.17
J	7878	142	18.0	22	22	22	1.25	1.23, 1.28	1.15	1.10, 1.20
K	11,619	142	12.2	6	3	1	0.87	0.86, 0.89	0.85	0.82, 0.88
L	10,951	161	14.7	13	15	10	1.03	1.01, 1.05	0.97	0.93, 1.01
M	6112	94	15.4	18	20	16	1.19	1.16, 1.22	1.05	0.99, 1.10
N	4861	56	11.5	2	4	7	0.88	0.85, 0.90	0.94	0.88, 0.99
O	10,556	140	13.3	9	10	14	0.95	0.94, 0.97	1.02	0.97, 1.06
P	18,684	286	15.3	16	16	18	1.04	1.03, 1.06	1.13	1.09, 1.16
Q	8887	138	15.5	19	19	21	1.10	1.08, 1.13	1.15	1.10, 1.19
R	8840	108	12.2	5	6	13	0.92	0.90, 0.94	1.01	0.96, 1.06
S	4975	62	12.5	7	9	12	0.95	0.92, 0.98	1.01	0.95, 1.07
T	6818	90	13.2	8	12	15	0.99	0.97, 1.02	1.03	0.98, 1.08
U	6771	80	11.8	3	2	5	0.84	0.82, 0.86	0.87	0.83, 0.92
V	6108	84	13.8	11	8	2	0.95	0.92, 0.97	0.86	0.81, 0.90

*E_1 was the expected counts using the demographic model from Table 2 (eg, adjusting for age, gender, and race only). E_2 was the expected counts using the final model from Table 2.

our full risk adjustment model did not alter significantly the identification of outlier status of the VISNs, despite the markedly higher C-statistic observed in the full model compared with the demographic model. The small variation in amputation rates in our study may be due to the use of larger regional areas (ie, VISNs) as well as a more homogeneous patient population and the systematization of care within the VHA compared with the private sector.[25,26]

The strengths of this study include the fact that we were able to ascertain reliably both diabetes status and predictor variables over a 2-year period, with ascertainment of virtually all outcome events for cohort members in an interval distinct from baseline risk determination.[27] The higher C-statistic values obtained from bootstrap samples suggest that the final model results are not simply artifacts of the data used to develop the model. Several potential limitations are that comparability of VHA and Medicare coding practices have not been well described, and that coding practices, especially for the insensate foot,[28] may change longitudinally.

In conclusion, we demonstrate that individual-level longitudinal claims data can be used to develop a risk adjustment model for diabetes-related total amputation rates that has greater predictive power than demographic data alone. This model could potentially enable more accurate trending of amputation rates. However, we suggest that this model be validated in other settings with availability of individual-level national claims data, especially the Medicare and Medicaid programs.

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